

**CBS / School of Information Systems**

**Design and Evaluation of DSRCRSA: An Ontology-Based Approach to  
Design Science Research Content Representation and Summarisation**

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**This thesis is presented for the Degree of  
Doctor of Philosophy  
of  
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**Declaration**

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

**Human Ethics** The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number # **HRE2016-0003**

Signature:  .....

Date: 30/1/2018

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# List of Abbreviations

5Cs	Conciseness, Comprehensiveness, Coherence, Clarity, and Correctness
A-Box	assertional box
ADR	Action Design Research
AIF	Argument Interchange Format
API	Application Program Interface
BFO	Basic Formal Ontology
BIE	Building, Intervention, Evaluation
DAML	DARPA Agent Markup Language
DESRIST	Design Science Research in Information Systems and Technology
DMOZ	<a href="http://directory.mozilla.org">directory.mozilla.org</a>
DoCo	Document Components Ontology
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering
DSR	Design Science Research
DSRCRSA	Design Science Research Content Representation and Summarisation Architecture
DSRDCO	Design Science Research Document Core Ontology
DSRDO	Design Science Research Document Ontology
DSRKB	Design Science Research Knowledge Base
DSRKBO	Design Science Research Knowledge Base Ontology
DUC	Document Understanding Conferences
FRBR	Functional Requirements for Bibliographic Records

GRAONTO	Graph-Based Approach for Automatic Construction of Domain Ontology from Document Corpus
IE	Information Extraction
IEEE	Institute of Electronics and Electrical Engineers
IRI	Internationalized Resource Identifier
IS	Information Systems
IT	Information Technology
LaTeX	Lamport TeX
LIDO	Legal Information Document Ontology
LOD	Linked Open Data
MARC	Machine Readable Cataloging
OBDA	Ontology-Based Data Access
OIL	Ontology Inference Layer
OWL	Web Ontology Language
OWL-DL	OWL Description Logic
PDF	Portable Document Format
POS	Part Of Speech
RDF	Resource Description Framework
ROUGE	Recall-Oriented Understudy for Gisting Evaluation
SALT	Semantically Annotated Latex
SDSM	Soft Design Science Methodology
SKOS	Simple Knowledge Organisation System
SPARQL	SPARQL Protocol and RDF Query Language
SQL	Structured Query Language
SUMO	Suggested Upper Merged Ontology
SWAN	Semantic Web Applications in Neuromedicine
SWRL	Semantic Web Rule Language
T-Box	terminology box

TU Technical University

UMBEL Upper Mapping and Binding Exchange Layer

URI Uniform Resource Identifier

XML Extensible Markup Language

YAGO Yet Another Great Ontology

# Abstract

This thesis uses a design science research (DSR) approach to propose, design and evaluate a novel purposeful artefact that is named ‘Design Science Research Content Representation and Summarisation Architecture’ (DSRCRSA). DSRCRSA is capable of storing and providing conceptualisations that represent DSR publications. Additionally, DSRCRSA provides a process to automatically generate single and multi-document summaries that fulfil the 5Cs (conciseness, comprehensiveness, coherence, clarity, and correctness).

State-of-the-art academic search engines search millions of scientific publications. For instance, Pubmed, which is a search engine that is provided by the National Institutes of Health and the U.S. National Library of Medicine, includes 26 million publications. Researchers, as well as practitioners, want to retrieve articles that match a certain search query. Search engines usually include capabilities to search full-texts (if the publication is available online) and to search meta-data that is stored about a specific publication. State-of-the-art search engines, such as Google Scholar, have a high recall. Such search engines provide result sets that often include a high number of documents. However, the query terms need to match the text in the document. Even though documents might include a specific query term, such documents are very often not of interest to a specific user. This thesis shows that conceptualisations of DSR publications provide additional information that can be used to compare and summarise DSR publications. One additional information are the concepts that a specific information within a paper belongs to. Such concepts can be used within search queries to, for instance, only retrieve papers that include a specific text that belongs to a specific concept. Such conceptualisations could increase the precision of a search result. An aspect that is evaluated in this thesis is the identification of DSR concepts to enable the generation of overview summaries.

Summaries of search results are rarely described in the literature. However, research has been conducted in the field of automatic summarisation. Formal ontologies are used in many summarisation approaches. However, formal ontologies that are used in these approaches consist either of a small set of relations (most approaches only work with generalisation / specialisation relations) or generate ontologies automatically. Such approaches cannot be used to provide readable and coherent lexical representations of content that is provided in a summary because more detailed relations, such as relations that express cardi-

nality constraints, are missing. More detailed relations can be utilised to provide overview summaries. Overview summaries need to express information, such as the amount of a specific concept that is necessary for a specific artefact or relations that describe how a specific set of concepts are connected. Additionally, automatically generated ontologies do not provide lexical presentations that are clear enough to be comprehended by the user.

DSRCRSA provides an ontology repository that includes the Design Science Research Knowledge Base Ontology (DSRKBO) and the Design Science Research Document Core Ontology (DSRDCO). This ontology repository can be used to express and store knowledge that is contained in DSR publications. Finally, the utility of DSRCRSA is demonstrated by generating overview summaries of DSR publications. DSR is a sub-domain of research with practical application, which this thesis is concerned with. DSR publications are defined in this thesis as scientific publications that present, discuss, and evaluate novel, purposeful artefacts.

Two design principles have emerged out of this research. The first design principle prescribes the use of the semiotic framework in formal ontologies to express concepts in formal conceptualisations. The semiotic framework utilises semiotic layers that enable the representations of concepts from different perspectives (empiric, syntactic, and pragmatic). Such a differentiation supports the generation of formal ontologies that provide a lexical, syntactic, and pragmatic representation of the concepts that are stored in a specific ontology. The second design principle prescribes the use of the semiotic triangle and complex classes to describe concepts at each semiotic layer by utilising concepts that are described in the lower-layer. Complex classes that are described by axioms that make use of lower-layer concepts enable a clear separation between different perspectives of each semiotic layer.

The evaluations that are presented in this thesis show that the proposed architecture is capable of generating single document and multi-document summaries if the content of the DSR publications is correctly represented utilising the formal ontologies (DSRDCO and DSRKBO) that are presented in this thesis. Single document summaries and multi-document summaries that can be generated utilising the proposed architecture were evaluated with the help of DSR experts in several interview sessions. It was identified that salient DSR concepts are represented and that the provided summaries fulfil the 5Cs (conciseness, comprehensiveness, coherence, clarity, and correctness).

# Chapter 1

## Introduction

## 1.1 The Problem - Lack of Search Result Summaries

This thesis proposes a design theory that includes a general design to enable the creation of search result summaries of DSR publications. This design theory, if instantiated properly, can provide researchers as well as practitioners with overview summaries of DSR work in regards to a specific topic of a query.

Current state-of-the-art search engines produce search results that typically consist of long lists of links to documents or web pages. Examples of such search engines include Google or Yahoo, but also search engines used in digital libraries, such as the Curtin University library catalogue <sup>1</sup> or the TU Graz Library Catalogue <sup>2</sup>.

Most search engines provide a comprehensive list of search results and also only display documents or web pages related to a specific query (at least on the first pages of a search result). The problem is that this list of documents still has to be read, compared and synthesised to retrieve important information about a specific search result. Additionally, some results might not be relevant to the topic that a user is interested in at all. The huge amount of information that is available nowadays makes comparing and synthesising documents very time intensive. To compare and synthesise documents listed in a search result, a user currently needs to read the documents that a search engine result refers to. Then, this user needs to understand the documents' content, followed by identifying important aspects in these documents, to finally be able to compare and synthesise these documents. Only after such an extensive search and review process can a user gather a comprehensive picture of a specific topic.

Most state-of-the-art search engines do not provide overview summaries of a search query. Search engines that provide overview summaries belong to a group called semantic search engines. Semantic search engines make use of semantic-driven search technologies (Usbeck et al., 2016). It is also possible to create summaries without the use of semantics. However, such techniques do not include a reliable way to process semantics (Berners-Lee et al., 2001, Qiang et al., 2016). Such semantics are necessary to relate concepts mentioned in one or a number of documents (Berners-Lee et al., 2001).

Some commercial products that make use of semantic-technologies include additional information in their search results. Examples include the Google Knowledge Graph <sup>3</sup> or WolframAlpha<sup>4</sup>.

The Google Knowledge Graph provides, for instance, additional information about a specific person as can be seen on the right-hand side in Figure 1.1. Wolfram Alpha specialises in answering questions and provides different representations in regards to the topic of a question. For example, a query about the name Martin Heidegger returns the result shown in Figure 1.2. Both tools de-

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<sup>1</sup><http://catalogue.curtin.edu.au>

<sup>2</sup><http://tugraz.summon.serialssolutions.com>

<sup>3</sup><https://www.google.com/intl/es419/insidesearch/features/search/knowledge.html>

<sup>4</sup><https://www.wolframalpha.com>

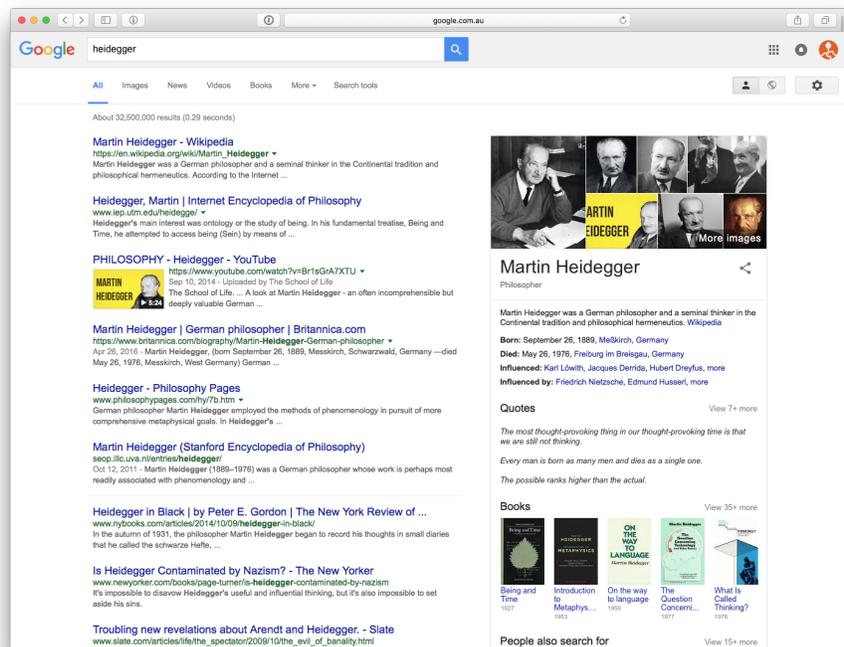


Figure 1.1: Google Knowledge Graph of Martin Heidegger

WolframAlpha<sup>®</sup> computational knowledge engine

heidegger

Input interpretation:  
Martin Heidegger (philosopher)

Basic information:

full name	Martin Heidegger
date of birth	Thursday, September 26, 1889 (127 years ago)
place of birth	Messkirch, Baden-Württemberg, Germany
date of death	Wednesday, May 26, 1976 (age: 86 years) (40 years ago)
place of death	Freiburg, Baden-Württemberg, Germany

Image:

Timeline:  
Martin Heidegger

Notable facts:  
Author of *Being and Time*, a philosophical work with wide influence in the fields of psychology and literature.  
Worked in philosophical disciplines of existentialism and phenomenology to explore "questions of being"  
Considered controversial due to his statements supporting Adolf Hitler and his membership in the Nazi party

Familial relationships: [Show full dates](#)

Parents:  
Friedrich Heidegger | Johanna Heidegger

Siblings:  
Fritz Heidegger | Marie Heidegger

Spouse:  
Elfride Petri (1917–1976)

Children:  
Jörg Heidegger | Hermann Heidegger

Wikipedia summary:  
Martin Heidegger (26 September 1889 – 26 May 1976) was a German philosopher and a seminal thinker in the Continental tradition and philosophical hermeneutics.

Stephen Wolfram  
*Idea Makers*  
★★★★☆  
Top seller on Amazon in multiple categories »

Take Wolfram|Alpha anywhere...

Figure 1.2: WolframAlpha result of Martin Heidegger

liver exceptionally good results depicting information about specific fields, such as information about influential proponents of a specific field of research.

Current state-of-the-art in practice search engines only produce overview summaries of topics that the search engine understands and stores information about. For example, a search query about a specific output of scientific research does not deliver the expected results, as can be seen for the query “design science research methodology”. For this query, Google does not show a Google Knowledge Graph box at all (Figure 1.3) and WolframAlpha (Figure 1.4) misinterprets this query by comparing the terms science and research. Nonetheless, Google produces an acceptable list of search results.

WolframAlpha and the Google Knowledge Graph utilise knowledge bases that have to be maintained to represent additional topics. WolframAlpha calls the stored knowledge in the knowledge base ‘curated data’ and stores this knowledge in models (WolframAlpha, 2016). The Google Knowledge Graph describes this knowledge in collections (Google, 2016). This means that knowledge needs to be built up first to represent other domains. Currently, scientific results are not part of these structured collections.

Most other semantic search engines use semantics to rank their results, but do not provide overviews next to a search result. Examples include Microsoft Academic<sup>5</sup> and Semantic Scholar<sup>6</sup>. Semantic techniques support the ranking process by exploiting formal ontologies, as can be seen in Sah and Wade (2013), Cohen et al. (2003), Alani et al. (2003), Lei et al. (2006), Usbeck et al. (2016), and Laura and Me (2015). More information about different search techniques can be found in Section 2.3.

All important academic search engines currently lack overview summaries. Some well-known academic search engines include the Web of Science<sup>7</sup> containing 12,500 journals, 170,000 conference proceeding and 700 books, IEEE Xplore<sup>8</sup> containing 3,861,202 publications, and Pubmed<sup>9</sup> with 26 million citations. None of these academic search engines, including Microsoft Academic, Semantic Scholar, and Google Scholar, provide an overview related to a specific topic.

Some academic search engines use formal ontologies in the search process. Most academic search engines provide refinement techniques to limit the scope of a specific search using bibliographic information. One search engine, GoPubmed<sup>10</sup>, enhances this refinement process utilising a formal ontology (the Gene Ontology). More information about the use of formal ontologies in current state-of-the-art academic search engines can be found in Section 2.3.

The complete lack of overview summaries in current state-of-the-art academic search engines presents an interesting research opportunity. The massive amount of publications available that researchers and practitioners have

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<sup>5</sup><http://academic.research.microsoft.com>

<sup>6</sup><https://www.semanticscholar.org>

<sup>7</sup><http://ipsience.thomsonreuters.com/product/web-of-science/#>

<sup>8</sup><http://ieeexplore.ieee.org/>

<sup>9</sup><https://www.ncbi.nlm.nih.gov/pubmed/>

<sup>10</sup><http://www.gopubmed.org>

The image shows a screenshot of a Google search result for the query "design science research methodology". The browser window is titled "google.com.au" and the search bar contains the query. The search results are displayed on the "All" tab, showing approximately 34,100 results in 0.55 seconds.

The search results include several scholarly articles and PDFs:

- Scholarly articles for "design science research methodology"**
  - A design science research methodology for information ... - Peffers - Cited by 2050
  - A design science research methodology and its ... - Geerts - Cited by 67
  - Design science research in information systems - Hevner - Cited by 254
- [PDF] Design Science Research in Information Systems - desrist...**
  - desrist.org/desrist/.../design-science-research-in-information-systems.pdf
  - [Design Science Research Methodology] [Outputs of Design Science Research]. [Philosophical Grounding of Design Science Research] [An Example of IS ...]
- [PDF] A Design Science Research Methodology for Information ...**
  - wise.vub.ac.be/thesis.../Design\_Science\_Research\_Methodology\_2008.p... - by K Peffers - 2007 - Cited by 2050 - Related articles
  - A Design Science Research Methodology for Information Systems Research. Ken Peffers. 1,2. University of Nevada, Las Vegas, College of Business ...
- A design science research methodology and its application to ...**
  - www.sciencedirect.com/science/article/pii/S1467089511000200 - by GL Geerts - 2011 - Cited by 67 - Related articles
  - Mar 26, 2011 - (2008) who defined such a template for design science research for information systems: the design science research methodology (DSRM).
- Images for "design science research methodology"**
  - Report images
  - Three diagrams illustrating design science research methodology frameworks, including a flowchart of the DSRM process and a diagram of the DSRM process.
- More images for "design science research methodology"**
- A Design Science Research Methodology for ... - ACM Digital ...**
  - dl.acm.org/citation.cfm?id=1481768 - by K Peffers - 2007 - Cited by 2046 - Related articles
  - Dec 1, 2007 - The design science research methodology (DSRM) presented here incorporates principles, practices, and procedures required to carry out ...
- A Design Science Research Methodology for Information Syst...**
  - www.tandfonline.com/doi/abs/10.2753/MIS0742-122240302 - by K Peffers - 2007 - Cited by 2046 - Related articles
  - Dec 8, 2014 - The paper motivates, presents, demonstrates in use, and evaluates a methodology for conducting design science (DS) research in information ...
- Design Science Research Methodology: An Artefact-Centric ...**
  - aisel.aisnet.org/cgi/viewcontent.cgi?article=1078&context=acis2011 - by MD Ahmed - Related articles
  - Jan 1, 2011 - Adaptation of the Design Science Research methodology has never been easy. There have always been concerns regarding the validity of ...
- "Design Science Research Methodology: An Artefact-Centric ...**
  - aisel.aisnet.org / CHAPTERS / ACIS / ACIS2011 / 79 - by MD Ahmed - 2011 - Related articles
  - Adaptation of the Design Science Research methodology has never been easy. There have always been concerns regarding the validity of design science and ...
- A Design Science Research Methodology for Expert Systems ...**
  - journal.acs.org.au/index.php/ajis/article/view/1329

Figure 1.3: Google search result for "design science research methodology"

The screenshot shows the WolframAlpha interface with the search query "design science research methodology". The results are categorized into "Science (periodical)" and "Research (periodical)".

**Input interpretation:** Science (periodical) | Research (periodical)

**Basic properties:**

	Science	Research
circulation	128 000	94 000
frequency	weekly (Friday)	monthly
subject	science	finance
publisher	American Association for the Advancement of Science	Summit Business Media LLC
country	United States	United States
website	www.sciencemag.org	www.researchmag.com

(based on 2008 estimates)

**Impact factor:** [Show history](#)

	Science
impact factor	33.61

(2014)

**Images:**

Science	Research

**Wikipedia summary:**

**Science:**  
A science magazine is a periodical publication with news, opinions and reports about science for a non-expert audience. A periodical publication for scientific experts, in contrast, is called a "scientific journal". Science magazines are read by non-scientists and scientists who want accessible information on fields outside their specialization.

**Research:**  
An academic or scholarly journal is a periodical publication in which scholarship relating to a particular academic discipline is published. Academic journals serve as forums for the introduction and presentation for scrutiny of new research, and the critique of existing research. They are usually peer-reviewed

Figure 1.4: WolframAlpha result for “design science research methodology”

to review regularly increases the need to find a solution to this problem. For example, [Ronzano et al. \(2016\)](#) mentioned that a new publication is published every 20 seconds. PubMed, Elsevier’s Scopus and Thomson Reuther’s ISI Web of Knowledge contain more than 171 million papers ([Ronzano et al., 2016](#)).

Although solving the problem of summarising scientific articles in general would be the ultimate goal, this goal would be too ambitious for one PhD. This thesis focuses on the problem of presenting summaries of publications that incorporate DSR aspects (in this thesis called DSR publications). DSR involves the invention and evaluation of a purposeful artefact to solve a generalised problem ([Venable and Baskerville, 2012](#)). The fields in which research is conducted are diverse and cover a huge variety of beliefs, ideas, topics, research methods, and theories. This thesis is concerned with DSR publications. Often, publications in the applied fields cover DSR concepts. Such publications publish research that develops new technological means to solve problems and make improvements, as argued by [Venable \(2010a\)](#). This applies to most applied fields, such as health science, engineering, architecture and many more.

Overview summaries of DSR publications would be of practical significance to most researchers and practitioners. Both researchers and practitioners could save time by receiving overview summaries that compare different DSR artefacts.

Although the availability of 171 million scientific publications ([Ronzano et al., 2016](#)) sounds impressive, this number covers scientific publications in general. Nevertheless, the number of DSR related publications is reasonably high. For instance, the search query “design science research methodology” on Google Scholar on November 23, 2016 returned 2720 results. The extensive amount of DSR published in applied disciplines makes researching a solution for the generation and presentation of overview summaries of DSR publications worth pursuing. Additionally, given the number of researchers and practitioners in the applied fields, the impact is potentially significant.

## 1.2 Solution - Ontology-Based Summary Generation

Automatically generated summaries are a possible solution to the problem of missing overviews in DSR search result presentations.

A summary is a brief but accurate representation of the contents of a document or a set of them ([Lloret and Palomar, 2012a](#)). In comparison to a list of documents, which are currently returned by most search engines, a summary can condense important information and attempts to present this information in a concise way. Such concise representations facilitate the search process by providing an overview of DSR content that is related to a specific search result. Such an overview depicts the most important aspects of DSR by comparing and synthesising DSR content that is included in a search result. In comparison to a search result list, such a summary also provides a coherent interpretation of

DSR content and simultaneously excludes information unrelated to a specific DSR topic.

Textual summaries are a good choice for presenting overview summaries. Nevertheless, summaries can also be presented as graphs, diagrams, pictures, or videos. Videos and pictures are hard to create on the fly for a specific search result. Graphs or diagrams can only express limited aspects of a set of documents. Textual summaries, on the other hand, are versatile and can provide comprehensive representations of a set of documents.

Summaries that summarise a set of documents are called multi-document summaries. A multi-document summary “targets to condense the most important information from a set of documents to produce a brief summary” (Canhasi and Kononenko, 2016). Further information about single and multi-document summaries can be found in Section 2.4.3.2.

Textual summaries can be categorised into abstractive or extractive summaries. Abstractive summaries provide a condensed, abstract view of one or many documents. An abstractive summary consists of text that is not extracted word by word but paraphrases the source text. Extractive summaries consist of extracts from a specific text. Abstractive summaries are much more useful than extractive summaries, as identified in a study by Murray et al. (2010). A more complete definition and comparison of extractive and abstractive summaries can be found in Section 2.4.3.2.

Abstractive as well as extractive summaries can be created using term-based or ontology-based methods (Qiang et al., 2016). In comparison to ontology-based methods, term-based methods focus on term-based features in text(s), such as term frequencies or distances between terms in a specific text. In extractive summaries, such term-based methods are utilised to select pertinent sentences. In abstractive summaries term-based methods are used, for example, to compress sentences by only using the most important terms. More information about the difference between ontology-based and term-based methods can be found in Section 2.4.4.

An ontology is a shared, formal, and explicit conceptualisation (Studer et al., 1998). Ontology-based methods utilise semantics in the summarisation process to identify pertinent sentences or to create summaries, as can be seen in Baralis et al. (2013), Qiang et al. (2016), Wu et al. (2013), Hennig et al. (2008), and Alani et al. (2003). More information about formal ontologies and the use of ontologies in the summarisation of documents can be found in Section 2.2 and Section 2.4.4, respectively.

The purposeful artefact proposed, designed, developed, and evaluated in this thesis is based on the use of ontological representations of DSR content. This solution focuses on the construction and provision of textual, abstractive representation of multi-document overview summaries of DSR publications.

Such an overview summary, also called an indicative summary (Lloret and Palomar, 2012b), can provide an overview of a specific DSR result in a concise way. Such an overview is concise because indicative summaries provide a brief idea of what the source text(s) is/are about (Lloret and Palomar, 2012b). Nevertheless, such an overview still has to be comprehensive enough to cover the

topic of interest. Such an overview summary also needs to be correct, clear, and coherent to be of better use to the user. The properties mentioned above include the following summary criteria that are evaluated in this research. In this thesis, these criteria are called the 5Cs: conciseness, comprehensiveness, coherence, clarity, and correctness. More information about the choice of these criteria and their definitions can be found in Section 2.4.5.

As noted earlier, this thesis develops a design theory that describes a purposeful artefact to create abstractive multi-document summaries of DSR publications. This purposeful artefact, depicted in Figure 1.5, is an architecture, named Design Science Research Content Representation and Summarisation Architecture (DSRCRSA). The symbol named “Search Result” in Figure 1.5 depicts an abstractive multi-document summary, which is then presented to the user. DSRCRSA consists of the following components: an ontology repository (called DSR Knowledge Base in Figure 1.5), an ontology design (called DSR Ontology in Figure 1.5) and two processes, which are included in Search & Summarise DSR Pubs in Figure 1.5.

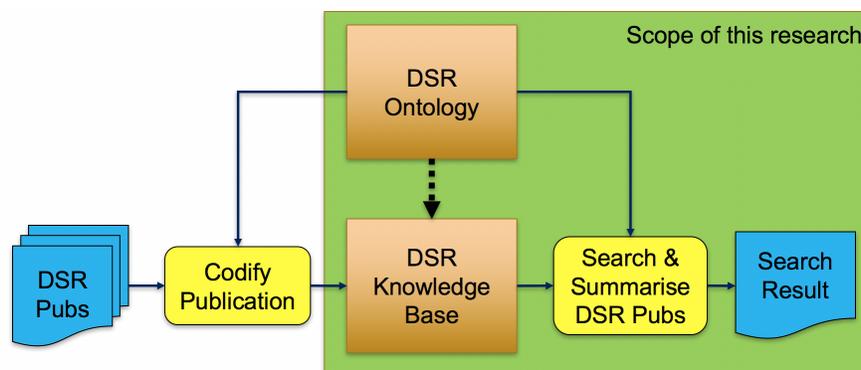


Figure 1.5: DSRCRS architecture

DSRCRSA depicted in Figure 1.5 could be used in digital libraries or in any other system that needs to represent and summarise information about DSR outcomes.

Figure 1.5 also delineates the scope of this research. This research investigates the ontological representation of DSR publications, the summarisation of a specific DSR publication, the integration of the knowledge from multiple DSR publications, and the generation of multi-document summaries over a number of DSR publications. Out of scope of this research is the extraction process of conceptualisations out of a set of DSR publications, which could be achieved utilising natural language processing techniques or form filling.

The step ‘codifying publications’ is out of scope of this research and could be interpreted as a limitation of this research. However, the codification of this information only needs to be done once per publication. In the information retrieval process this information can then be used many times. Therefore, the

researched scope is still significant for practitioners because a much more accurate representation can be extracted than just a list of links once the publication has been codified.

The ontology repository is labelled “DSR Knowledge Base” in Figure 1.5. This repository consists of DSR ontologies of each DSR publication and an ontology that serves as a reference ontology. This reference ontology (also called DSR Knowledge Base) includes statements that refer to individuals that are included in one or more DSR ontologies.

To enable the creation of single and multi-document summaries, two processes have been designed, which are part of the “Search & Summarise DSR Pubs” process in Figure 1.5.

The two processes are:

- A process to create natural language representations out of DSR publications - also called single-document overview summaries.
- A process to create representations of a combination of DSR publications - also called multi-document overview summaries.

A more detailed discussion of the summarisation process can be found in Section 4.4.

### 1.3 Significance

**Practical Significance:** As mentioned in Section 1.1, there is a vast number of scientific publications available nowadays. Researchers as well as practitioners have to spend a lot of time in reviewing and synthesising scientific articles.

Literature research of the massive amount of DSR publications would be enhanced by providing overview summaries for those scientific articles that fit a certain search query.

Researchers could benefit from a realisation of DSRCRSA in their daily work. Researchers need to review and search literature frequently. Being able to retrieve a comprehensive overview that also excludes irrelevant information could support the review process and could save a significant amount of time.

Realisations of DSRCRSA could also support practitioners to get a brief overview of solutions to a certain problem. Practitioners could use such an overview to improve their products or to take some other actions to improve their situation.

Finally, DSRCRSA could be used by software architects to introduce a summarisation capability into academic search engines.

**Theoretical Significance:** This thesis presents a design theory to create abstractive summaries of DSR publications, which has not been attempted yet. This design theory includes a novel purposeful artefact (or meta-design as described in (Walls et al., 1992)) that fulfils the meta-requirement (Walls et al., 1992) to create abstractive overview summaries of DSR publications. This

purposeful artefact consists of a novel design of an architecture that utilises a repository of semantic representations of DSR publications to create abstractive, multi-document summaries. The following paragraphs provide evidence for the importance and novelty of such an approach.

This thesis extends prior work on the use of ontologies to produce summaries. Many automatic summarisation approaches that generate extractive summaries utilise ontologies to improve the identification of salient sentences. Examples include approaches in [Baralis et al. \(2013\)](#), [Qiang et al. \(2016\)](#), and [Sarker et al. \(2016\)](#). Some approaches that utilise ontologies are also intended to be used to create abstractive summaries, such as in [Alani et al. \(2003\)](#), [Lee et al. \(2005\)](#), and [Moawad and Aref \(2012\)](#). A number of abstractive summarisation approaches make use of semantics in the source text as proposed in [Moawad and Aref \(2012\)](#), [Khan et al. \(2016\)](#), [Balaji et al. \(2016\)](#), [Gerani et al. \(2016\)](#), and [Lee et al. \(2005\)](#). This thesis focuses on the use of formal ontologies to create abstractive summaries. Abstractive summaries can be a solution to the problem of how overview summaries can be presented and generated. However currently, the generation of abstractive summaries is still a challenge ([Kim et al., 2016](#)).

This research invented, realised, and evaluated a novel process to create abstractive, multi-document summaries from a formal ontology. There are a few approaches published that utilise ontologies to generate abstractive summaries, such as in [Alani et al. \(2003\)](#), [Lee et al. \(2005\)](#), and [Moawad and Aref \(2012\)](#). However, these approaches utilise ontologies that cannot easily be transferred into the domain of scientific publications.

[Alani et al. \(2003\)](#), for instance, use CIDOC CRM <sup>11</sup> to create biographies of famous painters. CIDOC CRM is used in cultural heritage documents, which cannot be applied to the domain of DSR. Another approach, which has been proposed in [Lee et al. \(2005\)](#), covers and provides an ontology of the weather domain. Again, such an approach cannot easily be applied to the domain of DSR.

Other approaches, such as in [Moawad and Aref \(2012\)](#), propose a more general approach by extracting nouns and verbs out of documents to build a domain ontology. This approach is used in the generation of single document summaries. Due to the generality of the approach in [Moawad and Aref \(2012\)](#), the comparison and accurate representation of multi-document summaries can be a problem.

Most other summarisation approaches that make use of ontologies, such as in [Baralis et al. \(2013\)](#), [Qiang et al. \(2016\)](#), and [Sarker et al. \(2016\)](#), do not make use of ontologies in the summary generation process, but only in the process of identifying salient sentences.

The approach proposed in this thesis is novel because it specialises in DSR publications to create context specific overview summaries. However, this approach is still general enough to cover publications in all applied fields, within which novel, purposeful artefacts are invented and evaluated. In addition to that, this approach is novel because it firstly offers an ontology-based approach

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<sup>11</sup><http://www.cidoc-crm.org>

to store semantics about DSR publication content, and also to create abstractive overview summaries of multiple DSR publications.

As part of this approach, this research invented, realised, and evaluated a novel ontology that describes DSR publications. Abstractive summaries require a knowledge base to create such abstracts from a specific piece of work. Formal ontologies can be used to serve as a knowledge base. Although there are ontologies available to describe bibliographic aspects, such as in [Leukel et al. \(2011\)](#), [Warren \(2012\)](#), [Palmirani et al. \(2011\)](#), and [Buchanan \(2006\)](#), there are only a few formal ontologies available that describe content that is represented in scientific publications, such as in [Groza et al. \(2007\)](#), [Ciccarese et al. \(2008\)](#), and [Constantin et al. \(2016\)](#). Although there are ontologies that describe scientific content, there is no ontology that specialises in DSR publication content yet. Thus, this thesis introduces a novel ontology that fulfils the purpose of storing semantics about DSR publications and of producing abstractive, multi-document summaries.

## 1.4 Research Questions

The main research question in this research is:

How can search results about DSR publications be automatically generated as a textual summary that is concise, comprehensive, coherent, clear, and correct?

This main research question has been sub-divided into the following research questions:

1. Can cloze text sentences be used to create concise, comprehensive, clear, coherent, and correct single document summary representations of DSR publications?
2. Is it possible to extract a multi-document summary from ontological representations of DSR publications?
  - (a) What are the classes, relations, and axioms that have to be covered in a formal ontology that describes DSR publications?
  - (b) What competency questions does a formal ontology that describes DSR publications have to be able to answer?

The research questions are related to each other as follows:

Research questions one and two answer the main research question.

Research question one is concerned with whether cloze text sentences can enable the generation of single document summaries that fulfil the 5Cs. A correct answer to research question one, which includes the successful generation of single document summaries, leads to the next step in this research.

Research question two is concerned with whether formal ontologies can be used to support the generation of multi-document summaries. Formal ontologies were identified as a technique to structure DSR knowledge that then can be used

to provide a unified structure to store and relate information that is stored in multiple scientific articles. Research questions 2.a. and 2.b. were identified to research this topic.

Research question 2.a relates to the design of formal ontologies by identifying classes, relations, and axioms that describe formal ontologies that are then used in the proposed architecture. Research question 2.b researches competency questions that were utilised to evaluate the ability that the resulting formal ontologies can be used to compare and summaries multiple documents.

## 1.5 Research Methodology

This work follows the paradigm of DSR. DSR involves the invention and evaluation of a purposeful artefact to solve a generalised problem (Venable and Baskerville, 2012).

This thesis presents a novel design theory. For this design theory, the research that is presented in this thesis invented a novel purposeful artefact. This purposeful artefact is a novel architecture. This architecture (DSRCRSA) solves the generalised problem of storing semantics of publications in the applied fields. This architecture also solves the generalised problem of creating abstractive, single and multi-document summaries of publications in the applied fields. This thesis also includes an evaluation of a design realisation of the proposed purposeful artefact.

The work that is presented in this thesis follows the guidelines for DSR as outlined in Hevner et al. (2004).

The DSR methodology that has been utilised in this research is named Soft Design Science Methodology (SDSM) (Pries-Heje et al., 2014). SDSM has been chosen because of the need to iterate between the design thinking world (the creation of artefact designs) and the real world (the creation of the design realisations). These iterations make it possible to shape the artefact designs. Chapter 3 depicts how these iterations inform the design world as well as the real world respectively.

## 1.6 Findings

### 1.6.1 Major Findings

This thesis has three major findings. Firstly, this research identified that it is possible to automatically generate machine readable presentations of DSR publications. Secondly, this research also identified that representations of DSR publications enable the generation of single and multi-document summaries of DSR publications. Thirdly, this research identified that these summaries fulfil the 5Cs mentioned in Section 1.2. The next paragraphs explain the emergence of these findings.

Firstly, an architecture (DSRCRSA) enables the creation of single and multi-document summaries as the general design. DSRCRSA consists of an ontology

repository in addition to two processes. Further information about the artefact designs can be found in [Chapter 4](#).

Secondly, formative and summative evaluations provide evidence for the efficacy and effectiveness of the proposed artefact designs. The summative evaluation provides an answer to the main research question mentioned in [Section 1.4](#).

All artefact designs and their realisations were evaluated formatively, in terms of efficacy, at the end of each iteration, which provides answers to research question 4. Descriptions of each iteration can be found in [Chapter 3](#).

The summative evaluation provides evidence that it is possible to create abstractive summaries that are concise, comprehensive, coherent, clear, and correct (the 5Cs). This summative evaluation answers research questions 1, 2 and 3 in [Section 1.4](#).

Instantiations of summaries were evaluated by DSR experts. These summative evaluations provide evidence for the ability of the proposed artefact to generate single document summaries about a specific DSR publication as well as multi-document summaries about specific DSR content. Both types of summaries were qualitatively evaluated by DSR experts in a series of interviews. The criteria evaluated in these interviews were conciseness, comprehensiveness, coherence, clarity, and correctness (the 5Cs) of single and multi-document summaries.

Thirdly, a design theory was developed that formalises the findings at the beginning of this section. This design theory extends design theories about the design of search engines to achieve the general requirement to create single and multi-document summaries of a set of DSR publications. A summative evaluation provides evidence that DSRCRSA is capable of storing semantics of DSR publications and of generating single and multi-document summaries of DSR publications.

Finally, the discussion chapter describes the ability of DSRCRSA to produce summaries of any level of detail, which contributes to different needs of different users.

### 1.6.2 Design Principles

Two design principles emerged as a reflection on the design. These design principles, if faithfully implemented, should enable the major findings discussed above.

These two design principles are as follows: (see [Section 6.1](#) for more information)

1. The use of semiotic layers in formal ontologies
2. The use of complex classes at each semiotic layer

**The use of semiotic layers in formal ontologies:** It could be identified that semiotic layers that are represented in formal ontologies support the generation of summaries. If the vocabulary is stored according to syntactic, semantic,

and pragmatic aspects, summaries can be generated that firstly cover the aspects that a reader of a summary is interested in (pragmatic aspect), scientific articles can be categorised and compared more easily (semantic aspect), and summaries can be generated that fulfil the 5Cs (syntactic aspect).

**The use of complex classes at each semiotic layer:** Complex classes include logical expressions. These logical expressions are comprised of concepts themselves. Semiotic layers can provide a clear separation of concepts into three layers. Each layer depends on concepts of lower layer concepts. Complex classes that utilise concepts of the lower layer firstly enable a clear separation between these layers. Secondly, such complex classes enable algorithms to work with a specific layer by still incorporating or referring to lower layer concepts, which can then be used by, for instance, other processes.

## 1.7 Structure of this Thesis

This thesis is structured into the following chapters.

Firstly, [Chapter 1](#) (Introduction) describes the problem to be solved and its significance, followed by the identified solution for this problem. The practical significance and theoretical significance ([Section 1.3](#)) then describes the importance of this research. Finally, the introduction outlines the research questions ([Section 1.4](#)), the research methodology ([Section 1.5](#)) that is used in this research, as well as the main findings ([Section 1.6](#)).

[Chapter 2](#) (Literature Review) firstly outlines the main concepts that are used in this thesis. Following that, an analysis of relevant prior research in the field of search engines and automatic summarisation provides further support regarding the significance of this work. A discussion of formal ontologies and DSR then outlines the context of the proposed solution. Readers that are knowledgeable in DSR can skip [Section 2.5](#), and readers that are knowledgeable in formal ontologies can skip [Section 2.2](#).

[Chapter 3](#) (Research Methodology) outlines the DSR methodology that has been chosen for this research. Information about each stage of this methodology explains how these stages have been implemented in this research.

[Chapter 4](#) (Artefact Design) depicts the purposeful artefact (DSRCRSA) and how it can be incorporated into existing systems. This chapter explains the design of an ontology repository that supports the processes that produce single and multi-document summaries. This chapter introduces each of these processes. Additionally, each research iteration is briefly highlighted.

[Chapter 5](#) (Evaluation) describes the setting of the evaluations as well as the outcomes. The final design realisations are evaluated summatively to provide evidence towards the utility of generating overview summaries, as well as the correctness of the proposed design theory.

Finally, [Chapter 6](#) (Discussion and Conclusion) discusses the implications of this work, followed by a conclusion and future research opportunities.

The appendices include interview guides, generated summaries, interview transcripts, excerpts of the code that has been developed to generate summaries, and the ontologies that were designed and generated for this research.

## Chapter 2

# Literature Review

## 2.1 Introduction

This chapter outlines the problem space (the researcher's understanding of the problem (Venable, 2006)) and the solution space (description of the concepts that describe the solution of the problem (Venable, 2006)) that is researched in this thesis. This literature review defines and describes salient concepts of the topics that are covered in this thesis and identifies research gaps that are addressed.

The following sections discuss topics and techniques, research gaps, and evaluation techniques regarding (1) formal ontologies, (2) search engines, and (3) automatic summarisation. Finally, literature about (4) DSR provides a basis for the artefact design that is proposed in this thesis.

Section 2.2 discusses formal ontologies. Formal ontologies are used in this thesis to automatically summarise DSR publications. The concept of a formal ontology is an integral concept of the solution space that is discussed in this thesis. Firstly, Section 2.2 provides a definition of formal ontologies and highlights their important qualities. Secondly, reasoning techniques in formal ontologies and the evolution of formal ontologies are discussed to identify important aspects that are researched in this thesis. Thirdly, ontology engineering techniques are highlighted that build the basis of the ontology engineering methodology that is used in this research. Further, gaps in formal ontologies that are related to the artefact designs that are proposed in this thesis are discussed. Section 2.2 concludes by summarising ontology evaluation techniques.

Section 2.3 (Search engines) describes the problem space - the lack of search result summaries in academic search engines - that is researched in this thesis. This section consists of a general introduction to search engines to discuss and define the terminology that is used in this thesis. Then, the literature about academic search engines is outlined to identify the gaps that are researched in this thesis. Further, the scope of the problem space is discussed. Following that, current research on search result representations and state-of-the-art search result representations in practice highlight research gaps and define the problem space that is discussed in this thesis.

Section 2.4 (Automatic summarisation) describes a possible solution space for the problem that search results in academic search engines lack summaries. After outlining some important definitions, this section delineates the significance of automatic summarisation to highlight the importance of this research. Important terminology and techniques are discussed to highlight research gaps. This section ends with a discussion of summary evaluation techniques. These evaluation techniques include the criteria that are used to evaluate the purposeful artefact that is presented in this thesis.

Finally, the literature review chapter concludes by covering the field of DSR. Section 2.5 provides a basis for the development of a formal ontology that represents DSR, which is used in the automatic summarisation process. This formal ontology has to include all major DSR components and relations between DSR components in order to generate summaries of single and multiple DSR publications.

## 2.2 Formal Ontologies

Section 2.2 introduces formal ontologies as a solution to formalise DSR content. Additionally, Section 2.2 introduces terminology that is used throughout this thesis.

Section 2.2.1 defines the term ‘formal ontology’ that is used in this thesis. Section 2.2.1 also highlights important aspects of formal ontologies. A discussion about these aspects should facilitate the design and development of formal ontologies.

Section 2.2.2 delineates different ontology languages that serve as a means to formally represent an ontology. A discussion about general components and a general syntax of formal ontologies provides an overview of the structure of formal ontologies. This section introduces the concepts A-Box (assertional box) and T-Box (terminology box), which are then further used throughout this thesis. Finally, different types of formal ontologies and their different uses are discussed and terms used in this thesis are introduced.

Section 2.2.3 focuses on the expressiveness of formal ontologies and provides a definition of the term ‘expressiveness’ in this context. The section also provides an introduction to different levels of expressiveness in formal ontologies. The term expressiveness of formal ontologies is discussed in this thesis because it is a prerequisite to the employment of more sophisticated reasoning techniques, which are discussed in Section 2.3, and Section 2.4.

Section 2.2.4 discusses reasoning techniques in formal ontologies and describes the logical language that is used to reason in an ontology repository. This section further discusses the use of reasoning techniques in search engines and highlights that more expressive ontologies could enhance reasoning techniques in semantic search engines.

Section 2.2.5 discusses how ontologies can change over time. This section presents methodologies to support the evolution of ontologies. Additionally, the different triggers that trigger an ontology change are briefly introduced. This introduction includes data-driven discovery, which is the main trigger to identify ontology changes for the formal ontologies that are presented in this thesis.

One of the main artefacts that are described in this thesis is a set of manually designed formal ontologies. These designs were developed by following an ontology engineering methodology. Therefore, Section 2.2.6 (Ontology engineering) provides an overview of ontology engineering methodologies and a discussion of the main steps that ontology engineering methodologies have in common.

The ontology repository that is presented in this research covers core concepts of DSR publications. Therefore, Section 2.2.7 discusses ontologies from the literature that describe bibliographic records and documents. A comparison of document ontologies identifies gaps in document ontologies in the literature that have to be filled for the solution design that is proposed in this thesis.

Finally, ontology evaluation methodologies (Section 2.2.8) in the literature are outlined to describe commonalities and differences between different ontology evaluation methodologies.

### 2.2.1 Definition

This section introduces and defines the term ‘formal ontology’ that is utilised in this work.

Ontology is “the study of attributes of things that belong to things because of their very nature” (Guarino et al., 2009). The term ontology has been adapted in computer science and information systems and converted into a formalised notation, also called formal ontology. An ontology in computer science is used as an information object. Gruber (1993) introduced the following definition for the term ontology: “An ontology is an explicit specification of a conceptualization”. Borst (1997) then adapted the definition in his thesis to express the shared aspect of a formal ontology. According to his definition, “An ontology is a formal specification of a shared conceptualization”. This definition was further extended by Studer et al. (1998). Studer et al. (1998) added explicitness to the definition, which then transformed the definition by Borst (1997) into “an ontology is a formal, explicit specification of a shared conceptualisation”.

Gruber (1993) borrowed the term ontology from philosophy to refer to the systematic account of existence. Gruber (1993) explained that the content of a knowledge base is what exists in a knowledge base. Thus, a knowledge base can be seen as a systematic account of existence. Guarino et al. (2009) reflected on the point that ontology focuses on the nature and the structure of things and therefore a thing that is represented in a formal ontology is independent of its existence. Computational (from now on called ‘formal’) ontologies in information systems are often used to model and / or describe the data structure of an information system.

As mentioned above, formal ontologies describe a systematic, explicit account of existence. This account of existence is expressed as a conceptualisation and represents a specific topic or thing. The following paragraphs firstly discuss the term conceptualisation, before the main properties of formal ontologies are delineated, namely existence, explicitness and expressiveness, formalism, and shareability. After that, the concept ‘thing’ is discussed, which is the highest-level concept in formal ontologies.

#### 2.2.1.1 Conceptualisation

Guarino et al. (2009) defined conceptualisation as an abstract, simplified view of the world - a world that the author wants to conceptualise for some purpose. Borst (1997) defined conceptualisation as a structured interpretation of a part of the world. A conceptualisation always expresses a certain view of the world. This thesis delineates a conceptualisation (DSRKBO - see Section 4.3.4) that aims to combine and relate different world states.

Gruber (1993) referred to Genesereth and Nilsson (1987) by proposing that a conceptualisation consists of “objects, concepts, and other entities that are presumed to exist in some area of interest and the relationships that hold them”.

To summarise, a conceptualisation is an abstract view of a specific part of the world and consists of objects, concepts, and other entities that exist in the

area of interest in addition to the relations between these entities.

### 2.2.1.2 Existence

Gruber (1993) stated that what can be represented with a knowledge base is what exists in that knowledge base. Guarino et al. (2009) argued that the nature and structure of things are represented in an ontology, but that the thing that is represented in an ontology does not have to exist per se. Thus, Gruber (1993) and Guarino et al. (2009) agreed that a thing that can be described using an ontology does not have to exist in real life.

However, an ontology should describe a thing that belongs to a specific world view (even imaginary) and can be described by a set of axioms.

### 2.2.1.3 Explicitness and Expressiveness

A formal ontology is an explicit conceptualisation. Studer et al. (1998) mentioned that an explicit conceptualisation demands that the type of concepts and constraints are explicitly defined. Explicit representations facilitate the use of ontologies in information systems. A conceptualisation that is described in natural language cannot be easily translated into a structure that can be understood by computers. If a conceptualisation is expressed using an explicit set of concepts and constraints, information systems can utilise these structures to, for instance, reason over an ontology or search within an ontology.

The term ‘explicitness’ is also related to the expressiveness of an ontology. Explicit ontologies might not be expressive enough because components that are available in a specific ontology might not incorporate components that are needed to completely describe a certain thing. Formal ontologies or conceptualisations that have been written in natural language are very expressive. However, such an ontology cannot be interpreted easily by a computer. Thus, the right level of expressiveness has to be chosen in order to use ontologies in information systems. More about the expressiveness of formal ontologies can be found in Section 2.2.3.

### 2.2.1.4 Formalism

Formal, as defined by Studer et al. (1998), means machine readable. Any document that contains information that can be stored and read by a computer is machine readable. However, only information that follows a formal, explicit structure can be used efficiently by computers.

Formal ontologies demand a certain degree of formality. The degree of formality depends on the purpose of the formal ontology.

Depending on the expressiveness that a certain ontology requires, the right level of formality has to be chosen. For instance, a formal ontology needs to include cardinality constraints to express, for example, that a child has two parents. Another formal ontology might not need cardinality constraints to express the conceptualisation that is represented in the ontology. More about different levels of expressiveness and formality can be found in Section 2.2.3.

### 2.2.1.5 Shareability

A formal ontology represents a conceptualisation that should be shared by a number of people or systems. [Borst \(1997\)](#) maintained that there “must be an agreement on the conceptualization”. [Studer et al. \(1998\)](#) stated that an ontology captures consensual knowledge. However, [Guarino et al. \(2009\)](#) identified that, although sharing is important, it can be at best partial. Also, [Guarino et al. \(2009\)](#) stated that only approximations of conceptualisations can be shared.

Whether a conceptualisation represents a shared understanding depends on the people that use a specific ontology and the purpose of a specific ontology. People that use a specific ontology, or people that could be identified as potential users of a specific ontology, have to have a shared understanding of the axioms that are included in a specific ontology. For instance, an ontology that describes relations between people, such as in the friend-of-a-friend ontology ([Brickley and Miller, 2014](#)), can be shared among a high number of people. This high number of people agree on the ontology because it expresses concepts that can be easily followed and agreed upon. People agree because their understanding matches the relationships that are expressed in the ontology.

However, the purpose of an ontology influences the number of people that use a specific ontology, or the number of people that use the output of a process that includes a specific ontology. For instance, a social network identifies relationships between users of the social network. However, this social network only uses this information internally. Therefore, no user will ever receive information in regards to the identified relationships. Thus, for the applicability of the ontology in this example, the ontology only needs to find an agreement among the developers of the social network.

In comparison to ontologies that are only used internally, there also exist ontologies that need a broader consensus. The same ontology that has been used in the social network situation to represent relations between users could be used to relate people across a number of webpages. Because many systems would incorporate this ontology, and the users of these systems might receive an explanation that describes these relations, there has to exist a much broader consensus.

Finally, more specific ontologies usually result in ontologies that are much harder to agree upon than more abstract ontologies. Thus, the more people share a specific ontology, the more approximations have to be included to support different opinions.

### 2.2.1.6 Thing

The concept ‘thing’ is the top-level concept of every formal ontology that is expressed in the Web Ontology Language (OWL) (more information about ontology languages, such as OWL, can be found in [Section 2.2.2](#)). But what does ‘thing’ mean and when does a ‘thing’ exist?

**Definition of Thing:** Döring and Isham (2010) support Heidegger’s interpretation that “a thing is always something that has such and such properties, always something that is constituted in such and such a way. This something is the bearer of the properties; the something, as it were, that underlies the qualities” (Döring and Isham, 2010, p. 12)(Heidegger, 1967).

Döring and Isham (2010) interpret the meaning of ‘realist’ from a classical physicist’s point of view. The authors express that a “property of the system is meaningful and mathematically representable in theory”, “propositions about the system are handled using boolean logic”, and that “there is a space of microstates where each microstate encodes the way things are” or that a microstate “leads to unequivocal truth values for all propositions about the system” (Döring and Isham, 2010).

Döring and Isham (2010) identify that Heidegger’s interpretation of ‘thing’ and the meaning of ‘realist’ from a classical physicist’s point of view resemble each other. Thus, a thing can be described by a set of meaningful properties and propositions that are described in boolean logic. Propositions assert that the system has a specific property. A microstate includes unequivocal truth values for all propositions of a system. Such a microstate can be seen as a realisation of a specific system. A realisation can be described as an object that fulfils all properties of a specific system. The difference between things and objects is discussed below in the paragraph named “Thing vs. Object”.

OWL ontologies support the description of a ‘thing’ by providing the concept of a ‘property’ and propositions (axioms) that assert that a property has been met. The expression of microstates can be achieved in OWL by adding assertions to the ontology that include individuals. Individuals express instances of concepts (i.e., a cat is an instance of the concept animal). However, OWL cannot describe properties and concepts only by the use of individuals. The paragraph below named “Semiotic triangle or meaning triangle” describes this problem with the help of semiotic triangles. The artefact design chapter (Chapter 4) describes why such a representation was chosen in the formal ontologies (DSRDCO and DSRKBO) that are presented in this thesis. These representations make it possible to reason over formal representations of DSR publications. These representations can support the identification of things that appear in DSR publications, but are utilised in this thesis to generate natural language summaries.

**Thing vs. Object:** Harman (2013) agreed with Heidegger’s interpretation that a thing and an object have to be clearly separated. Things are events and cannot be reduced to a list of properties and qualities because there is always another aspect to it (Harman, 2013). Such additional aspects emerge by viewing the ‘thing’ in question from different perspectives. In contrast, an object consists of a specific, well-defined set of properties.

In her seminal work, Miller (2008) clearly separated objects and things. However, Miller outlined that things and objects are related to each other. She also stated that objects only exist if there are things with the right sort of

properties and proposed that a thing constitutes an object at a time  $t$ .

Heidegger (1967) interpreted things as events because they describe how and what. Things are always something deeper than the total reality. Harman (2013) mentioned that things “have significance, they belong to a system of relations with other things in the environment”. Harman (2013) also added that things have a meaning because humans care.

To summarise, things are different to objects. Objects are things with the right sort of properties at a time  $t$ . Thus, time can change an object into another thing.

This thesis proposes the use of an ontology repository to formally represent things. Things have to be formally represented utilising an open world assumption. In an open world assumption, it is not possible to deduce from missing properties. It is always possible that another property is added to an existing ontology. There is always another aspect of a certain thing that has not been described in the first place. Thus, ontologies can and have to evolve because new aspects can be added at any time.

There are always new aspects to observe by viewing an object from different perspectives. For instance, a rose has different properties when looking at it with one’s own eyes instead of, for instance, using a microscope. Thus, from an ontological point of view, a thing can be described by an infinite set of properties. Nevertheless, by adding additional properties to an ontological representation of a specific thing (for example, by adding properties from another perspective), objects that were previously entailed by the thing in question might be excluded due to newly identified properties.

An ontology has to be able to cope with the above interpretation of a thing. An ontology needs to evolve. An ontology needs to describe a thing that exists in all worlds this ontology is designed for. Finally, instances, which represent objects, might lose their relation to a specific thing over time because objects can lose specific properties.

**Semiotic Triangle or Meaning Triangle:** Ogden et al. (1923) presented the semiotic triangle. Sowa (2000) discusses an adapted version of the semiotic triangle, also called the meaning triangle (see Figure 2.1). The vertices of the meaning triangle represent the symbolic representation of an object, the object itself, as well as an impression of the object. An impression of an object (also called concept) makes it possible to relate between a symbol and an object.

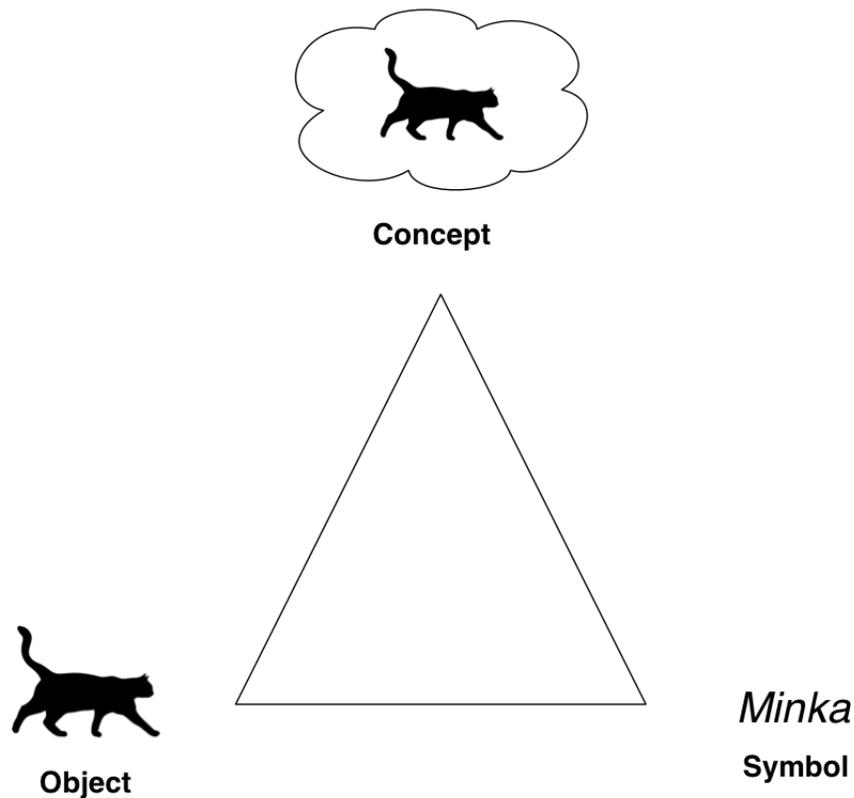


Figure 2.1: The meaning triangle. Adapted from [Sowa \(2000\)](#)

The symbol can be a lexical representation of an object. An example would be the word ‘Minka’ for a cat. The object (the cat) creates an impression in the mind of the reader. This impression represents the concept of a cat. The reader can then create a connection from the symbol to the object via the concept / impression. If this concept is not known to the reader and cannot be related to the symbol, the reader cannot create a mapping between the sign and the object. Additionally, a reader cannot directly relate the object and the symbol without understanding the concept of a cat.

[Sowa \(2000\)](#) described that the meaning triangle can be expanded by adding another set of meaning triangles to the vertices of the meaning triangle (see [Figure 2.2](#)). For instance, the impression of a cat (the concept) in the first triangle can become the object in the adjacent triangle. The symbol of the adjacent triangle represents a symbol that expresses the concept of a cat. The impression (or concept) of the adjacent triangle describes the idea that the concept ‘cat’ can be mapped to the symbol ‘cat’. This expresses the neural excitation that enables this deduction.

Such a representation enables the description of a specific object on several

conceptual layers. The first level in Figure 2.2 expresses that ‘Minka’ can be assigned to the object by the idea that the symbol ‘Minka’ relates to a cat. The second level in Figure 2.2 delineates the relation of a symbol to a specific object. The concept that describes such a relation includes the idea that a cat can be represented by a symbol, which expresses the name of a specific cat. Such a representation cannot be easily expressed in formal ontology languages, such as OWL. However, the representation of different layers can be beneficial to represent content of DSR publications. Chapter 4 delineates how OWL ontologies can make use of such interpretations.

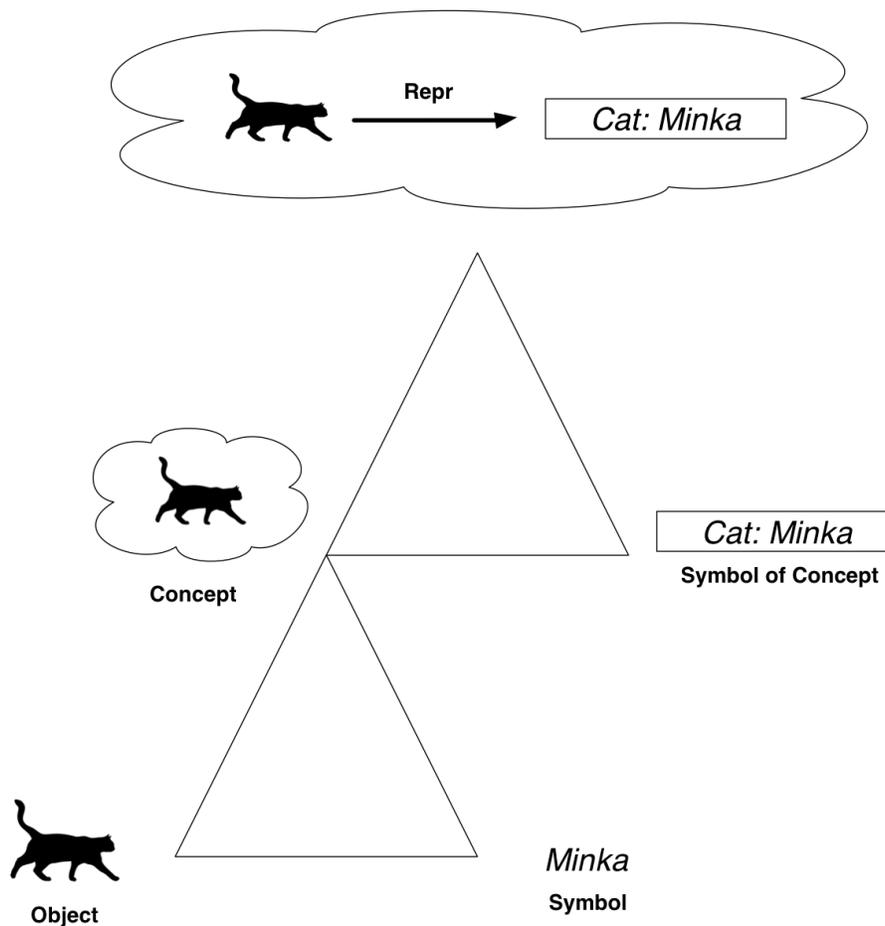


Figure 2.2: Object by concept. Adapted from Sowa (2000)

Sowa (2000) also delineated that an adjacent triangle cannot only be added to the impression or concept of another meaning triangle, but also to the symbol (see Figure 2.3). In such a case, the symbol in the first meaning triangle

is transformed into an object of the adjacent meaning triangle. The symbol of the adjacent triangle now becomes the symbol of the name ‘Minka’. This enables different symbolic representations of the concept ‘cat’, which can either be a word or a number of characters. This representation can be expressed by relations that relate the concept ‘cat’ to the word that describes the concept ‘cat’, and the word that describes the concept ‘cat’ to the string that represents the word for the concept ‘cat’. All conceptual layers (the representation as a word, and the representation as a string) describe a different perspective or world state to describe the concept ‘cat’. The first representation (the word ‘Minka’) might belong to a semantic layer that expresses the meaning of the word. The second representation (the string ‘Minka’) might belong to a lexical layer that expresses the composition of the word ‘Minka’ as a string.

Such a conceptualisation can either be represented in different formal ontologies, or by a specific terminology that has to be added to the ontology to store such different views. The first option would dedicate an ontology to each conceptual layer. Each layer could then utilise the representations of a lower layer to express higher-level concepts. Nevertheless, this does not include relations between concepts of different layers. However, such relations can be defined in a formal ontology that combines the concepts of each layer.

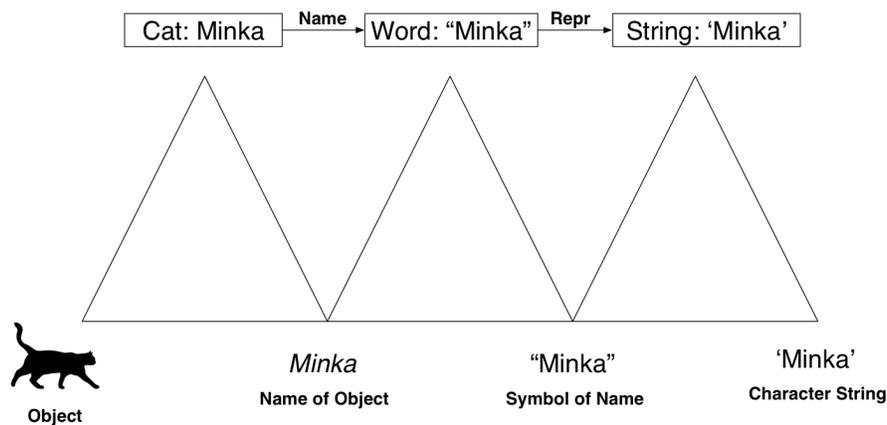


Figure 2.3: Object represented by different symbols. Adapted from Sowa (2000)

The example in Figure 2.2 shows that a concept can be expressed by another concept. An example that is related to the research in this thesis is the representation of a scientific article. Let’s assume that a scientific article presents a novel architecture. This architecture supports information retrieval in digital libraries. The symbol for this architecture could be ‘SciOntoPresenter’. The symbol ‘SciOntoPresenter’ refers to the specific architecture that is presented in the article. This specific architecture can be mapped to a symbol by understanding the concept of an architecture. Further, the concept of an architecture

can be described as an artefact. The concept that describes an artefact needs to express that an artefact is something artificial, human-made. If the architecture inherits these properties, the architecture belongs to the type ‘artefact’. With this information the reader can create a mapping from the object architecture to the symbol artefact.

The meaning triangle expresses another feature of formal ontologies - that is, the ability to represent subsumption relations (specialisation / generalisation relationships). The example above shows that the concept artefact subsumes the concept architecture. However, the identified concepts, including the subsumption relations, have to be valid in all possible worlds the conceptualisation is designed for.

This thesis focuses on the use of different layers to present a specific concept. The example above can be expressed by subsumption relations. However, if such a concept is represented by different semiotic layers, SciOntoPresenter becomes the symbol for the concept architecture. The concept architecture is described by a set of axioms. Further, the concept architecture can be represented as an artefact. The concept artefact itself consists of a different set of axioms that represent an artefact on a more abstract layer.

Another aspect that relates to the discussion above is that an object can be transformed into a symbol, or a concept, by moving this object into an adjacent meaning triangle. If these transformations are included in a formal ontology, the formal ontology might result in non-well-formed formal ontologies because an ontology can then include classes that are also expressed as individuals. To reduce the risk of any misinterpretation in a formal ontology, an ontology specification should clearly define how the ontology differentiates between classes and instances. Some ontologies include the class ‘Sauvignon Blanc’ to represent Sauvignon Blancs from several wineries. In another ontology, ‘Sauvignon Blanc’ becomes an instance of the class ‘wine’. Depending on the specification of a formal ontology, some resources can become a class or an instance.

**Ontologies and Artefacts:** A thing can be naturally occurring or human-made. However, among other things, this thesis is concerned with artefacts, which are by definition human-made.

An artefact can be described by a set of properties; it is constituted by a number of parts and it is the bearer of the set of properties and underlies certain qualities.

Thus, the concept artefact is a subclass of the concept ‘thing’ and can therefore be expressed in a formal ontology.

**Ontology of Artefacts:** [Mizoguchi and Kitamura \(2009\)](#) described the function of an artefact as a defining feature of an artefact. The device ontology that is described by Mizoguchi and Kitamura can be used to describe artefacts. This device ontology consists of the concepts entity, structure, behaviour, and function. The concepts ‘structure’ and ‘entity’ can express directly related components. The concept ‘behaviour’ expresses certain qualities, and the concept

‘function’ expresses properties. Additionally, [Houkes and Meijers \(2006\)](#) described artefacts as having structural as well as functional characteristics. The literature shows that an artefact can be described by structural and functional characteristics, together with certain qualities.

Functional characteristics describe the purpose of an artefact. However, the purpose of an artefact can also express characteristics other than solely functional ones. However, artefacts that do not have a purpose can still be seen as an artefact as long as they are human-made. Artefacts that have a purpose (also called purposeful artefacts) and solve a generalised problem are an output of DSR as described by [Venable and Baskerville \(2012\)](#). Further discussion on DSR and purposeful artefacts can be found in Section 2.5.

### 2.2.1.7 Definition of “Formal Ontology” - Conclusion

Ontology deals with the nature and structure of reality ([Guarino et al., 2009](#)). Aristotle defined ontology as the study of the attributes of things that belong to things because of their very nature. In information systems, ontologies or formal ontologies are used as an information object ([Guarino et al., 2009](#)) to describe things.

This work utilises the definition of formal ontologies proposed by [Studer et al. \(1998\)](#). However, the property of a shared understanding is used in this thesis with a slight adaptation. The concept of a shared understanding always depends on the context that an ontology is used in and the context that an ontology is used for. However, there should be a shared understanding between the users of such a system or at least the users of a system should accept this interpretation for the sake of the purpose that the formal ontology is intended for.

This section also explained that the concept ‘artefact’ can be subsumed by the concept ‘thing’. This is true for all ontologies that are based on the root concept ‘thing’. However, this knowledge has guided the development of the formal ontologies that are presented in this thesis to reflect different interpretations and expressions of a specific artefact.

Finally, this section gives a brief introduction to vital concepts of formal ontologies and their definitions.

## 2.2.2 Representations of Formal Ontologies

A formal ontology is a conceptualisation (see Section 2.2.1) that is often expressed as a set of triples. Each triple consists of a subject, a predicate, and an object. Formal ontologies are formalised by the use of a specific ontology language. OWL (the web ontology language) ([Hitzler et al., 2012](#)) is capable of representing such triples.

This section firstly describes general components of formal ontologies and discusses the concept ‘ontological commitment’. Then, different ontology languages are briefly described. The differentiation between an A-Box and a T-Box delineates two main components of formal ontologies. The difference between

open world assumptions and closed world assumptions delineates different interpretations of formal ontologies that result in different applications of formal ontologies. Finally, a categorisation of different types of formal ontologies depicts the general differences in the vocabulary of formal ontologies.

### 2.2.2.1 Components of Formal Ontologies

The definition at the beginning of Section 2.2.1 defines a formal ontology as a formal, explicit specification of a shared conceptualisation. Any conceptualisation that conforms to this definition can be treated as a formal ontology. The level of formality is specified in the specification of an ontology language.

One well-known ontology language is OWL (the Web Ontology Language) (Hitzler et al., 2012). Other ontology languages include RDF, XOL, SHOE, OML, OIL (as discussed by Antoniou et al. (2005)), and F-Logic (Kifer et al., 1995). Although most languages use different terms for the components of an ontology, these components have a similar meaning as identified in Euzenat and Shvaiko (2013).

The general components or building blocks of formal ontologies are classes, individuals, relations, data types, and data values (Euzenat and Shvaiko, 2013). Classes express the concepts that a specific ontology knows about. Individuals are instantiations of these classes. Relations describe how classes are related to each other. Data types define the type that can be stored for a specific class. Data values are simple values. Data values conform to a specific data type.

Relations in formal ontologies express relations between a number of classes or between classes and instances. However, there are more common types of relations that are already included in, for instance, OWL, but also in other ontology languages. These relations are specialisation relationships (also called subsumption relationships), exclusion relationships (also called disjointness), or instantiation relationships.

### 2.2.2.2 Ontological Commitment

Guarino et al. (2009) introduced the term ‘intensional relational structure’ to define the term ‘conceptualisation’.

An intensional relational structure is a triple that consists of a domain vocabulary  $D$ , a set of possible worlds  $W$ , and a set of relations  $R$ .  $R$  are conceptual relations on the domain space  $\langle D, W \rangle$  (Guarino et al., 2009).

Guarino et al. (2009) argue that the term ‘extensional relational structure’ coined by Genesereth and Nilsson (1987) needs to be extended to reflect different world states. Thus, the term ‘intensional relational structure’ is introduced to include relations that have a different meaning depending on a specific world state.

Guarino et al. (2009) introduced the term ‘intensional first-order structure’ that they relate to ‘ontological commitment’. Such an ‘intensional first-order structure’ is a tuple that consists of an ‘intensional relational structure’ and an ‘intensional interpretation function’. The intensional interpretation function is a

function that maps a vocabulary onto an element or a relation. The intensional interpretation function maps the whole vocabulary to elements of the universe of discourse (the individuals) or relations.

Thus, an ontological commitment clearly defines the intensional structure that an ontology has to conform to. An intensional first-order structure is a key component of a conceptualisation. In this thesis, intensional interpretation functions are a key component of the formal ontologies that are introduced in this work. Such functions enable the integration of semiotic layers in the proposed ontologies. Semiotic layers are introduced to differentiate between different interpretations of signs (see [Chapter 4](#)). Each semiotic layer can be interpreted as a different world state.

### 2.2.2.3 Ontology Syntaxes

Ontology languages have one or more formal representations or syntaxes that can be used to store and disseminate formal ontologies. OWL, for instance, is based on RDF (the resource description framework) ([W3C, 2009](#)). Thus, formal ontologies in OWL can use the RDF syntax. RDF can be stored utilising an XML representation. However, RDF also supports other representations that are easier to read and understand, such as Turtle ([Prud'Hommeaux and Carothers, 2014](#)). Other ontology languages, such as F-Logic, developed their own syntax as can be read in [Angele et al. \(2009\)](#) and [Michael Kifer \(1995\)](#).

High quality formal ontologies need the capability to reason over these ontologies. These reasoning capabilities rely on logical expressions. Description logics (as described in [Baader et al. \(2009\)](#)) can be used to depict knowledge utilising logical expressions. OWL is based on description logics. Description logics express concepts in a domain with atomic concept descriptions (unary predicates) and atomic roles (binary predicates) ([Baader, 2003](#), [Baader et al., 2009](#)). Description logics also introduce conjunctions, negations, existential restrictions, value restrictions, and number restrictions ([Baader et al., 2009](#)). However, there are additional extensions to description logics that are used in OWL as described in [Baader et al. \(2009\)](#).

### 2.2.2.4 A-Box vs. T-Box

Formal ontologies can be divided into two components: T-Boxes (terminology boxes) and A-Boxes (assertional boxes).

A T-Box, or terminology box, consists of the terminology that is provided by a specific formal ontology. T-Boxes include role inclusion axioms and general concept inclusions ([Baader et al., 2009](#)). Role inclusion axioms define specific relational roles that can be used to relate two concepts, but also to relate concepts with their instances, which are stored in an assertional box. General concept inclusions define the types of concepts that a formal ontology consists of.

A-Boxes store assertions about two instances (role assertions), or about concepts and their instances (concept assertions). An example of such assertions are those that assert that an individual belongs to a specific concept. Such as-

sertions are concept assertions. The other type of assertions are role assertions. Role assertions express that individual A is related to an individual B by the assertion R.

### 2.2.2.5 Open World Assumption vs. Closed World Assumption

Logical representations in ontology languages use either an open world assumption or a closed world assumption. A formal ontology that follows an open world assumption can be extended at any time. This means that another assertion can be added to a formal ontology at any time. Thus, deductions that include missing assertions cannot be answered in an open world assumption. In an open world assumption, it is not possible to reason with non-existent information.

Ontology languages, such as OWL support an open world assumption.

The following example highlights why non-existent information cannot be easily included in open world assumptions. Let's assume that, amongst other components, a laptop consists of a display, a keyboard, and a processor. In a formal ontology it is possible that not all 'laptops' that are mentioned in the formal ontology include a relation that relates a specific laptop to a CPU. However, these missing assertions do not infer that the CPU is missing in a specific laptop. It is not possible to assert that this laptop does not include a CPU at all. In fact, there can be any kind of CPU implemented in such a laptop.

A formal ontology that follows a closed world assumption uses a fixed assertional box. In the previous example, the assertional box would consist of a complete laptop configuration, which has to include a relation that asserts that this specific laptop includes a certain CPU. This would enable the identification of all CPUs that are used in laptops of a specific brand. The possibility to infer a complete list of processors for a specific type of computer, or to identify whether a specific processor is missing in the provided configurations, is not possible if a formal ontology follows an open world assumption. [Baader et al. \(2009\)](#) explained the concept of an open world assumption using the example of Harry Potter. If only one parent is mentioned in the knowledge base, it is impossible to know whether both parents were sorcerers unless there is a T-Box that includes an axiom that defines that.

Although many ontology languages such as OWL and RDF use an open world assumption, a closed world assumption might be useful in some circumstances. [Antoniou and Van Harmelen \(2009\)](#), for instance, explain the advantage of a closed world assumption in environments that are well defined and where it is very unlikely that the formal ontology changes. For instance, a closed world assumption can be used in an organisational chart for a company. Even though the organisational chart might change in the future, the assertional box in the formal ontology always includes a complete representation of the company.

The artefacts that are presented in this thesis use an open world assumption. This is because the formal ontologies that are proposed in this work are always subject to change because new content is being added at a constant rate. However, temporary closed world representations are used to extract information,

such as summaries. These closed world representations are only correct at a certain point in time.

#### 2.2.2.6 Ontology Types

Muntjewerff and Bredeweg (1999) divided ontologies into core, domain, and top-level ontologies. Grimm et al. (2007) divided ontologies into top-level, domain and task ontologies, and application ontologies.

Top-level ontologies include formal ontologies that can be used universally. Every ontology should be able to include a top-level ontology without creating any inconsistencies. Top-level ontologies include DOLCE (Masolo et al., 2002), SUMO (Oberle et al., 2007), and BFO (Grenon et al., 2004). Top-level ontologies can be shared over many different applications and domains (Grimm et al., 2007).

Domain and application ontologies, as proposed in Grimm et al. (2007), describe a specific domain or, in a task ontology, a specific task, such as a planning task, or the execution of clinical guidelines. Task ontologies are not mentioned in Muntjewerff and Bredeweg (1999). However, Muntjewerff and Bredeweg (1999) defined that domain ontologies are repositories for organising knowledge, or that such an ontology can become the basis of how people can work together. Thus, Muntjewerff and Bredeweg (1999)'s definition of a domain ontology can include Grimm et al. (2007)'s interpretation of a task ontology.

Core ontologies are not mentioned in Grimm et al. (2007). Core ontologies, as described in Muntjewerff and Bredeweg (1999), describe the main concepts and the major structure of reasoning in a specific domain. In comparison to domain ontologies, core ontologies are not used as a knowledge base. However, core ontologies can be used in a domain ontology to provide an overarching structure of a specific field. Such core ontologies can also be expressed as a T-Box that provides the terminology of a specific domain, whereas the domain ontology contains the knowledge about the domain. The domain ontology can be expressed as an A-Box that utilises the terminology of the T-Box.

In this thesis, there is a strict differentiation between a T-Box and an A-Box as well as core ontologies and domain ontologies (see Chapter 4). This differentiation, in concert with an ontology specification, clearly defines how classes and instances are differentiated.

#### 2.2.2.7 Representation of Formal Ontologies - Conclusion

Computers prefer structured information. A formal ontology language provides such a structure. A formal ontology in information systems or computer science is an information object to represent a conceptualisation. There is a vast number of unstructured information available on the web but also in digital libraries in general. If this information could be structured and transformed in a computer readable representation, computers could reason over these structures.

This section discussed the components that constitute a formal ontology. This section also discussed structural representations that enable computers to

read and reason over ontologies.

Intensional first-order structures and ontological commitment enable the generation of conceptualisations that can differentiate between different world states.

Core ontologies can be used to provide a major structure of a field, which can be used to create assertions about a specific piece of research or topic in this field.

### 2.2.3 Expressiveness of Ontologies

Formal ontologies can have different levels of expressiveness. As will be seen in Section 2.4.4, many formal ontologies that are used in information systems, for instance in automatic summarisation approaches, are not very expressive.

An example of formal ontologies with limited expressiveness are formal ontologies that only include subsumption relations. Subsumption relations are specialisation / generalisation relationships. In many applications, such ontologies might be sufficient for the purpose of a specific application. However, there are many more applications that need more expressive formal ontologies. In particular, knowledge-intensive applications depend on the expressiveness and quality of an ontology (Völker et al., 2008).

An ontology language  $L_2$  is as expressive as another ontology language  $L_1$  if there is a total function that translates all sentences in language  $L_1$  into language  $L_2$  by expressing the same meaning, and vice versa (Borgida, 1996).

Guarino et al. (2009) stated that a relation between two instances cannot differentiate between different world states. Guarino et al. (2009) used the example of the relation ‘cooperates-with’. This relation makes sense in two different world states. The first world state uses the relation ‘cooperates-with’ to show that people are sharing the same goal. The other world state expresses with the relation ‘cooperates-with’ that people are working with each other. To express different world states in regards to the relation ‘cooperates-with’, additional information about the world state itself needs to be expressed. Ontology languages that do not support this feature are not expressive enough to support such relations.

Guarino et al. (2009) also outlined three properties that influence the expressiveness of an ontology. These properties are the richness of the domain of discourse, the richness of the vocabulary chosen, and the axiomatisation.

Different ontology languages support different levels of expressiveness. OWL, for instance, introduces three languages that provide different levels of expressiveness. These languages are OWL-Lite, OWL-DL, and OWL-Full (Hitzler et al., 2012, Pan, 2009). OWL-Lite and OWL-DL are very expressive description logics (Pan, 2009). OWL-Full, on the other hand, supports the expressiveness of OWL-DL, but also adds the full power of RDF.

RDF, the resource description framework, can express classes, resources, and properties (W3C, 2009, Pan, 2009). Classes are intended to be used to describe concepts in RDF. Resources and properties are used to describe roles. These are the only restrictions of the RDF language, which means that any type of relation

and any type of constraint can be expressed with RDF. This makes RDF very expressive. However, this level of expressiveness results in formal ontologies that are undecidable. The more expressive an ontology, the less constrained is a specific ontology. Thus, a predefined set of features should ensure, if chosen properly, the decidability of a specific formal ontology.

The most expressive and decidable ontology language is OWL-DL. OWL-DL is based on RDF and adds a number of other features, such as the local scope of properties, disjointness of classes, boolean combination of classes, cardinality restrictions, and special characteristics of properties ([Antoniou and Van Harmelen, 2009](#)). These features limit the expressiveness of OWL-DL. However, such a limited set of features results in a decidable ontology language. Decidability in formal ontologies enables reasoning capabilities.

## 2.2.4 Reasoning over Formal Ontologies

This section introduces reasoning techniques for formal ontologies. This section further outlines the use of reasoning techniques in semantic search engines.

Reasoners work with formal ontologies that support a specific level of expressiveness. As mentioned in Section 2.2.3, OWL-DL is an ontology language that supports the development of expressive ontologies that are supported by many reasoners. OWL-DL is a successor of the ontology languages OIL (Fensel et al., 2000) and DAML (Hendler and McGuinness, 2000)(Horrocks and Sattler, 2001).

Logical reasoning techniques in formal ontologies can be used to, for example, check the consistency of formal ontologies or to reason high level context from low-level context (Wang et al., 2004). Other reasoner tasks in formal ontologies perform instance checking, classification checking, or entailment checking (Matentzoglou et al., 2015). Reasoners can also be used to explain entailments or inconsistencies and to extract modules, or are used for ontology-based data access.

### 2.2.4.1 Reasoners

A reasoner analyses an ontology to infer a number of axioms from the statements that are stored in a formal ontology. There are three main categories of calculi in ontological reasoners. These are consequence-based, model construction-based, and rewriting based calculi (Matentzoglou et al., 2015). Most reasoners that support OWL-DL are currently using consequence-based and model-construction-based reasoners of the tableau type (Matentzoglou et al., 2015).

Consequence-based reasoners add logical consequences, also called entailments, to a formal ontology (Matentzoglou et al., 2015).

Model-construction-based reasoners build a model out of a formal ontology and check this model to see whether there are inconsistencies. Tableau-based techniques are techniques that are often used in model-construction-based reasoners. A tableau-based reasoner builds a model of the input formulae and checks this model for obvious contradictions to identify whether the formulas are unsatisfiable (Möller and Haarslev, 2009).

Rewriting-based calculi rewrite axioms that are stored in a formal ontology (Matentzoglou et al., 2015).

Popular reasoners that are used for OWL-DL are a combination of consequence-based techniques and tableau-style techniques (Matentzoglou et al., 2015).

The formal ontologies that are used in this thesis utilise tableau reasoners, such as the Pellet reasoner (Sirin et al., 2007).

### 2.2.4.2 Complex Classes

Reasoners can infer high-level contexts from low-level contexts. This can be achieved by the use of complex classes.

An example for such a complex class could be the class ‘car’. A ‘car’ consists of a ‘body’, an ‘engine’, and four ‘tyres’. An axiom that can infer the complex

class ‘car’ by utilising the concepts ‘engine’ and ‘tyre’ could be as follows. There exists an ‘engine’ that runs a ‘car’ and there exist exactly four ‘tyres’ that belong to a ‘car’. This axiom can be used in the definition of a complex class (in this example it is the complex class ‘car’). If a specific A-Box in a formal ontology contains instances of ‘engine’, ‘body’, and ‘tyres’ and if these instances fulfil these axioms, it can be deduced that this instantiated complex class is of type ‘car’.

#### 2.2.4.3 Reasoning Techniques in Semantic Search Engines

Semantic search engines can be divided into ontology search engines and semantic search engines (further information about this differentiation can be found in Section 2.3).

Semantic search engines can either process one semantically enriched query (Sakthi Murugan et al., 2013) or several queries that combine semantically enriched queries and standard database queries (Bošnjak and Podgorelec, 2016).

Most semantic search engines do not utilise reasoners; instead, semantic search engines search existing semantic representations, such as formal ontologies (see Section 2.3.6.1). However, there are a number of search engines that are proposed in the literature, such as in Angele (2014) and Bošnjak and Podgorelec (2016), that include reasoning capabilities. These approaches utilise complex class descriptions to infer instantiations of complex classes. Other approaches use reasoners to limit a search query by enriching the query with ontological relations. However, the approaches in Angele (2014) and Bošnjak and Podgorelec (2016) search an existing database, rather than text in natural language.

Inferred instantiations of complex classes can be used to refine search results, such as in Bošnjak and Podgorelec (2016), or they can be used to extend a search query and to infer complex classes in the indexing phase as in Angele (2014).

The use of reasoners in the search process can enhance the retrieval process in semantic search engines. Additionally, a reasoner can infer complex classes at indexing time, which reduces the search process load. More about the use of ontologies in semantic search engines can be found in Section 2.3.

#### 2.2.4.4 Reasoning - Conclusion

A difference between the use of reasoners and standard query interfaces is that reasoners can deduce information after new assertions are added to a formal ontology. This can increase the efficiency in querying a formal ontology because inferred concepts that have been identified by a reasoner can be retrieved easily. The efficiency of the querying phase is reduced, if such deductions need to be made in the querying phase. However, in order to enable effective reasoning strategies, expressive ontologies that include a rich set of axioms are required. If an ontology is not expressive enough and only consists of, for instance, subsumption relations and no logical expressions (axioms) that enable the deduction of higher-level concepts, the capabilities of a reasoner are limited.

Although most semantic search engines do not include reasoning capabilities and the creation of axioms can be labour intensive, the use of reasoners in search engines opens up many possibilities. For instance, reasoners that reason over expressive ontologies can be used to generate summaries of the content of a retrieved document. An approach that relies on such techniques and that can be used to summarise scientific articles is presented in this thesis (see [Chapter 4](#) for more details).

### 2.2.5 Ontology Evolution

This section briefly discusses the topic of ontology evolution. Formal ontologies evolve over time. Although the terminology box of a formal ontology needs to be carefully created and, depending on the application, not changed rapidly, the assertion box usually evolves more quickly. Thus, an effective ontology evolution methodology is needed to cope with changes in the ontology. Even though instances change more often than classes, instances can also invalidate a specific ontology.

“Ontology evolution aims at maintaining an ontology up to date with respect to changes in the domain that it models or novel requirements of information systems that it enables” ([Zablith et al., 2015](#)).

[Flouris et al. \(2008\)](#) included ontology evolution in the more general field of ontology change. The authors identified several research fields that fit into ontology change, such as ontology evolution, ontology versioning, ontology merging, ontology mapping, and ontology matching. This thesis is concerned with the evolution of formal ontologies.

[Zablith et al. \(2015\)](#) described an ontology evolution cycle that consists of five stages. [Lambrix et al. \(2016\)](#) identified that these five stages overlap with several other ontology evolution methodologies. The five stages in [Zablith et al. \(2015\)](#) are as follows. The first stage is concerned with the discovery of potential changes in the formal ontology. The second stage suggests changes. The third stage validates the suggested changes. The fourth stage assesses the impact of the evolution. Finally, the fifth stage manages the changes.

**Change Discovery:** [Zablith et al. \(2015\)](#) identified three types of change discoveries in the literature: usage-driven change discovery, data-driven change discovery, and structure-driven change discovery. Usage-driven change discovery triggers a change by analysing the user’s behaviour. Data-driven change discovery identifies whether data has been updated that influences the formal ontology and then triggers a change. Structure-driven change discovery identifies anomalies in the structure that then trigger a change.

This thesis is concerned with data-driven change discovery. There are several ways to trigger a possible change request from data. Changes can be detected either by analysing external data sources (such as documents), by analysing metadata, or by analysing structured data.

## 2.2.6 Ontology Engineering

“A high-quality ontology requires a rigorous, systematic engineering approach” (De Nicola and Missikoff, 2016). In the literature, the terms ‘ontology engineering’ and ‘ontology development’ are used interchangeably to express the processes involved in the creation of a formal ontology. This thesis uses the term ‘ontology engineering’.

Ontology engineering methodologies in the literature focus on the manual engineering of formal ontologies, rather than prescribing methodologies that can be used in an automatic ontology engineering approach. One reason for that is that ontology engineering is a complex process that is usually performed by ontology engineers.

The main challenges faced in ontology engineering are (1) the creation of general terms, (2) the organisation of terms into a taxonomy of classes, and (3) the expression of these terms in an explicit way (Cristani and Cuel, 2005). However, ontology engineering methodologies in the literature prescribe additional tasks that focus on other challenges, such as the creation of complex classes.

The following section introduces the main phases that are involved in an ontology engineering process.

### 2.2.6.1 Ontology Engineering Phases

The following common main stages can be identified throughout the ontology engineering methodology literature. Most of these phases handle one of the main challenges that are identified in Cristani and Cuel (2005). The phases presented in Cristani and Cuel (2005) include (1) the identification of a domain terminology, (2) organising the domain terminology into a taxonomy (a generalisation / specialisation hierarchy), and (3) the identification of predicates.

The domain terminology includes classes and relations that form a complete vocabulary of the things in question. These classes and relations are then categorised and presented in a generalisation / specialisation hierarchy. Finally, predicates are identified that logically describe how these classes are related to each other.

**Additional Stages:** Some ontology engineering methodologies in the literature present additional phases that are not described in Cristani and Cuel (2005).

Noy et al. (2001) and Suárez-Figueroa et al. (2016) included an additional phase that is concerned with the identification of reusable ontologies.

The identification of reusable ontologies in the ontology engineering process was added to firstly cope with the increasing numbers of formal ontologies on the web since the beginning of the semantic web. Secondly, the reuse of formal ontologies prevents the creation of formal ontologies that ultimately express the same thing. Thirdly, ontologies can be more easily integrated into existing applications if a commonly used vocabulary is reused and extended by another ontology.

However, there are exceptions that prevent the reuse of another formal ontology. There might exist formal ontologies that contain a concept that could be used in a newly generated ontology. One problem that would prevent a reuse of such an ontology is that the reused ontology is not valid in the set of world states that the newly designed ontology is designed for.

For instance, an ontology that represents the concept 'house' can be used to describe a brick house perfectly because the ontology was made for a world that includes brick houses. However, a new ontology that describes settlements in an area that does not, or not only, contain brick houses might not be able to reuse this ontology. One reason for not being able to reuse this ontology might be that the original ontology does not include concepts that are necessary to express, for instance, the material clay.

An ontology might contain a concept that resembles another concept that should be added to the vocabulary of a new ontology. However, this concept misses some properties that enables it to be reused in the vocabulary of the new ontology. To accommodate these missing properties, the reused ontology could be extended to include the missing properties. However, the amended ontology then needs to be tested to ensure that all possible models in the world states that a specific ontology has been initially designed for are still valid. Thus, it sometimes makes sense to create another ontology that solely represents these new world states.

[De Nicola and Missikoff \(2016\)](#) added a phase that is concerned with the development of a domain glossary. Such a phase is crucial to understand the domain that is represented in a formal ontology. Without proper definitions of the terms that appear in an ontology, the terminology can be misinterpreted.

[Bošnjak and Podgorelec \(2016\)](#) highlighted the importance of the creation of complex classes. Complex classes firstly lead to more expressive ontologies and secondly, more expressive ontologies enable the identification of concepts that can be deduced out of other concepts and complex classes.

**Taxonomy Development:** The development of a taxonomy can follow three approaches as described in [Noy et al. \(2001\)](#). A taxonomy can be created using a top-down approach, a bottom-up approach, or a combination of these two. In a top-down taxonomy creation process, firstly the most general concepts are identified before each concept is split up into its sub-components. A bottom-up taxonomy creation process starts with the identification of the most specific concepts and then generalises on these concepts to identify more general concepts. A combination of a top-down and a bottom-up taxonomy creation process starts with the identification of the most salient concepts and then identifies more specific concepts as well as more general concepts of these salient concepts.

**Scenarios:** [Noy et al. \(2001\)](#) and [Suárez-Figueroa et al. \(2016\)](#) outlined the importance of specifying scenarios that trigger the engineering of an ontology. [Suárez-Figueroa et al. \(2012\)](#) already expressed the following ontology engineering scenarios: the development of ontologies from scratch, the reengineering of

non-ontological resources or ontological resources, as well as merging ontological resources, the use of design patterns, the restructuring of ontological resources, and the localisation of ontological resources.

**Ontology Life Cycles:** Ontology engineering is part of an ontology life-cycle. [Suárez-Figueroa et al. \(2016\)](#) and [De Nicola and Missikoff \(2016\)](#) presented two life cycle models. [Suárez-Figueroa et al. \(2016\)](#) proposed a waterfall model as well as an iterative stage model. The waterfall model follows the example of waterfall models in systems development. The second, iterative model consists of the same steps that have been identified in the waterfall model. However, each step can be repeated as many times as needed.

#### 2.2.6.2 Competency Questions

To identify whether an ontology is expressive enough for the specified applications, a set of competency questions needs to be created. Competency questions (introduced by [Grüninger and Fox \(1995\)](#)) should be aligned with the intended use of an ontology.

[Ren et al. \(2014\)](#) stated that competency questions are the functional requirements of ontologies.

[Katsumi and Grüninger \(2016\)](#) defined competency questions as logical sentences that an ontology should entail. Thus, competency questions impose a requirement on the scope of the concepts and their semantics.

Competency questions are “queries that impose demands on the expressiveness of the underlying ontology” ([Katsumi and Grüninger, 2010](#)). If a competency question cannot be answered or only answered vaguely, the ontology might not be expressive enough. This can be changed by adding axioms. However, too many axioms can reduce the expressiveness of an ontology.

Competency questions should not be simple lookup queries ([Grüninger and Fox, 1995](#)).

#### 2.2.6.3 Ontology Engineering - Reflection and Conclusion

Ontology engineering is a complex process that involves ontology engineers who manually create formal ontologies.

There are four main tasks in ontology engineering: project initiation tasks, the identification of a terminology, the creation of a taxonomy, and the identification of predicates.

In addition to these three main tasks, there are four other tasks within the literature that support the engineering of high-quality ontologies. Firstly, a domain glossary has to be created. A domain glossary can limit misunderstandings in the use of a specific ontology. Secondly, ontologies have to be identified that can be reused for certain concepts in the newly engineered ontology. Thirdly, the generation of complex classes enhances the reasoning capabilities of an ontology.

A proper execution of these seven tasks should result in a usable and expressive formal ontology.

The initiation phase includes the identification of a suitable ontology language. An ontology language should provide the expressiveness that is needed for the application of the ontology.

Finally, the identification of competency questions is also included in the initiation tasks. Competency questions can be used, together with a glossary, to evaluate the newly generated ontology.

In this thesis, an iterative life-cycle has been chosen. In addition to that, a top-down and bottom-up approach has been used to identify the taxonomy. More about the design of formal ontologies in this research can be found in [Chapter 4](#).

## 2.2.7 Bibliographic and Document Ontologies

This section introduces bibliographic ontologies and document ontologies, which are later used in this thesis.

One important aspect in ontology engineering is the reuse of ontologies. By reusing ontologies, the integration of an ontology into another ontology can be facilitated. Applications that use a specific ontology do not have to be updated significantly to integrate an extension of a specific ontology because the new ontology is based on the original ontology. Additionally, the reuse of ontologies can reduce the number of ontologies that cover the same topic.

This thesis is concerned with the ontological representation of scientific articles that follow a DSR approach. The following subsections provide an overview of formal ontologies that represent bibliographic aspects as well as general aspects of documents.

### 2.2.7.1 Bibliographic Ontologies

Bibliographic record systems (also called library classification systems) are classification systems that are widely used in libraries to categorise publications. There are many different standards for bibliographic records, such as Dewey's Decimal Classification (introduced in 1872), Universal Decimal Classification (introduced in 1904), Library of Congress Classification (introduced in 1897), Machine Readable Cataloging (introduced in the 1960s), Dublin Core (introduced in 1995) and the International Standard Bibliographic Description (introduced in 2007) (Kruk and McDaniel, 2008).

A library classification system enables the storage, the search, and the distribution of bibliographic records. However, these systems do not provide the ability to reason over a set of bibliographic records. For instance, such systems cannot identify whether a set of authors are related to each other without the implementation of a specific algorithm. Formal ontologies provide a solution for this issue.

FRBR (functional requirements for bibliographic records) is an “approach to clearly define entities of interest to users of bibliographic records” ([International Federation of Library Associations and Institutions. Section on Cataloguing. Standing Committee and IFLA Study Group on the Functional Requirements for Bibliographic Records, 1998](#)). FRBR enables the definition of attributes for each entity and additional relationships between entities. The objective of this formal ontology is to provide a framework to structure relations in bibliographic records. The authors of FRBR defined a bibliographic record as an “aggregate of data that are associated with entities described in library catalogues and national bibliographies.”

The formal ontology for FRBR consists of the following main concepts: (1) products of intellectual or artistic endeavour, (2) entities for intellectual and artistic content, and (3) entities that serve as the subjects of intellectual or artistic endeavour. The concepts ‘work’, ‘expression’, ‘manifestation’, or ‘item’ can be used to describe a product. Entities for the intellectual and artistic

content are persons or corporate bodies. Entities that serve as a subject for intellectual or artistic endeavour are concepts, objects, events, or places.

FRBR can be used in digital libraries to relate specific meta-data with each other. However, there are no specifications of how the content of publications can be represented and searched.

MarcOnt is an ontology that is based on MARC 21 (Machine Readable Cataloging) (Kruk et al., 2005, Kruk and McDaniel, 2008). MARC 21 is the successor of MARC and revised versions are published since 1987. MarcOnt attempts to integrate the bibliographic data of MARC 21. MarcOnt reuses ontologies, such as FOAF (friend of a friend), BibTex, Dublin Core, and others. The main concepts MarcOnt provides are ‘resource’, ‘organisation’, ‘event’, ‘coverage’, and ‘access medium’. The major properties are ‘hasPublisher’, ‘hasCreator’, ‘hasCopyright’, ‘hasSource’, ‘hasDomain’, and ‘hasTagging’.

MarcOnt incorporates the main aspects of bibliographic data. However, this ontology does not cover the possibility to conceptualise the content of a specific document. Additionally, this ontology is not accessible online and seems to be discontinued.

Although Dublin Core is not intended to be represented as a formal ontology, there have been efforts to translate the Dublin Core terminology into an RDF schema. This RDF schema is called the Dublin Core Abstract Model (Powell et al., 2007). This Dublin Core Abstract model provides a set of general terms that can be used to describe bibliographic elements. However, there is no official OWL2 conforming version of Dublin Core available. This means that the Dublin Core Abstract model cannot make use of the expressiveness of OWL2, which would enable more sophisticated reasoning capabilities.

CIDOC CRM is another ontology that models bibliographic data. CIDOC CRM is an ISO standard that can be used to model cultural heritage information. Because this ontology is tailored to cultural heritage information, this ontology cannot be easily adapted to other fields.

Most bibliographic ontologies discussed above provide a well-defined vocabulary to handle bibliographic records. However, none of these ontologies offer the vocabulary to express a conceptualisation of the content of a specific publication.

### 2.2.7.2 Document Ontologies

Document ontologies usually serve the purpose of describing content that is represented in a document.

Leukel et al. (2011) defined a set of core elements of electronic documents in business. The authors defined three categories of information that are represented in electronic documents: (1) content information, (2) structure information, and (3) presentation information that stores information about formatting. Leukel et al. (2011) identified four key concepts in their document ontology: ‘actor’, ‘project’, ‘activity’ / ‘component’, and ‘document’. The concept ‘document’ is the top-level concept and can consist of a finite set of components that represent the three other key concepts. The concept ‘actor’ refers to an indi-

vidual or a corporate actor that takes part in business ventures. The concept ‘project’ is comprised of a “finite set of temporal and factually logical related dynamic and static elements” (Leukel et al., 2011). Lastly, the concept ‘activity’ or ‘component’ represents dynamic and static elements in a project.

The document ontology presented in Leukel et al. (2011) represents documents in business. Thus, the proposed ontology focuses on concepts that are important in business projects.

Another document ontology named LIDO is presented in Palmirani et al. (2011). This document ontology is named legal document ontology. Thus, it focuses on legal knowledge that is represented in documents. This ontology is based on FRBR. The purpose of LIDO is to represent legal actions, legal temporal events, such as the date of commencement, the structure of legal resources, and the semantic structure of legal document organisation.

LIDO covers the legal domain and can therefore not easily be translated into other domains. However, the proposed multi-layer informative architecture might be adaptable to other domains as well. This multilayer informative architecture splits up the information that is presented in a document into a text layer, a layer for the text structure, a meta-data layer, an ontology, and the legal knowledge representation.

The text layer contains the text of the document. The structure layer represents how a specific text is organised. The meta-data layer consists of meta-data specific to this field. The ontology layer represents the content by storing the concepts that appear in the document. The legal knowledge model layer is the fifth layer that provides the legal knowledge represented in the document.

Another project that provides a formal ontology to represent documents is Muninn (Warren, 2012). The idea of Muninn is to mark up documents with structural elements. This ontology covers classes, such as collection, document, image, page, text, and snippet. The authors believe that these kinds of annotations can be used to provide linkages between original and transcribed or transformed documents.

Besides ontologies that provide a conceptualisation to represent the structure of a document in addition to some meta-data, there are formal ontologies that focus on discourse elements. Ciccarese et al. (2008) provide such an example. The discourse elements in SWAN (the ontology proposed in Ciccarese et al. (2008)) are research statements (claims or hypotheses), research questions (topics under investigation), and structured comments. There are also other formal ontologies available that primarily capture arguments, as presented in a survey by Schneider et al. (2013).

SALT (Groza et al., 2007) includes one of the most complete document ontologies available because SALT consists of a document ontology, a rhetorical ontology that includes discourse elements, and an annotation ontology. These three ontologies represent the internal structure of documents; the rhetorical structure and the annotation ontology serves as a bridge between the document and the rhetorical structure, but also includes meta-data information. However, the ontologies presented in Groza et al. (2007) are meant to be used as tags in LaTeX documents. This means that the ontology would have to be translated

to be used in other environments. One option would be to create, for instance, an OWL ontology that can be shared and used in other systems.

One of the most recent document ontologies is presented in [Constantin et al. \(2016\)](#). The name of this document ontology is DoCo. Similar to SALT, DoCo is divided into document components and discourse components, but also consists of a pattern ontology. The discourse component reuses SALT rhetorical blocks. [Constantin et al. \(2016\)](#) argued that one of the main differences to SALT is that all components are combined into one ontology. DoCo is meant to harmonise the SALT ontologies. DoCo implements a number of complex classes to describe, for instance, a paragraph. These complex classes enable the identification of elements, such as sentences. A complex class is defined by predicates that a reasoner can use to identify instances of this complex class.

DoCo includes essential components to represent documents. However, context specific information cannot be conceptualised with this ontology. For instance, DSR concepts, such as ‘artefact’, are missing in DoCo because DoCo was not designed to represent such high-level concepts.

DoCo can be used to tag text in a document with concepts that are represented in DoCo. More fine-grained operations, such as the composition of components that can then be merged into sentences, cannot be easily achieved with the DoCo ontology. However, information, such as part of speech information, can support such operations, as presented in this thesis. Nevertheless, DoCo includes important concepts to properly represent content in documents.

### 2.2.7.3 Document Ontologies - Conclusion

There are many formal ontologies that are proposed in the literature that can be used to describe documents. Nevertheless, there are only a few formal ontologies available that are designed to conceptualise the content of a specific publication. Additionally, most ontologies are specifically made to represent a specific field. Other ontologies do not provide formal, explicit conceptualisations that support description logics or another logical language. DoCo ([Constantin et al., 2016](#)) is the most promising document ontology at the moment. Nevertheless, this ontology cannot be used to represent fine-grained information in publications, such as part of speech information. Part of speech information can be reliably extracted out of natural language with part of speech taggers. Part of speech information could facilitate the reasoning process if the complex classes that were defined in DoCo ([Constantin et al., 2016](#)) can cope with part of speech information. This thesis will show that such low-level information, such as part of speech trees or dependency trees, can be used to infer higher-level concepts (see [Chapter 4](#)).

### 2.2.8 Ontology Evaluation

Ontology evaluation assesses different qualities of a formal ontology. The usability of an ontology can be identified by analysing its classes, object properties, data properties, individuals, and logical axioms (Matentzoglou et al., 2013).

Ontologies can be evaluated from a logical perspective by the use of competency questions. Grüninger and Fox (1995) proposed the completeness theorem for ontologies. This completeness theorem states that an ontology is complete if the TBox ( $T_{ontology}$ ) and its instances ( $T_{ground}$ ) entail the previously defined competency questions. However, competency questions should not only have the form of simple lookup queries. Simple lookup queries either infer that the ontology in question is not well-designed or that the wrong competency questions have been chosen (Grüninger and Fox, 1995). If competency questions do not affect and assess different levels of depth of an ontology, as it would be the case with simple lookup queries, an ontology cannot be properly evaluated.

Competency questions are not the only criteria to evaluate ontologies. Obrst et al. (2007), Vrandečić (2009), Burton-Jones et al. (2005), Fernández et al. (2009), Liu et al. (2016), and Gómez-Pérez (2001) provided other means to evaluate ontologies, as described below.

#### 2.2.8.1 Evaluation Criteria

Burton-Jones et al. (2005) proposed a set of metrics that assess four qualities of ontologies: syntactic, semantic, pragmatic, and social qualities. These qualities are derived from the semiotic framework presented in Stamper et al. (2000). Stamper et al. (2000) proposed six layers of properties of signs. Each layer expresses certain properties of signs. These properties are physical, empiric, syntactic, semantic, pragmatic, and social properties. Burton-Jones et al. (2005) expressed each layer as follows. The physical layer refers to physical properties, such as the mass of an object. The empiric layer refers to the statistical properties of signs. Stamper et al. (2000) and Burton-Jones et al. (2005) included communication properties, such as channel capacity, noise, or entropy, in the empiric layer. In this thesis, the empiric layer consists of natural language processing tasks that return empiric results that can be used to reason higher-level concepts if noise and entropy levels are not too high. Syntactic properties express the relationship among signs, such as the logical formal arrangement. Semantic properties represent the meaning of signs as well as the mappings between them. Pragmatic properties are concerned with the consequences of relationships between signs. Social properties express the meaning of a sign in regards to social consequences. Each layer depends on the previous layer (Burton-Jones et al., 2005).

Obrst et al. (2007) defined an extensive set of ontology evaluation criteria. These criteria include the coverage of the domain, the complexity of coverage, specific use cases, scenarios, requirements, applications, data sources, formal properties (consistency and completeness), the representation language, and whether an ontology can be mapped to a top-level ontology.

Vrandečić (2009) identified eight evaluation criteria: accuracy, adaptability, clarity, completeness, computational efficiency, conciseness, consistency, and organisational fitness.

Common quality criteria that have been identified in this thesis within the literature can be categorised into contextual criteria (pragmatic layer), structural criteria (syntactic layer), semantic criteria (semantic layer), and application criteria (social layer).

Contextual criteria correspond to the pragmatic layer and evaluate the usefulness of an ontology. Contextual criteria are evaluation criteria that can be used to assess whether the components (concepts, properties, axioms) of a formal ontology are sufficient to cover all aspects the ontology specification demands. Additionally, criteria, such as accuracy, are included in the set of contextual quality criteria. Accuracy is a contextual criterion because it defines whether the context that the ontology is specified for has been interpreted accurately.

Burton-Jones et al. (2005) included comprehensiveness, accuracy, and relevance as attributes that assess the pragmatic quality of an ontology. Liu et al. (2016) evaluated the coverage of a vocabulary and defined the term ‘vocabulary’ as the set of names for concepts, instances, attributes, and relations. Obrst et al. (2007) mentioned the coverage of the domain, and the complexity of the coverage. Vrandečić (2009) named completeness, accuracy, and conciseness. Obrst et al. (2007) also defined the applicability to specific use cases or scenarios that a formal ontology is intended for. All of these criteria can be used to evaluate whether the context has been included properly in the evaluated ontology.

Structural criteria relate to the syntactic layer in Burton-Jones et al. (2005). Burton-Jones et al. (2005) proposed the metrics richness and lawfulness of a formal ontology as metrics to evaluate the syntactic layer. The criterion richness in Burton-Jones et al. (2005) is used to express the richness or breadth of the syntax. In comparison to the breadth of the vocabulary, the richness of an ontology depends on the expressiveness of the used ontology language. The lawfulness identifies whether the correct syntax has been used. Both criteria assess the structure of a specific ontology. Thus, structural criteria relate to the structural composition of a formal ontology. Object properties, as well as the set of classes or concepts, belong to the syntactic layer. However, only the lawfulness of classes should be evaluated in regards to structural criteria. The richness of classes is a contextual criterion, that asserts the usefulness of a formal ontology. Structural criteria also include a criterion that is mentioned in Obrst et al. (2007). This criterion assesses whether an ontology can be mapped to a specific top-level ontology. Another structural criterion is the criterion consistency (see Vrandečić (2009)). Vrandečić (2009) defined two types of consistencies in formal ontologies: logical consistency and consistency between formal and informal descriptions. A structural criterion to evaluate the consistency of ontologies is the logical consistency. It is only when there are no contradictions that the ontology’s formal logical arrangement is correct. Clarity is another criterion that is mentioned in Vrandečić (2009). An ontology confirms the criterion clarity if the intended meaning can be expressed with the ontology. Thus, the structure has to be able to clearly and effectively convey the meaning of the ontology. Addi-

tionally, an efficient and effective structure also enables computational efficiency. However, the criterion computational efficiency that is proposed in [Vrandečić \(2009\)](#) better fits into the set of application criteria that are discussed in the following paragraph.

Semantic criteria refer to the semantic layer of the semiotic framework, which is described in [Burton-Jones et al. \(2005\)](#). [Burton-Jones et al. \(2005\)](#) identify interpretability, consistency and clarity as semantic criteria. Competency questions (as proposed in [Grüninger and Fox \(1995\)](#)) are criteria that have to be fulfilled to ensure that the ontology expresses the meaning that the ontology is intended for. [Vrandečić \(2009\)](#) defined semantics as the common characteristics of all possible models that can be expressed by an ontology. An ontology should be able to express an infinite set of models that all follow the same semantics. A formal ontology is developed for a set of use cases, scenarios, requirements, applications, and data sources ([Obrst et al., 2007](#)). Thus, these use cases, scenarios, etc. define the requirements to the semantics of the ontology.

Finally, application criteria relate to the social layer in [Burton-Jones et al. \(2005\)](#). Social criteria assess the importance of a specific ontology. Application criteria assess whether an ontology is used in other applications or whether an ontology is included in other ontologies. Application criteria are, for instance, adaptability ([Vrandečić \(2009\)](#)). Computational efficiency is another criterion that fits into the set of application criteria. If an ontology is computationally efficient, the probability is much higher that an ontology is used. Expandability, which is proposed in [Gómez-Pérez \(2001\)](#), is another application criterion. Similarly to computational efficiency, an ontology that can be extended has a greater chance of being used in applications or other ontologies.

The four types of ontology evaluation criteria (contextual criteria, structural criteria, semantic criteria, and application criteria), which refer to four layers of the semiotic framework (the pragmatic layer, the syntactic layer, semantic layer, and the social layer), have to be fulfilled to a certain extent to provide a high-quality and usable formal ontology.

Each layer depends on the criteria of the lower layer. For instance, the criteria of the semantic layer depend on the fulfilment of criteria of the structural layer.

### 2.2.8.2 Evaluation Techniques

[Liu et al. \(2016\)](#) identified 37 metrics to evaluate the vocabulary, the structure, the semantics, and the context of a formal ontology. [Vrandečić \(2009\)](#) identified 23 methods to evaluate an ontology. [Vrandečić \(2009\)](#) highlighted that evaluation criteria should be tailored to the formal ontology that has to be designed in regards to the requirements of the formal ontology.

There are two types of techniques (proposed in [Vrandečić \(2009\)](#)) that are utilised in the research that are described in this thesis. These two types are task-dependent evaluation techniques and techniques that compare an ontology against domain data (data-driven evaluation). These two techniques have been chosen because (1) the resulting ontology repository includes application

ontologies that can be evaluated utilising a task-dependent evaluation, and (2) the development of these ontologies include a formalised representation of DSR content and therefore domain data was available to develop and evaluate the developed formal ontologies.

Task-based evaluation techniques can be used for application ontologies. If the application that utilises a specific ontology fulfils its specified requirements, the ontology is valid. This type of evaluation can also make use of competency questions because competency questions can be used to test whether a formal ontology fulfils its requirements. If the requirements of the formal ontology are aligned to the requirements of the application, a specific task can be correctly executed.

Data-driven evaluation evaluates whether a specific ontology fits a specific data set. This data set can be, for instance, a textual corpus about a specific topic. A method to achieve such a data-driven evaluation could be a top-down / bottom-up approach. The top-down approach takes a set of textual documents that describe the topic that should be represented in an ontology. The ontology itself will then be compared to salient concepts in the corpus. If all salient concepts are represented in the ontology, the domain is sufficiently covered in the ontology. The bottom-up approach then takes, for instance, the literature that can be assigned to a specific domain and compares whether concepts that are extracted out of the literature align to salient concepts of the domain in question. This approach can also be used to engineer a specific ontology.

### 2.2.8.3 Ontology Evaluation - Conclusion

The selection of suitable evaluation techniques depends on the context that an ontology is used in, the scope that a specific formal ontology should represent, and the type of the evaluated ontology. Nevertheless, the aspects context, structure, semantics, and application have to be covered properly to effectively evaluate an ontology.

However, an ontology should also be evaluated by a set of competency questions that reflect the requirements of the developed formal ontology.

Additionally, ontology evaluation techniques should fit into the ontology engineering process. An iterative process might evaluate different aspects in each iteration to provide targeted evaluation results in respect to a specific iteration.

## 2.3 Search Engines

Section 2.3 discusses the context of the researched problem (also called the problem space (Venable, 2006)). This section introduces the terms “search engine” and “information retrieval” (Section 2.3.1) before the transition from search catalogues to semantic search engines (Section 2.3.2) is delineated. Section 2.3.3 (academic search engines) and Section 2.3.4 (requirements for semantic search engines) further outline the scope of this thesis. Section 2.3.5 depicts the general architecture of semantic search engines. Section 2.3.6 discusses semantic driven techniques by delineating semantic models used in indexing and querying processes. Additionally, Section 2.3.6 discusses gaps that have been researched and are discussed in this thesis. Finally, Section 2.3.7 depicts different categories of research result representation in semantic search engines.

### 2.3.1 Definition

Search engines are computerised mechanisms that search for items in a collection of documents (Langville and Meyer, 2006). The process of searching is also called information retrieval (Langville and Meyer, 2006). Information retrieval can be split up into web information retrieval and traditional information retrieval (Langville and Meyer, 2006). In traditional information retrieval, the search process searches through a smaller, more controlled, but non-linked collection, whereas web information retrieval searches through the world’s largest and linked collection, the Internet (Langville and Meyer, 2006).

This thesis adapts the definition of traditional information retrieval by Langville and Meyer (2006). The definition used in this thesis is as follows:

“Traditional information retrieval is a search process that searches through a more controlled collection of documents.”

This definition has been chosen due to advances in search engines. For instance, many newer traditional academic search engines include capabilities to interlink scientific articles. Therefore, in this thesis, the aspect in the definition by Langville and Meyer (2006) that documents in traditional information retrieval systems are not linked has been removed. However, traditional information retrieval systems still provide information retrieval capabilities over a controlled collection of documents.

The main differentiator between web search engines and traditional search engines is that web search engines search a collection of documents that is not controlled by a central system or organisation. New documents appear and disappear frequently without a system managing this collection. This usually requires the existence of a web crawler to identify the documents to be searched.

The design theory that is presented in this thesis could be used in both traditional and web information retrieval. This design theory is only concerned with the storage of semantics that are expressed in DSR publications and the representation of search results. Therefore, this design theory does not consider web crawling activities to gather documents. However, the architecture proposed in this design theory could be easily extended to include such capabilities.

### 2.3.2 From Search in Catalogues to Search in Web 3.0

This section provides a very brief history of information retrieval and depicts the current research focus in search engines.

The Roman author Valerius was the first known person to organise topics in his books in AD 30 (Langville and Meyer, 2006). However, the word of mouth of librarians in AD 30 was still the most accurate way to search (Langville and Meyer, 2006). Due to the increased number of books, even the best librarian cannot provide an accurate and complete answer to every customer's search query. Thus, a number of cataloguing systems have been developed to support librarians in providing an accurate and complete search result.

The many cataloguing systems include Dewey's Decimal Classification developed in 1872, Library of Congress Classification in 1897, Universal Decimal Classification developed in 1904, MARC (Machine Readable Cataloguing) developed in the 1960s, BibTex developed in 1985, and Dublin Core developed in 1998 (Weibel et al., 1998, Kruk and McDaniel, 2008). A description of most cataloguing systems can be found in Kruk and McDaniel (2008). All these techniques support the search process by providing structured meta-data about documents, such as the title, the publisher, the author, etc.

With the invention of the first distributed hypertext system by Berners-Lee (1989), the World Wide Web was born. This idea was based on the memex system developed by Vannevar Bush (Bush, 1945). Bush (1945) presented the idea of a system, named memex, that is capable of combining facts by creating a trail of read documents. After the successful realisation of the  $W^3$  architecture (Berners-Lee et al., 1992), based on the concept paper by Berners-Lee (1989), search engines quickly became important due to the increase of web servers and websites. Early search engines offered a keyword-based search. Examples of such search engines were the WebCrawler, World Wide Web Worm, and Altavista, as mentioned in Page and Brin (1998).

Page and Brin (1998) then invented Google, a search engine, which exploits the structure of the web to improve search results. This search engine introduced the PageRank algorithm (Page et al., 1999), which exploits the link structure of web documents.

In 2001, Berners-Lee et al. (2001) introduced the idea of the semantic web. Before the semantic web was born, web pages only had a very general structure. This general structure consisted of headings and other structural elements and design elements, as well as links that refer to other web pages. Computers were not able to reliably extract semantics out of web pages. However, such semantics could enable automated reasoning processes. Thus, formalised representations of semantics in web documents and reasoning techniques were introduced. Such representations can, for instance, support a job candidate who has his or her own web page that contains his or her CV. This CV could include a formal representation of the semantics in addition to the human readable CV representation. This formal representation clearly states this candidate's educational history. Another service could then take these semantics and reason over them to identify the job that fits this candidate. Such formalised representations include,

for instance, formal ontologies (see Section 2.2). The introduction of semantics on the web, or the semantic web, is also called web 3.0 (Hendler, 2009).

The use of semantics opened up a number of opportunities for search engines and semantic search engines were born. Semantic search engines make use of semantic-driven search technologies (Usbeck et al., 2016).

Semantic search engines can be divided into two groups.

The first group enhances standard search engines by utilising semantics. This includes the use of semantics to improve the ranking of search results as well as the navigation within search results, such as in Widyantoro and Yen (2001), Pretschner and Gauch (1999), Sah and Wade (2013), Lei et al. (2006), Usbeck et al. (2016), Laura and Me (2015), and Fernández et al. (2011). Semantics can also improve standard search engines by providing additional information, such as in Stab et al. (2012) or the Google Knowledge Graph. Stab et al. (2012), for instance, provide graphs that show relations between the query and the search results. The Google Knowledge Graph provides information boxes next to a search result that, for instance, show how a specific person is related to another person.

The second group of semantic search engines focuses on retrieving data objects that store semantics on the web, such as in Ding et al. (2004), Zhang et al. (2005), and Patel et al. (2003). Through the introduction of the semantic web, there are many semantic web documents available that represent a certain topic. Semantic web documents are usually expressed as formal ontologies. Formal ontologies can be, for instance, stored in OWL (the Web Ontology Language) (Hitzler et al., 2012). An example of such a formal ontology is the Friend of a Friend (FOAF) ontology<sup>1</sup>. In this thesis, Section 2.2 introduces the concept of formal ontologies.

This thesis focuses on the enhancement of standard search engines by providing overview summaries that could be added to search results. More about semantics and the representations of semantics with the help of formal ontologies can be found in Section 2.2. Section 2.4 describes the use of semantics in automatic summarisation. Additionally, the following sections provide more detailed information about different semantic-driven techniques used in search engines.

### 2.3.3 Academic Search Engines in Practice

This section provides an overview of operational and available academic search engines.

Academic search engines provide information retrieval capabilities over a collection of scientific publications.

Some academic search engines belong to the group of traditional search engines for the following reasons. These academic search engines provide search capabilities over a collection of documents that are stored in more controlled environments. New websites are being added in an uncontrolled fashion. This is

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<sup>1</sup><http://xmlns.com/foaf/spec/>

not the case for many academic search engines. However, some academic search engines perform a federated search over a number of systems. These academic search engines include a component that crawls these systems at regular intervals or query each system independently and combine the search results. Most other academic search engines belong to traditional search engines.

However, there exist academic search engines that browse the web and are therefore exposed to this rapidly changing environment. To cope with this rapidly changing environment, there also exist a number of web academic search engines. These search engines crawl the web for new publications to build an index of publications on the web. Such search engines often provide a more comprehensive list of search results. However, these search engines often also include low quality publications.

The following sections provide an overview of traditional academic search engines in practice and web academic search engines in practice. In this thesis, academic search engines are divided into library cataloguing systems, academic search engines that are maintained by publishers of scientific literature, and independent search engines. Section 2.3.3.4 discusses semantic academic search engines. Semantic academic search engines can belong to any of the three types of academic search engines (library cataloguing systems, academic search engines run by publishers, and independent search engines). This thesis focuses on semantic search engines. Therefore, academic semantic search engines are covered separately.

### 2.3.3.1 Library Catalogues

Many universities maintain their own cataloguing system. Some examples are the Curtin University Catalogue<sup>2</sup> or the Graz University of Technology Catalogue<sup>3</sup>. Most of these cataloguing systems serve two purposes. Firstly, they provide information about books that a library has to offer. Secondly, these cataloguing systems also provide access to a variety of online publications.

Most of these search engines are traditional search engines because they cover a curated set of collections.

Although many books are available online as well, there are still books that cannot be searched by automatic data retrieval algorithms. For these books, only meta-data is maintained in databases. Other books are available online and therefore provide a full text search. Cataloguing systems usually implement a specific cataloguing schema.

Such library cataloguing systems try to provide comprehensive search results about offline books that a library has to offer. Additionally, modern cataloguing systems provide search functionalities for a variety of online publications.

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<sup>2</sup><http://catalogue.curtin.edu.au>

<sup>3</sup><http://ub.tugraz.at>

### 2.3.3.2 Proprietary Search Engines

Many, if not most publishers in the scientific sector maintain their own academic search engine to advertise and offer their publications. Examples of such systems are “the Web of Science”<sup>4</sup> by Thomson Reuters, “Academic Search” by ESBCO<sup>5</sup>, IEEE Explore<sup>6</sup>, Elsevier’s Science Direct<sup>7</sup>, Springer Link<sup>8</sup>, and the Cochrane Library<sup>9</sup> by Wiley.

All of these publishers focus on disseminating publications that are owned by the publisher. Therefore, only their own publications are searchable with these search engines. Some of them, such as Wiley, have alliances with other publishers and therefore include material from other publishers as well.

These search engines belong to traditional search engines because they cover a curated set of collections.

All of these search engines provide full-access to documents. Nevertheless, most of these publications are behind a pay wall.

Some publishers provide publications in multiple disciplines, such as Springer Link, Elsevier’s Science Direct, the Web of Science, and ESBCO. Cochrane Library and IEEE Explore, on the other hand, focus on health science and on computer science, engineering, and electronics, respectively.

### 2.3.3.3 Independent Academic Search Engines

There are a number of independent or semi-independent academic search engines available. These independent providers either focus solely on the academic field, or are spin-offs of general search engines.

Examples of such search engines are JSTOR<sup>10</sup> by ITHAKA, Pubmed<sup>11</sup> by the National Institutes of Health and the U.S. National Library of Medicine, Scopus<sup>12</sup> by Elsevier, arXiv<sup>13</sup> by Cornell University, and CiteseerX<sup>14</sup> by Pennsylvania State University.

All of these search engines, except CiteseerX, are traditional academic search engines. CiteseerX is a web academic search engine. CiteseerX crawls the web for open-access publications.

ArXiv and CiteseerX only focus on open-access publications. ArXiv stores preprints of scientific publications in physics, mathematics, computer science, non-linear sciences, quantitative biology and statistics. Many of these publications are later submitted to journals. CiteseerX indexes open-access publications

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<sup>4</sup><https://apps.webofknowledge.com>

<sup>5</sup><https://www.ebscohost.com/academic/academic-search-complete>

<sup>6</sup><http://ieeexplore.ieee.org>

<sup>7</sup><https://www.elsevier.com/solutions/sciencedirect>

<sup>8</sup><http://link.springer.com>

<sup>9</sup><http://www.cochranelibrary.com>

<sup>10</sup><https://www.jstor.org>

<sup>11</sup><https://www.ncbi.nlm.nih.gov/pubmed>

<sup>12</sup><https://www.scopus.com>

<sup>13</sup><https://arxiv.org>

<sup>14</sup><http://citeseerx.ist.psu.edu/index>

using a crawler. Authors can also upload their work to get their work indexed by CiteseerX.

JSTOR was created to support libraries in providing large collections of publications electronically and out of one hand. They provide full-access scientific publications in more than 20 fields.

Pubmed is a search engine that only provides citations and abstracts to papers in health science. Full access to publications can only be provided by the respective publisher.

Scopus is a semi-independent search engine because it is owned by the publisher Elsevier. Nevertheless, Elsevier wants to provide unbiased search results. To achieve that, Elsevier introduced a content selection and advisory board with strict criteria in regards to the content that should be included<sup>15</sup>. Scopus describes itself as the largest abstract and citation database of peer-reviewed literature<sup>16</sup>.

**General Search Engines:** In addition to the search engines mentioned above, there are two search engines that are spin-offs of standard web search engine providers. These two are Google Scholar<sup>17</sup> and Microsoft Academic<sup>18</sup>. Google Scholar indexes most peer reviewed online academic journals and books<sup>19</sup>. Microsoft Academic indexes 120 million publications<sup>20</sup>. These two search engines use a web crawler and therefore belong to web academic search engines.

#### 2.3.3.4 Semantic Academic Search Engines

Some academic search engines also make use of semantic technologies. Three academic search engines that make use of semantic technologies are Microsoft Academic<sup>21</sup>, Semantic Scholar<sup>22</sup>, and GoPubMed<sup>23</sup>.

These three search engines belong to the category of independent academic search engines.

Microsoft Academic claims to use semantic technologies<sup>24</sup>. However, Microsoft did not maintain this search engine appropriately for some time. [Orduña-Malea et al. \(2014\)](#) identified a significant decline in publications that are indexed by Microsoft Academic. However, Microsoft announced on their website<sup>25</sup> that the former version of their academic search engine has been replaced with a newer version. The paper by [Sinha et al. \(2015\)](#) explains the new Microsoft Academic Service (MAS), which is based on a heterogeneous entity graph that

<sup>15</sup><https://www.elsevier.com/solutions/scopus/content>

<sup>16</sup><https://www.elsevier.com/solutions/scopus>

<sup>17</sup><https://scholar.google.com.au>

<sup>18</sup><http://academic.research.microsoft.com>

<sup>19</sup><https://scholar.google.com.au/intl/en/scholar/about.html>

<sup>20</sup><http://academic.research.microsoft.com>

<sup>21</sup><https://academic.microsoft.com>

<sup>22</sup><http://allenai.org/semantic-scholar/>

<sup>23</sup><http://www.gopubmed.org/web/gopubmed/>

<sup>24</sup><https://academic.microsoft.com/FAQ>

<sup>25</sup><https://academic.microsoft.com/FAQ>

consists of six types of entities: field of study, author, institution, paper, venue, and event. The web page<sup>26</sup> itself shows one of the features that are proposed in [Sinha et al. \(2015\)](#). For instance, Microsoft Academic displays a number of sub-disciplines in the field of machine learning when querying the term “machine learning”.

Semantic Scholar utilises semantic-technologies to, for instance, identify meaningful citations ([Valenzuela et al., 2015](#)) or to extract figures and tables together with their captions out of scientific articles in computer sciences ([Clark and Divvala, 2015](#)). Meaningful citations are citations that depict that the cited work is used or extended in other publications. Semantic Scholar also proposes on their web page that they are working on providing overviews of specific topics. However, this feature is not part of the current system yet. Semantic Scholar also provides graphical representations that depict the degree to which a publication has influenced another publication.

Finally, another semantic academic search engine is GoPubMed. This search engine enhances PubMed by providing a facility to browse through search results using the Gene Ontology ([Doms and Schroeder, 2005](#)). Although the website was available in November 2016, it seems that it is impossible to query Pubmed via this engine at the current date.

### 2.3.3.5 Features of Academic Search Engines in Practice

This section provides an overview of features that are provided in academic search engines in practice. This section also identifies that overview summaries are currently not provided by academic search engines in practice. This underlines the novelty of the artefacts that are researched in this thesis.

All search engines that were discussed in Section 2.3.3 return a list of scientific articles to a specific search query.

Most of these academic search engines also provide additional information, such as the abstract of an article, when and where a specific article was published, the author, or the ISBN number. If there is the full text of the publication available, these systems also provide access to these full texts.

Most search engines provide an option to refine a specific search result using certain refinement criteria. For example, many academic search engines provide a slider or a link to limit the results to a certain time frame. Another feature that is implemented frequently in academic search engines lets the user restrict a specific search to publications of a specific author or publications in a specific journal.

Additionally, information about the number of citations has become a feature in many academic search engines. Such a feature provides information on how often a specific paper has been cited. In addition to that, Semantic Scholar also provides information on publications that have influenced a specific publication in the search result. Semantic Scholar also provides citation velocities that show how often a specific publication has been cited in a certain year. Additionally,

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<sup>26</sup><https://academic.microsoft.com>

Semantic Scholar provides a metric that shows how influential a specific article is by displaying the number of “highly influential citations”. If an author cites a publication and this citation has highly influenced the work that the author is proposing, this citation is identified as a highly influential citation, as discussed in [Valenzuela et al. \(2015\)](#)<sup>27</sup>.

Many academic search engines also provide snippets of a certain publication or the abstract.

Additionally, some academic search engines provide links to other related publications. The set of linked publications is usually more comprehensive in independent academic search engines. Proprietary academic search engines often only refer to publications in their own journals.

Most search result presentations in academic semantic search engines do not differ significantly from search result presentations in non-semantic search engines. However, this might change in the future as can already be seen to some extent on the Semantic Scholar website.

Overview summaries are currently not provided in any of these search engines. However, the purposeful artefact that is researched in this thesis provides mechanisms to generate such overview summaries. More about DSRCRS architecture, which fulfils the requirement of providing overview summaries, can be read in [Chapter 4](#).

### 2.3.4 General Requirements of Semantic Search Engines

One of the main requirements of a search engine in terms of effectiveness is to provide a comprehensive but accurate list of documents that match a specific search query. The effectiveness can be measured by recall and precision. Recall expresses the percentage of relevant documents that have been retrieved out of documents that are marked as relevant in the searched set of documents. Precision expresses the percentage of relevant documents out of the retrieved set of documents ([Baeza-Yates and Ribeiro-Neto, 1999](#)).

Precision and recall are metrics that are often used in evaluating modern search engines. However, modern search engines, which also include semantic search engines, offer additional features apart from providing a list of documents. These features introduce another set of requirements and criteria to evaluate the effectiveness of such approaches.

Below are some examples of features in modern search engines and their requirements.

One feature is to provide excerpts or summaries below a specific search result. Snippets, for instance, display excerpts of a document below a search result. Snippets are extracts of documents that contain important information out of a retrieved document. Thus, the feature of providing extracts below a search result results in the requirement of providing readable and useful extracts.

Other features in current search engines include the provision of additional information or metrics next to a search result, such as the number of citations

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<sup>27</sup><https://www.semanticscholar.org/faq#influential-citations>

that refer to a specific article. Thus, another requirement of a search engine is to provide an accurate number of citations to provide meaningful results.

Query answering or the communication with users in natural language has been identified as another requirement of a semantic academic search engine in [Sinha et al. \(2015\)](#).

The requirements above provide an overview of the requirements of modern search engines. These requirements deviate significantly from the effectiveness requirements of standard search engines, which are concerned with an increase in precision and recall. Although precision and recall remain important, other requirements that extend standard search engine functionalities are becoming equally important.

Most semantic search engines belong to modern search engines. Thus, semantic search engines fulfil similar requirements to general modern search engines. However, requirements vary from search engine to search engine.

[Lei et al. \(2006\)](#) identified the following requirements for semantic search engines: a low access barrier for ordinary end users, dealing with complex queries, precise and self-explanatory results, and a quick response. The requirement of providing a low access barrier means that ordinary users should not need to understand the semantic technologies that are used in the background to query the system. The requirement to provide self-explanatory search results should enable a user to quickly absorb and understand a specific result.

[Usbeck et al. \(2016\)](#) identified another set of requirements of a semantic search engine. These requirements are bound to a set of specific use cases. Notable requirements in [Usbeck et al. \(2016\)](#) are knowledge extraction from unstructured or semi-structured text, runtime efficiency, quality of search results, and the verbalisation of search results. Firstly, knowledge has to be extracted to provide a machine readable presentation of a specific text. Secondly, queries should be processed efficiently. Thirdly, search results of semantic search engines should be of high quality. A high quality search result implies high precision in the search process ([Usbeck et al., 2016](#)). [Usbeck et al. \(2016\)](#) argued that preciseness is more important than comprehensiveness in the search results of semantic search engines. Finally, search results should not consist of a list of links, but should be verbalised.

[Sinha et al. \(2015\)](#) also identified the need to communicate with the user in natural language and to implement prediction behaviours.

In this thesis, the following four meta-requirements regarding the effectiveness of semantic search engines have been identified. A meta-requirement describes a class of goals to which a theory applies ([Walls et al., 1992](#)).

- Semantic search engines should provide a user friendly search interface. Users prefer to state questions in an intuitive way without the need to know the knowledge structure on which a search engine is based ([Lei et al., 2006](#), [Usbeck et al., 2016](#)). However, this depends on the type of formal ontology that is used. A formal ontology is a formal representation of a conceptualisation (see Section 2.2 for more information). For instance, [Doms and Schroeder \(2005\)](#) utilised the Gene Ontology ([Gene Ontology](#)

[Consortium and others, 2004](#)) and provided an interface to browse this Gene Ontology. Thus, in specific applications, where users are familiar with a specific ontology, an ontology can be provided to the user in the search process, such as in [Doms and Schroeder \(2005\)](#) and [Giese et al. \(2015\)](#). In such cases, a self-explanatory interface to browse through an ontology is crucial. However, in most other cases, ontologies that are used in semantic-driven technologies of a search engine should be hidden from the user.

- Semantic search engines should provide a precise set of results. Users are looking for more precise answers ([Lei et al., 2006](#), [Tang et al., 2008](#), [Usbeck et al., 2016](#)) to cope with the overload of information. Users would like to retrieve a small but correct set of documents, rather than having to browse through a plethora of documents that might be related to a specific query.
- Semantic search engines should provide comprehensive answers. Although precise answers are more important than comprehensive answers as identified in [Usbeck et al. \(2016\)](#), users are interested in a complete, but concise answer. However, a comprehensive answer should be correct and therefore the search result has to be precise. If a user searches for artefacts that solve a specific problem, the search result should include a comprehensive list of artefacts. If essential artefacts are omitted, practitioners, for instance, might not find the most efficient and effective solution to solve a specific problem.
- Semantic search engines should provide self-explanatory results. A user should see more than a URI ([Usbeck et al., 2016](#)) or a link to a document. A verbalised answer, rather than a list of search results, can significantly reduce the time to search. Such a verbalised answer can be, for instance, a summary of the retrieved documents. If a summary is expressive enough, the search result summary should be self-explanatory. Additionally, other representations that summarise a search result or support the querying or browsing process can also enhance the search experience, such as in [Laura and Me \(2015\)](#).

The meta-requirements above express effectiveness requirements of semantic search engines. This thesis does not discuss efficacy and efficiency requirements. However, there is one notable efficacy requirement that many semantic technologies in the literature of semantic search engine approaches include, which is the requirement to utilise formal ontologies in the search process ([Lei et al., 2006](#), [Usbeck et al., 2016](#)). Approaches that utilise formal ontologies can be found in Section 2.3.6.

### 2.3.5 General Architecture of Semantic Search Engines

This section derives a general architecture for semantic search engines from the literature. A semantic search engine consists of a set of processes and products.

The general architecture that is depicted in this thesis consists of four processes: a crawler (for web semantic search engines), an indexer, a query processor and a search result presentation generator. In addition to that, a general architecture also consists of two stores: a document store, and a set of indexes.

[Laura and Me \(2015\)](#) identified three main components of a semantic search engine: the crawler, the indexer and the query processor. The general architecture of a search engine that is presented in [Langville and Meyer \(2006\)](#) also includes two stores: the page repository, which stores the output of the crawling process, and a store that consists of a set of indexes. [Langville and Meyer \(2006\)](#) identified three indexes: a content index, a structure index, and a special purpose index. A special purpose index is an index that is used in special queries. A special query can be, for instance, a query about an image. For such queries, a special purpose index could be created that contains relations between the caption of an image and a specific image. In addition to a crawler, an indexer, and a query processor, [Langville and Meyer \(2006\)](#) proposed a ranking module. A ranking module is used to sort search results according to their relevance in regards to a specific query.

The components of a semantic search engine vary in whether the semantic search engine is a traditional semantic search engine or a web semantic search engine. The main difference between the two is that a web semantic search engine includes an additional module, which is named “crawler module”. This crawler module searches the web for new and updated content. With the exception of the crawler module, both the traditional semantic search engine and the web semantic search engine share all other components.

A general architecture of a semantic search engine consists of the following processes: an indexer, a query processor, and a search result presentation generator. Due to the increasing importance of search result presentations, in this thesis, in comparison to [Langville and Meyer \(2006\)](#) and [Laura and Me \(2015\)](#), the search result presentation generator is introduced as a separate component.

[Langville and Meyer \(2006\)](#) identified the ranking module as a main component of a search engine. However, in the general architecture that is presented in this thesis, the ranking module is included in the query processor and is not a separate main component. The reason for this decision is that the output of a query processor should provide a ranked list of documents. Additionally, in semantic search engines, it might even be possible that a result does not necessarily have to be ranked at all. For instance, if a comprehensive picture about a specific topic is requested (by providing a summary of the search result), the retrieved documents do not necessarily have to be ranked.

Semantic search engines share the following products with standard search engines: a document repository, a set of indexes, and a search result presentation specification.

The differentiation between web and traditional search engines (see [Section 2.3.1](#)) can also be applied to semantic search engines. The document repository of a web semantic search engine changes frequently without the supervision of a central authority. Traditional semantic search engines usually maintain a document repository that is maintained by a central authority and does not

change rapidly.

Unlike non-semantic search engines, the indexes in semantic search engines often include indexes that store semantic information, such as the semantic layer proposed in [Usbeck et al. \(2016\)](#) or the ones implemented in [Zhang et al. \(2013\)](#), [Doms and Schroeder \(2005\)](#), and DSRCRS architecture (DSRCRSA).

More about DSRCRSA design can be read in [Chapter 4](#).

### 2.3.6 Semantic-Driven Techniques in Semantic Search Engines

This section provides an overview and identifies gaps in regards to semantic-driven techniques in semantic search engines. This section briefly highlights information retrieval models that are used in general search engines. Following that, the general use of semantics in search engines is outlined. Finally, the use of semantics in indexing modules and querying modules is delineated.

#### 2.3.6.1 General Information Retrieval Models

A well-designed indexing component ensures real time querying. An index implements a data model, which is part of the information retrieval model, that supports a query component in producing relevant search results.

Crawler, indexer, query processor, and result presentation generator are interconnected components. Although there might be some modelling differences in the indexing process, the querying process, or the result presentation process, a set of general information retrieval models can be identified.

Information retrieval models in non-semantic search engines can be divided into set-theoretic models, algebraic models, probabilistic models, and structured-text-retrieval models ([Baeza-Yates and Ribeiro-Neto, 1999](#)). A combination of any of these models is called a meta-model ([Langville and Meyer, 2006](#)).

Set-theoretic models include boolean models. Boolean models use sets of keywords and boolean algebra to retrieve important documents. Boolean models have the drawback that a document is either part of a search result or not. Thus, boolean models do not support ranking methods, which are provided in other models ([Dong et al., 2008](#)).

Algebraic models are usually based on vector space representations of queries and documents ([Baeza-Yates and Ribeiro-Neto, 1999](#)). A vector space consists of vectors that represent keywords in a document or a query. The distance between a specific document vector and a specific query vector can be calculated by utilising comparison algorithms, such as the cosine similarity ([Büttcher et al., 2010](#), [Baeza-Yates and Ribeiro-Neto, 1999](#)). This distance then expresses the similarity between a document and a query ([Langville and Meyer, 2006](#), [Baeza-Yates and Ribeiro-Neto, 1999](#)). Latent semantic indexing ([Dumais, 2004](#)) is an extension of a vector space model ([Büttcher et al., 2010](#)). Latent semantic indexing incorporates the theory that terms that appear in similar pieces of text, such as the same paragraph or sentence, are semantically related.

Probabilistic models utilise probability theory to calculate the probability that expresses the relevance of a document. Such a model strives to calculate the probability of whether a user judges a document to be relevant to a specific query (Langville and Meyer, 2006, Büttcher et al., 2010, Baeza-Yates and Ribeiro-Neto, 1999).

Structured-text-retrieval models combine text with information about the document structure to retrieve important documents (Baeza-Yates and Ribeiro-Neto, 1999). Queries in structured-text-retrieval models consist of rules. Such rules utilise keywords but also structural information. An example for such a rule would be, for instance, to retrieve documents that contain a certain keyword that appears in the abstract of a publication.

Most of the models above can be enhanced by utilising semantics in various ways. The next sections explain semantic capabilities, which can be incorporated in these models.

### 2.3.6.2 Semantic-Driven Models in Semantic Search Engines

Semantic-driven technologies are often used in search engines to enhance standard retrieval algorithms. This section outlines the use of semantic-driven technologies in semantic search engines. This section also delineates that more expressive formal ontologies are only used rarely in semantic search engines that utilise ontologies. Most ontologies that are used in semantic search engines only express subsumption relationships as highlighted in the following sections. Subsumption relationships are subconcept/superconcept relationship between concepts (Küsters, 2001). More expressive ontologies enable to reason over more complex topics (Völker et al., 2008). More information about the expressiveness of formal ontologies can be found in Section 2.2.1

Formal ontologies can be transformed into a graph-based data model or a tree-based data model (see Section 2.2.2). Graph-based or tree-based data models can support the retrieval of information as described in the following paragraphs.

The main difference in regards to standard search engines is that semantic search engines utilise semantic representations. Semantics can be used implicitly or explicitly. Explicit semantic representations include formal ontologies in the information extraction process. In this thesis, such models are called ontology-based models. In ontology-based models, formal ontologies describe the semantics of the content that is stored in a collection of documents, or relate to the content in a document collection. Semantic representations can also be used to describe additional information that accompanies a search result. An example of such additional information would be a relation between authors that expresses that an author influenced a set of other authors.

Implicit semantic representations, such as latent semantic technologies, use patterns or mathematical models to retrieve documents. If text in a document that follows a specific pattern or a specific mathematical model can be identified, this document can be retrieved as a search result. The identified text then expresses the meaning that is described by a pattern or a mathematical model.

The following paragraphs provide an overview of general semantic models that are used in semantic search engines. Section 2.3.6.3 and Section 2.3.6.4 then discuss different semantic approaches in indexing and query processes.

Most semantic-driven techniques utilise formal ontologies (see Section 2.2.1). Others use semantics implicitly or rely on non-semantic techniques that search for semantic web documents. This thesis categorises semantic search engine information retrieval models into five groups: *pre-defined ontology models*, *generic ontology models*, *non-document-related ontology models*, *implicit semantic models*, and *semantic web document models*. Semantic web documents are documents that represent semantics, are accessible via the web, and store formal ontologies. In addition to these three properties, a semantic web document has to be written in a semantic web language (Ding et al., 2004).

*Pre-defined ontology models* include an ontology and relate these ontologies to documents that are searched by the search engine. These relations can then be used in the query process to search for documents, to refine search results, or to rank search results.

*Generic ontology models* generate ontologies on the fly. Such generated ontologies can serve as an index for a document collection.

*Non-document-related ontology models* make use of ontologies that are not directly related to the documents that are retrieved in a specific search. Instead, such models use ontologies that describe, for instance, the personal profile of a user to, for instance, refine search results.

*Implicit semantic models* apply a certain pattern or a mathematical model to identify text passages that express the semantics that are reflected by the pattern or the mathematical model. The identified text passages could be used to categorise or rank documents.

A *semantic web document model* only searches through collections of semantic web documents. Such semantic web documents already express semantics in a structured form. A semantic web document model utilises indexing mechanisms that make use of a semantic web document structure. Therefore, they are distinct to other semantic search engine information retrieval models.

The next paragraphs briefly describe each of these models and discuss the literature that applies or introduces such models.

**Pre-defined Ontology Models :** A pre-defined ontology model utilises an ontology that has been built manually, or semi-automatically. These ontologies often express a general topic that is represented in a certain collection.

A drawback of many pre-defined ontology model approaches is that they utilise ontologies that consist of a shallow set of axioms. Many of these ontologies only make use of subsumption relations. More expressive ontologies can be used to provide, for instance, more elaborate search result summaries. Information on how expressive ontologies can be used to create search result summaries can be found in Chapter 4.

This paragraph outlines some pre-defined ontology model approaches before describing them in more detail in the next sections. Sinha et al. (2015) used

an ontology that models real-life academic communication activities. As mentioned in Section 2.3.3.4, this ontology consists of six entities: field of study, author, institution, paper, venue, and event. These six entities are then instantiated to describe documents in the stored collection of documents. *Cohen et al. (2003)* utilised the semantics of how generic XML components are interconnected in generic XML documents by introducing an interconnection relationship. *Cohen et al. (2003)* proposed a specialised system that works with structured generic XML data. This model represents interconnections between components by utilising the nested hierarchy of XML documents. *Barbagallo and Formica (2016)* semi-automatically created an ontology for a specific topic. *Barbagallo and Formica (2016)* utilised an ontology for the topic osteoporosis. This ontology is used to refer to reusable learning objects that are stored in the database. Reusable learning objects, according to *Barbagallo and Formica (2016)*, are reusable multimedia and interactive training modules. These learning objects then become searchable. The proposed ontology is based on subsumption relationships. *Doms and Schroeder (2005)* utilised the Gene Ontology (*Gene Ontology Consortium and others, 2004*). This ontology is used to categorise publication abstracts in Pubmed. This approach also utilises subsumption relations. *Giese et al. (2015)* implemented a search engine that is based on ontology-based data access (OBDA). OBDA utilises an ontology that describes the end user's domain vocabulary. This vocabulary is mapped to tables in a relational database model. Thus, the ontology represents the schema of the relational database model. *Bonino et al. (2004)*'s approach relies on an ontology that only consists of subsumption relations. This approach maps terms to concepts. These concepts are stored in an ontology that represents the domain of the document collection. *Bonino et al. (2004)* proposed an ontology navigation algorithm that utilises subsumption relations. This navigation algorithm can be used to limit the search result set by extending search queries with subsumption relations. *Sah and Wade (2013)* used a reference ontology called UMBEL<sup>28</sup>. Linked open data (LOD) (expressed in semantic web documents) on the web are then linked to UMBEL. *Sah and Wade (2013)* utilised an ontology search engine to identify semantic web documents. These documents are then mapped to concepts in the reference ontology. This model also builds on subsumption relationships. Another approach that uses a pre-defined ontology is presented in *Fernández et al. (2011)*. This approach links keywords in documents to concepts in a pre-defined ontology that describes concepts in the document text. Although the article does not explicitly mention the expressiveness of the used ontology, only concepts, and no other ontological components, are used in the identification of documents that match a certain search query.

Half of the approaches (*Bonino et al. (2004)*, *Doms and Schroeder (2005)*, *Barbagallo and Formica (2016)*, and *Sah and Wade (2013)*) that are mentioned above only use subsumption relations in their pre-defined ontology model. Such shallow models reduce the possibility to reason. For instance, complex class descriptions (discussed in Section 2.2.4) could be used to create meaningful

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<sup>28</sup><http://umbel.org>

summaries. For example the sentence “A bicycle includes 2 wheels” cannot be represented by solely using the concepts bicycle and wheel. Firstly, it would not be possible to create a relationship between bicycle and wheel using subsumption relations. Secondly, it is not possible to express the cardinality of 2 by solely relying on subsumption relationships. Pre-defined ontology model approaches that are not or not solely based on subsumption relations are described in [Sinha et al. \(2015\)](#), [Cohen et al. \(2003\)](#), [Fernández et al. \(2011\)](#), and [Giese et al. \(2015\)](#). [Sinha et al. \(2015\)](#) and [Cohen et al. \(2003\)](#) solely related concepts without any further specification of the relationship involved. However, both approaches use relations to express whether a relation between two specific concepts is meaningful or not. Although it is not clearly described whether [Fernández et al. \(2011\)](#) utilised expressive ontologies, the proposed approach, which identifies documents that match a certain query, does not use relations at all. The approach that is published in [Giese et al. \(2015\)](#) incorporates relations. However, this approach does not include reasoning capabilities. Additionally, once the database schema and the ontology are implemented, it is very labour intensive to update the schema and the ontology because the whole database has to be updated. Gaps in the indexing process and the querying process of these approaches will be outlined in the section with the heading “Generic ontology models”.

**Generic Ontology Models:** Generic ontology models include automatically generated ontologies. These automatically generated ontologies are used in the search process. Natural language processing is used to generate ontologies automatically. Although natural language processing techniques are continually improving, the resulting ontologies often include concepts with cryptic names, relationships that are not clearly defined, or concepts that are unrelated to the content. Thus, these techniques cannot be used in processes that rely on correct representations of content yet, such as the generation of overview summaries. However, once these approaches provide accurate results, the rich set of relations could result in ontologies that are more expressive and capable of producing summaries.

[Zhang et al. \(2013\)](#) created an ontology out of a domain corpus with the help of a semantic network. This semantic network can be interpreted as an ontology. The resulting ontology represents the engineering domain. This ontology was created by utilising the GRAONTO algorithm that is presented in [Hou et al. \(2011\)](#). This algorithm creates a graph or network out of a corpus of documents and then identifies the informativeness of a term. This algorithm then also creates clusters of the graph to identify concepts and relations. [Widyanoro and Yen \(2001\)](#) introduced a fuzzy ontology model. This approach generates an ontology by identifying subsumption relations in documents. These semantics are extracted using a fuzzy conjunction operator.

Although generic ontology models have the advantage of creating ontologies automatically, the ontologies that are presented in [Zhang et al. \(2005\)](#) do not reach the quality that is needed to, for example, generate summaries. [Widyan-](#)

toro and Yen (2001) did not present an example of their resulting ontology. However, ontologies that are generated using the approach in Widyantoro and Yen (2001) cannot be expressive enough for more complex tasks, such as the generation of summaries. This is because the ontologies that are generated by Widyantoro and Yen (2001)'s approach can only express subsumption relations. More expressive ontologies, that, for instance, make use of complex classes, can infer information that is suitable to generate summaries (see Chapter 4). An example of such a complex class would be the summary of a specific "artefact". If the concept "artefact" is defined as a complex class, the definition might include an axiom that expresses that there has to exist a requirement that is fulfilled by a certain concept (the artefact). Once this relation can be identified in the knowledge base, it can then be translated into a textual summary. It has to be noted that more axioms are needed to sufficiently describe an artefact than in the provided example.

**Non-Document-Related Ontology Models:** This paragraph briefly describes the approach that is presented in Pretschner and Gauch (1999) to provide an example of a non-document-related ontology model.

Non-document-related ontology models include semantic models in search engines that do not represent the searched document collection. For instance, Pretschner and Gauch (1999) utilised ontologies to describe a user profile.

Pretschner and Gauch (1999) used user profiles to refine search results. These user profiles were created out of the browser history. Pretschner and Gauch (1999) utilised a publicly accessible browsing hierarchy, called Magellan. Concepts in the browsing hierarchy are instantiated with web documents that are of interest to the user. This set of web documents describes a user profile by containing documents that a specific person has browsed. The semantics that are used in this approach describe a user's behaviour. The browsing hierarchy itself consists of subsumption relations.

**Implicit Semantic Models:** Valenzuela et al. (2015) and Khabsa et al. (2016) utilised machine learning to categorise a document collection. Valenzuela et al. (2015) extracted meaningful citations (see Section 2.3.3.4 for a definition of the term "meaningful citation"). This model uses 12 features to identify meaningful citations. These features are based on three key observations. Firstly, the authors identified that the more often a paper is cited, the more important is a citation. Secondly, it has been observed that a citation varies in meaningfulness depending on the position of a citation in a document (Valenzuela et al., 2015). Lastly, for identifying meaningful citations, all citations in a document have to be identified. Therefore direct as well as indirect citations have to be identified. Direct citations follow the standard of the publisher, are added in parentheses, and are added to a sentence without influencing the flow of the sentence. Indirect citations fit into the flow of a sentence. Indirect citations can be identified by looking for certain features in a document, such as the name of an author and a year.

For instance, the semantics of a citation can implicate that a citation is more meaningful than another citation in the text. One assumption in [Valenzuela et al. \(2015\)](#) is that the meaningfulness of a citation is expressed by the position of a citation in a document. If a citation appears in the related work section, it is less important than a citation that appears in the methods section. A citation in the methods section indicates that the author is extending on the other author's work ([Valenzuela et al., 2015](#)). Such information is not explicitly expressed in an article. However, such semantics enable the extraction or identification of meaningful citations.

**Semantic Web Document Models:** The last category of semantic search engine information retrieval models is semantic web document (see Section 2.3.6.2 for a definition of semantic web document) models. Semantic web document models retrieve and rank semantic web documents. Such models are used in so called ontology search engines. These models are distinct from other models because in comparison to other search engine models, their index utilises features of semantic web documents as can be seen in Section 2.3.6.3 and Section 2.3.6.4.

[Patel et al. \(2003\)](#), [Ding et al. \(2004\)](#), and [Zhang et al. \(2005\)](#) proposed ontology search engines. These ontology search engines use indexing and querying mechanisms that are tailored to semantic web documents (see Section 2.3.6.3 and Section 2.3.6.4 for more information). Whereas [Ding et al. \(2004\)](#) and [Patel et al. \(2003\)](#) proposed their own indexing and querying mechanism, [Zhang et al. \(2005\)](#) created a search engine that outsourced the crawling, indexing, and querying component to the Google Web API to retrieve semantic web documents. [Zhang et al. \(2005\)](#) focused on the representation of the identified ontologies.

The approaches that are mentioned above should provide an overview of semantic search engines. Although semantic web document models are not a focus in this research, some features, such as indexing mechanisms that are tailored to semantic web documents (see [Ding et al. \(2004\)](#), and [Patel et al. \(2003\)](#)), can be important in the retrieval of documents other than semantic web documents. One example that has been discussed above under the section with the heading "Pre-defined ontology models" is the approach that is proposed in [Sah and Wade \(2013\)](#). [Sah and Wade \(2013\)](#)'s approach firstly retrieves semantic web documents that are related to human readable documents. Utilising this relation, [Sah and Wade \(2013\)](#)'s approach can then return the human readable document once the semantic web document is identified.

### 2.3.6.3 Indexing Techniques in Semantic Search Engines

Semantic search engines incorporate semantics in the query process or to provide additional information in a search result. Thus, indexing processes in semantic search engines are not necessarily exclusively used to generate search indexes, but also to generate indexes that are utilised in search result presentation processes or search refinement processes.

Semantic indexing techniques are used to generate semantic models that are used in the querying process or the result presentation process. The following paragraphs titled “Presentation-phase indexing techniques”, “Instantiating existing knowledge bases”, “Generic ontologies”, and “Implicit use of semantics” provide an overview of semantic indexing processes. Firstly, presentation-phase indexing approaches are highlighted to depict that there exist semantic search engines that do not include a semantic index. Then, the most common indexing techniques are highlighted. These techniques generate an index that is based on an existing knowledge base. Thirdly, indexing processes are described that generate an index using generic ontologies. Lastly, indexing processes are discussed that are based on the implicit use of semantics.

In addition to Section 2.3.6.2, this section provides further information about the need of more expressive ontologies, especially for the use in more elaborate search result presentations. A novel approach that makes use of a more expressive ontology is introduced in this thesis (Chapter 4). Additionally, this section discusses indexing techniques that ontology-based information retrieval models (discussed in Section 2.3.6.2) utilise to generate an index.

**Presentation-Phase Indexing Techniques:** There exist semantic search engines that incorporate semantic techniques in the search result presentation-phase.

For instance [Doms and Schroeder \(2005\)](#), who presented a pre-defined ontology model (see Section 2.3.6.2), utilised the Gene Ontology ([Gene Ontology Consortium and others, 2004](#)) to categorise search results. However, this ontology is not used in the indexing process. [Doms and Schroeder \(2005\)](#)’s approach relies on the indexing system in Pubmed. The approach in [Doms and Schroeder \(2005\)](#) firstly retrieves relevant abstracts out of Pubmed. These relevant abstracts are then analysed to assign terms that appear in the Gene Ontology to these abstracts. The relations between abstracts and Gene Ontology terms can then be used to provide an interface that a user can use to refine search results.

[Sah and Wade \(2013\)](#) presented another pre-defined ontology model that utilises semantic techniques in the presentation-phase by providing concept lenses (see Section 2.3.7 for more information about the term ‘concept lens’). Additionally, the approach in [Sah and Wade \(2013\)](#) can be used to re-organise concept lenses, to re-rank results, and to suggest concept lenses ([Sah and Wade, 2013](#)). A difference to other presentation-phase indexing techniques is that [Sah and Wade \(2013\)](#)’s approach categorises results in the indexing phase. Other approaches, such as that of [Doms and Schroeder \(2005\)](#), only introduce semantic techniques in the presentation-phase. However, semantic techniques to personalise the search result by re-organising concept lenses, re-ranking results, or suggesting concept lenses are applied in the querying phase.

Such presentation-phase indexing techniques can be used in pre-defined ontology models, generic ontology models, non-document-related ontology models, as well as semantic web document models. Other approaches that utilise presentation-phase indexing techniques (presented in Section 2.3.6.2) are seman-

tic web document models, such as in [Zhang et al. \(2005\)](#), non-document-related ontology models, such as in [Pretschner and Gauch \(1999\)](#), and generic ontology models, such as in [Widyantoro and Yen \(2001\)](#).

The difference to other indexing approaches is that these approaches do not maintain an index of the document collection, but use semantics to calculate rankings or to suggest additional documents on the fly.

**Instantiating Existing Knowledge Bases:** There exist semantic search engines that instantiate existing knowledge bases. Existing knowledge bases are ontologies or other knowledge bases that describe a specific topic and exist before a search is conducted or a document is added to the repository. These knowledge bases are instantiated with information out of the retrieved documents. This type of technique is used in many semantic search engines. This includes pre-defined ontology models, as well as non-document-related ontology models (see Section 2.3.6.2).

[Sinha et al. \(2015\)](#) proposed a pre-defined ontology model (see Section 2.3.6.2). This model utilises an entity graph that is capable of expressing the semantics of six entities. These entities are field of study, author, institution, paper, venue, and event. These six entities and their relations build the existing knowledge base that is used in [Sinha et al. \(2015\)](#)'s approach. Instances of these entities are then extracted out of structured data that is stored in an internal knowledge base or crawled on the web. [Sinha et al. \(2015\)](#) extracted instances of these entities by utilising natural language processing techniques. For instance, [Sinha et al. \(2015\)](#) used patterns to parse semi-structured data from conference organiser hubs to identify conference venues.

[Barbagallo and Formica \(2016\)](#)'s approach, another pre-defined ontology model (see Section 2.3.6.2), automatically generated an ontology by using the tool `AlchemyApi`<sup>29</sup>, and refined this ontology with the help of experts. This ontology represents the topic osteoporosis and serves as the existing knowledge base in the system that is proposed by [Barbagallo and Formica \(2016\)](#). The system presented in [Barbagallo and Formica \(2016\)](#) stores learning objects. These learning objects are used to create curricula. These learning objects are assigned manually to concepts in the existing knowledge base. This existing knowledge base then serves as a searchable knowledge base to retrieve lecture components.

[Fernández et al. \(2011\)](#) also propose a pre-defined ontology model (see Section 2.3.6.2). This pre-defined ontology information retrieval model uses an index that assigns keywords in documents to ontological entities. [Fernández et al. \(2011\)](#) named this index a lexical ontology index. These ontological entities represent the existing knowledge base that is used as an index in the query process. This system additionally uses a second index. This second index is named taxonomical ontology index and relates ontological entities to direct sub-classes and super-classes.

The approach in [Pretschner and Gauch \(1999\)](#), a non-document-related ontology model (see Section 2.3.6.2), is used to build a personalised profile of a

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<sup>29</sup><http://www.alchemyapi.com>

user. This personal profile consists of the documents that a specific person has viewed as well as the time that a specific person has spent on viewing a web page. This information is used to identify the interests of a specific person. To calculate the interest for a specific web page, the web page itself is transformed into a keyword vector that is then compared to an ontology called Magellan. Magellan is a publicly accessible browsing hierarchy. In [Pretschner and Gauch \(1999\)](#), Magellan serves as an existing knowledge base to calculate the interest of a specific person in a certain web page. Magellan itself consists of subsumption relations.

Another approach to instantiate a knowledge base is to express semantics in a relational database schema or, as in [Giese et al. \(2015\)](#), use a database schema to extract a semantic representation out of the database schema. [Giese et al. \(2015\)](#)'s approach, a pre-defined ontology model (see Section 2.3.6.2), proposes such an approach, also called ontology-based data access (OBDA). OBDA expresses an end user's domain vocabulary by using an ontology and maps these concepts to tables in a relational database model. In [Giese et al. \(2015\)](#), this ontology was extracted out of a database schema. This ontology serves as the existing knowledge base that is then used to provide a user with the domain vocabulary to create a specific query. Because this domain vocabulary is extracted out of a database schema, this domain vocabulary represents the vocabulary of a typical user.

[Bonino et al. \(2004\)](#)'s approach, which utilises a pre-defined ontology model (see Section 2.3.6.2), includes an ontology that represents the domain of the document collection. This domain ontology serves as the existing knowledge base that is utilised in the information retrieval process. Document segments are related to concepts in the domain ontology. The process to assign concepts to document segments utilises lexical representations of concept classes to identify concept classes in a document.

Building indexes by utilising existing knowledge bases opens up new search capabilities. More elegant query mechanisms can be implemented, which utilise semantics that are expressed in these ontologies. Such semantic representations can also be used in the summarisation process, as proposed in this thesis. However, to generate coherent and expressive summaries, ontologies have to be more expressive. More expressive ontologies consist of expressions that, for example, include cardinality constraints or axioms that cannot be expressed using subsumption relations. Such expressive ontologies can be used to produce coherent summaries. [Fernández et al. \(2011\)](#) introduced a pre-defined ontology model (see Section 2.3.6.2) that provides search capabilities in more expressive ontologies. [Fernández et al. \(2011\)](#)'s approach utilises a number of domain ontologies. NLP tools are used to assign terms to entities in the provided ontologies. However, this approach does not include an ontology that relates all domain ontologies. If domain ontologies cannot be related to each other, it would complicate the summarisation of search results because approaches that are related to different domain ontologies cannot be related to each other.

**Generic Ontologies:** Generic ontology models generate generic ontologies on the fly by analysing the document collection. These ontologies can be used as an index as described below. All approaches below belong to generic ontology models, which are discussed in Section 2.3.6.2.

Cohen et al. (2003) created generic ontologies by utilising semantics that are embedded in an XML structure. However, such documents must adhere to the XML specification before an ontological index can be built. Cohen et al. (2003) used the relations between XML components to generate an ontological index.

The approach in Zhang et al. (2013) generates an ontology from a document collection that belongs to the engineering domain by utilising an algorithm named GRAONTO (Hou et al., 2011). GRAONTO creates a graph of important terms in the document collection and clusters these terms to identify concepts as well as relations.

The indexing technique in Widyantoro and Yen (2001) introduced a fuzzy ontology model. This approach builds an ontological model by extracting subsumption relationships utilising a fuzzy conjunction operator (see Section 2.3.6.2).

To summarise, the proposed generic ontology indexing techniques are not accurate enough to be used in the task of automatically creating summaries. This is mainly due to the lack of generating clear, self-explanatory concept names of extracted concepts and relations. Additionally, such techniques are currently not accurate enough to create reliable ontological representations of content in a document.

**Implicit Use of Semantics:** Approaches that use semantics implicitly do not generate or utilise formal ontologies in the indexing or the search process, but use semantics that are expressed as patterns or mathematical models in the indexing process.

Latent semantic indexing (described in Section 2.3.6.1) is an approach that makes implicit use of semantics. This approach creates an index that is based on the semantics in which terms that appear close to each other are related to each other. Thus, semantics are not expressed explicitly, but are incorporated in the indexing technique.

Ontology search engines (see Section 2.3.6.2) also use implicit semantics as can be seen in Patel et al. (2003), and Ding et al. (2004). However, these ontology search engines are tailored to semantic web documents. Such a search process works with the semantics that are expressed in a semantic web document.

#### 2.3.6.4 Querying Techniques in Semantic Search Engines

Querying techniques usually utilise indexes to retrieve relevant documents. In semantic search engines, and many other state-of-the-art search engines, indexes refer to more information than just the name of the document.

This thesis divides semantic search engine query techniques into four categories: *graph-based querying techniques*, *vector-based querying techniques*, *traditional query techniques*, and *semantic query interfaces*.

The general semantic information retrieval models (see Section 2.3.6.2) cannot be used to categorise querying techniques because approaches that belong to the same general model might utilise different query techniques. A table at the end of Section 2.3 depicts the different indexing and querying techniques that can be used in a specific general semantic information retrieval model.

**Graph-Based Querying Techniques:** Cohen et al. (2003) proposed a pre-defined ontology model (see Section 2.3.6.2) that includes a querying process for labels and keywords that appear in XML files. The authors used keywords to search in an index repository. The authors proposed a query language that is tailored to the document representation that is used in their model. This query language makes it possible to search within graphs. An index maps a keyword to a specific path in a document graph. Each path expresses how a specific keyword or label can be reached. In that graph, the index enables an efficient way of searching for keywords and labels to return matching document fragments.

Zhang et al. (2013) proposed a semantic web document model (see Section 2.3.6.2) that creates a graph representation of a specific query. This graph representation is then compared with graph representations of clusters that represent subgraphs of document representations. Each cluster contains a number of documents in the corpus. The distance between the query graph and the graph of the cluster is calculated to compare a query graph and a cluster graph. In comparison to vector-based querying techniques, the distance is calculated by computing graph distances. In Zhang et al. (2013) this is achieved by calculating the distance of a median graph of a cluster and the query graph. Each cluster describes a concept that is identified in a document. Clusters make this approach more scalable. By utilising clusters instead of document graphs, less graph pairs have to be compared to each other. If the query fits a specific cluster, all document graphs that this cluster relates to are compared with the query graph to retrieve the documents that match the initial query.

**Vector-Based Querying Techniques:** Vector-based querying techniques in semantic search engines utilise vectors to delineate whether a specific concept appears in a document. These concepts are described using a formal ontology. This formal ontology usually describes a topic that a specific document collection belongs to.

Barbagallo and Formica (2016) propose a pre-defined ontology model (see Section 2.3.6.2) that utilises a vector-based querying algorithm named *semsim*. *Semsim* is presented in Formica et al. (2013) to compare query vectors with document vectors. In comparison to Zhang et al. (2013), Formica et al. (2013) compared vectors instead of graphs. This comparison uses a similarity measure that is proposed in Lin (1998) and is based on the informativeness of each concept. Each vector consists of a number of weights that express the informativeness of a specific concept in regards to a reference ontology.

Fernández et al. (2011) proposed a pre-defined ontology model (see Section 2.3.6.2) that creates a vector space model that is based on the TF/IDF (term frequency / inverse document frequency) algorithm. Instead of calculating the frequency of a term in a document, this approach calculates the frequency of a specific concept in a document. Fernández et al. (2011) used SPARQL (W3C SPARQL Working Group, 2013) queries to access the knowledge base to retrieve concepts of interest. Following that, the similarity between the query vector that resulted out of the SPARQL query and each document vector is calculated. The documents with the highest similarities to the query vector are returned in a ranked list of documents.

Sah and Wade (2013)'s approach generates term vectors that combine semantic and syntactic similarity measures. Three similarity vectors are used in this approach: a vector of UMBEL<sup>30</sup> concepts, a vector of supertype categories and a vector of terms. UMBEL is a hierarchically organised reference ontology that consists of top-level concepts, also called supertype categories. Concepts that belong to a supertype are called reference concepts. Instead of using the term frequency / inverse document frequency measure (as used above) to calculate a weight of a concept for the vector representation of a document, only the term frequency is used. This results in a better performance in comparing similarities (Sah and Wade, 2013).

**Traditional Query Techniques:** Semantic search engines that are based on non-semantic query engines incorporate semantics in the refinement of a specific search result or use semantic techniques to provide additional information in the presentation stage. This subsection firstly discusses approaches that apply semantic techniques in addition to traditional query techniques in the querying phase. Following that, semantic search engines are highlighted that use traditional query techniques and semantic techniques to enhance the search result presentation. Finally, this subsection discusses ontology search engines that use semantic techniques to query semantic web documents.

**Semantic Techniques in Query Phase:** An example of such an approach is the refinement of a specific search result utilising personalised information, such as in Pretschner and Gauch (1999). Pretschner and Gauch (1999) proposed a non-document-related ontology model (described in Section 2.3.6.2) that utilises an ontology of a publicly accessible browsing hierarchy. By analysing a specific user's behaviour and by mapping this behaviour to this browsing hierarchy, it is possible to re-rank or filter a specific search result. However, the initial query process is performed by a standard query engine.

Widyantoro and Yen (2001) designed a generic ontology model (see Section 2.3.6.2) that uses a fuzzy ontology (see Section 2.3.6.2) to suggest related papers. However, the query process itself consists of a standard keyword-based engine.

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<sup>30</sup><http://umbel.org>

Valenzuela et al. (2015) proposed an implicit semantic model (see Section 2.3.6.2) that supports the ranking of search results by implementing a technique that identifies meaningful citations. The querying process itself relies on an external search engine component. The ranking process utilises a machine learning approach that is proposed in Valenzuela et al. (2015). Documents with meaningful citations are ranked higher because of their higher influence.

The next two subsections titled “Enhance search result presentation” and “Ontology search engines” discuss semantic techniques in search engines that utilise traditional query techniques. Firstly, search engine approaches are discussed that use a traditional query technique, but incorporate semantics in the search result presentation. Secondly, semantic search engines are highlighted that search for semantic web documents and use semantics that are expressed in these documents to rank search results.

**Enhance Search Result Presentation:** Approaches that focus on the presentation of search results are, for instance, described in Bonino et al. (2004) and Doms and Schroeder (2005).

Bonino et al. (2004) proposed a pre-defined ontology model (see Section 2.3.6.2) that refines a search result automatically by utilising a concept hierarchy. A standard search engine is used to retrieve results and a threshold identifies how many documents should be retrieved. The number of documents can be defined by the user. If the number of search results exceeds the defined threshold, the query will be expanded by adding concepts out of the utilised ontology to the query.

Doms and Schroeder (2005) proposed a similar approach (see Section 2.3.6.2) by providing an ontology to the user - the Gene Ontology. A user can browse through the hierarchy of this ontology to further refine a search result. Doms and Schroeder (2005) used Pubmed as a traditional search engine.

Sinha et al. (2015) proposed a pre-defined ontology model (see Section 2.3.6.2) that focuses on the presentation of search results. In Sinha et al. (2015), the presentation of search results is improved by providing information about a specific field next to the search results. Such information includes the provision of subfields of a specific field that has been identified in the search query. For instance, the result of the query “machine learning” in Microsoft Academic<sup>31</sup> returns a box that displays subfields of machine learning, such as “artificial neural network”, “hidden markov model”, and “unsupervised learning”.

**Ontology Search Engines:** Patel et al. (2003), Ding et al. (2004), and Zhang et al. (2005) proposed ontology search engines (see Section 2.3.6.2). As described in Section 2.3.6.2, such engines focus on retrieving semantic web documents. Such semantic search engines use indexing mechanisms that are tailored to such documents. Ding et al. (2004) used term reference information, the number of imports of other ontologies, whether an ontology extends another one, and version-specific relations to create a model of the retrieved ontologies.

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<sup>31</sup><https://academic.microsoft.com>

Term reference information is a metric to identify how many terms out of other ontologies have been used in a specific ontology. [Ding et al. \(2004\)](#) proposed an indexing technique that utilises a rational random surfing model. This rational random surfing model is based on the random surfing model by Google ([Page et al., 1999](#)). [Patel et al. \(2003\)](#) based their indexing model on the page rank algorithm. However, their algorithm only takes into consideration the total number of referrals from one ontology to another ontology. [Zhang et al. \(2005\)](#) used the Google Web API to search the web for semantic web documents and focused on the representation of the retrieved ontologies.

**Semantic Query Interface:** Another semantic query technique lets the user build queries that are limited to the semantics that are expressed in the generated search engine model.

[Giese et al. \(2015\)](#), for example, proposed a pre-defined ontology model (see Section 2.3.6.2) that uses a technique called ontology-based data access (OBDA). OBDA describes an end user's domain vocabulary and maps these concepts to tables in a relational database model. A user can then select the concepts he or she is interested in to construct a semantic query.

[Vega-Gorgojo et al. \(2016\)](#) proposed a similar approach that offers a tool to create a query using graphical elements that express concepts and relations that are described in a specific ontology. Whereas [Giese et al. \(2015\)](#) used SQL to access the ontology, [Vega-Gorgojo et al. \(2016\)](#) used the SPARQL query language. However, both approaches can make use of a highly structured query language because a user of the system is restricted to components that are expressed in the ontology.

### 2.3.6.5 Semantic Driven Techniques - Conclusion

[Zhang et al. \(2013\)](#) and [Barbagallo and Formica \(2016\)](#) described approaches that are related to DSRCRSA in this thesis. However, both approaches cannot be utilised to summarise articles. [Zhang et al. \(2013\)](#)'s approach uses an ontology that lacks proper names for concepts and relations. Such information is important to create clear and coherent automated summaries. [Barbagallo and Formica \(2016\)](#)'s approach does not utilise an ontology that is expressive enough to summarise articles. Their approach only utilises subsumption relations. Thus, only subsumption relations can be summarised. However, a summary usually expresses more than information about how components are hierarchically related to each other. Thus, the ontology that is proposed in [Barbagallo and Formica \(2016\)](#) lacks expressiveness that is needed to generate a complete summary.

### 2.3.7 Search Result Presentations in Semantic Search Engines

State-of-the-art search engines in practice usually present a list of links (see Section 1.1) as a search result. These links are often enriched with snippets

that summarise returned documents or other elements, such as the author of a returned document or the date that a document was last edited.

Semantic search engines can present additional information that result from semantic-driven techniques. For instance, [Valenzuela et al. \(2015\)](#)'s approach provides the number of papers that include meaningful citations to a specific article in the search result list (see Section 2.3.3). Other approaches can be categorised into summarisation elements and navigational elements. Summarisation elements are intended to summarise a specific search result from the search result list. Navigational elements offer refinement options to limit the number of retrieved documents. For instance, navigational elements can offer a list of concepts that, once clicked, limit the search result list to focus on documents that describe the selected concept.

This thesis focuses on the summarisation of search results. Although there are a few approaches proposed in the literature that summarise search results, most approaches are highly specialised to either a specific topic or specific types of documents. However, much research has been done in the automation of multi-document and single-document summarisations, which is highly related to the problem of summarising search results. More information about multi-document summarisation can be found in Section 2.4.

[Joho and Jose \(2008\)](#) identified that more detailed document representations can support users in formulating better queries. More detailed document representations can be, for instance, the provision of excerpts out of a document, the presentation of the number of citations, or other information, such as the authors of a document or the date that a document was last modified. The approach in this thesis could support users in formulating better queries by providing an overview of a certain topic. This overview could contain information that can be used to extent a query.

[Wang et al. \(2016\)](#) proposed a technique to predict the best presentation techniques for a search result. [Wang et al. \(2016\)](#)'s approach utilises presentation techniques out of real searches and place elements, such as ads, news, images, videos, and knowledge cards in a way that satisfies the user. [Wang et al. \(2016\)](#) evaluated that additional information, such as images, videos, or knowledge cards, which are placed using their algorithm, outperform standard ranking methods.

The findings in [Wang et al. \(2016\)](#) and [Joho and Jose \(2008\)](#) further support the utility of the architecture that is presented in this thesis (DSRCRSA), which provides summaries of searched topics. Due to the provision of summaries, users receive additional information that can be used to refine a search result.

The next subsections briefly introduce the three categories of search result presentation aspects that are provided by semantic search engines. These categories are (1) the provision of additional result-related information, (2) the provision of summaries, and (3) navigational elements.

### 2.3.7.1 Additional Result-Related Information

A typical example of result-related information is the presentation of snippets below a search result. Such representations are also common in standard search engines. For instance, [Valenzuela et al. \(2015\)](#)'s approach provides the number of meaningful citations next to a search result (see Section 2.3.3.4). Such information is presented next to a specific search result to provide a metric about the importance of a document. There is other additional result-related information that serves other purposes, such as providing meta-data about a search result.

### 2.3.7.2 Provision of Summaries

A few techniques that are proposed in the literature present summaries of search results. [Cohen et al. \(2003\)](#) and [Alani et al. \(2003\)](#) proposed two approaches that provide summaries. [Cohen et al. \(2003\)](#)'s approach produces excerpts out of generic XML documents. [Alani et al. \(2003\)](#)'s approach produces biographies about painters.

Although both approaches generate summaries, both approaches are of limited use in this research. [Cohen et al. \(2003\)](#)'s approach is tailored to generic XML documents. Thus, the approach that is presented in [Cohen et al. \(2003\)](#) is limited to the extraction of excerpts out of XML documents. Therefore, this approach cannot be applied to summarise natural language text.

[Alani et al. \(2003\)](#)'s approach does create natural language biographies. These biographies are created by utilising an ontology about painters. This ontology is instantiated with terms that are identified in documents on the web. Although this approach generates readable biographies, this approach is tailored to the topic of biographies of painters and cannot be applied to other topics.

### 2.3.7.3 Navigational Elements

Navigational elements can be used to navigate within a search result set. This can be achieved, for instance, by providing a set of concepts that can be selected to limit the list of search results. Examples of navigational elements can be found in [Sah and Wade \(2013\)](#), [Laura and Me \(2015\)](#), and [Widyantoro and Yen \(2001\)](#).

[Sah and Wade \(2013\)](#) chose an approach that personalised search results by providing concept lenses. A concept lens, as described in [Sah and Wade \(2013\)](#)'s approach, consists of a list of concepts that are extracted out of the user's search behaviour. A user can then select a concept to refine the search results. Concept lenses, as proposed in the work of [Sah and Wade \(2013\)](#), are used to re-rank search results once a user selects a specific concept lens.

[Laura and Me \(2015\)](#) produced a conceptual map that serves as a graphical representation of retrieved documents. This conceptual map is a graphical representation of text elements that have been identified in a specific document ([Laura and Me, 2015](#)). This graphical representation can be used to browse through search results.

Another example of navigational elements are elements that suggest documents that are related to documents that are retrieved by the search engine. [Widyantoro and Yen \(2001\)](#), for instance, propose related articles next to a specific search result.

#### **2.3.7.4 Search Result Presentations - Reflection and Conclusion**

This thesis focuses on the provision of summaries of DSR publications. Additional result-related information and navigational elements are examples of how semantic techniques can be used in the presentation of search results. This section also discussed that additional information and complete new representations of search results, rather than a list of search results, enhances the user's satisfaction. Additionally, although there are a few approaches available in the literature, the provision of summaries next to a search result list include a number of open research questions. There are only a few approaches discussed in the literature, but these approaches have limitations, such as the limitation on a specific topic or the focus on a specific type of document.

#### **2.3.8 Search Engines - Reflection and Conclusion**

Section 2.3 provided an introduction to search engines with a focus on semantic search engines.

Search engines can be divided into traditional and web search engines. Both types of search engines include an indexer, a query processor, and a search result presentation generator. However, web search engines additionally include a web crawler component. Nevertheless, there are other differences between traditional and web search engines that address efficiency requirements in the indexer, query, or result presentation component. However, this thesis is only concerned with a general architecture of search engines and semantic search engines. Also, this thesis only discusses effectiveness requirements of semantic search engines, rather than efficiency requirements.

In Section 2.3.2, a brief history of search engines depicted a trend toward semantic search engines.

Section 2.3.3 included a review of academic search engines in practice and provided an overview of the different areas that an academic search engine can be used in. This section also highlighted the fact that semantic-driven techniques are already used in some state-of-the art academic search engines in practice.

Section 2.3.4 and Section 2.3.5 proposed general requirements and a general architecture for semantic search engines that emerged out of the literature. These sections strengthened the argument that additional search result presentations are a popular research topic in the area of semantic search engines.

Section 2.3.6 discussed information retrieval models in general search engines followed by delineating and categorising information retrieval models in semantic search engines. It can be said that there is a high research interest in incorporating formal ontologies into semantic search engines. However, most techniques that incorporate formal ontologies rely on less-expressive ontologies.

This limits the usability of such ontologies in providing more complex search result information, such as the provision of summaries.

The last subsection (Section 2.3.7) provided a categorisation of search result presentations in semantic search engines. One category is concerned with the provision of summaries of documents in a search result. In Section 2.3.7, it was identified that additional information, rather than a list of search results, improves the user experience. One kind of additional information would be the provision of summaries that summarise retrieved documents. However, summarisation techniques in the literature suffer from limitations that prevent the creation of summaries of DSR articles. DSRCSA that is presented in this thesis proposes a solution to this problem as can be seen in [Chapter 4](#).

Approaches	Semantic Models	Indexing	Querying
<a href="#">Cohen et al. (2003)</a>	Pre-defined ontology model	Generic ontologies	Graph-based querying technique
<a href="#">Barbagallo and Formica (2016)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Vector-based querying technique
<a href="#">Bonino et al. (2004)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Traditional query technique
<a href="#">Ding et al. (2004)</a>	Semantic web document model	Implicit use of semantics	Traditional query technique
<a href="#">Doms and Schroeder (2005)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Traditional query technique
<a href="#">Fernández et al. (2011)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Vector-based querying technique
<a href="#">Giese et al. (2015)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Semantic query interface
<a href="#">Patel et al. (2003)</a>	Semantic web document model	Implicit use of semantics	Traditional query Technique
<a href="#">Pretschner and Gauch (1999)</a>	Non-document-related ontology model	Presentation-phase indexing techniques	Traditional query technique
<a href="#">Sah and Wade (2013)</a>	Pre-defined ontology model	Presentation-phase indexing techniques	Vector-based querying technique
<a href="#">Sinha et al. (2015)</a>	Pre-defined ontology model	Instantiating existing knowledge base	Traditional query technique
<a href="#">Valenzuela et al. (2015)</a>	Implicit semantic model	Implicit use of semantics	Traditional query technique
<a href="#">Widyantoro and Yen (2001)</a>	Generic ontology model	Presentation-phase indexing techniques	Traditional query technique
<a href="#">Zhang et al. (2005)</a>	Semantic web document model	Presentation-phase indexing techniques	Traditional query technique
<a href="#">Zhang et al. (2013)</a>	Generic ontology model	Generic ontologies	Graph-based querying technique

Table 2.1: Semantic Information Retrieval Models

**Semantic Models:** Table 2.1 depicts different pieces of research that propose semantic search engines that are discussed in this section.

A predominant number of approaches utilise pre-defined ontology models. All of these approaches rely on an ontology / knowledge base that is either generated manually or semi-automatically.

Non-document-related ontologies that are used in personalised search engines might be effective in the re-ranking of search results as proposed in [Pretschner and Gauch \(1999\)](#). However, non-document-related ontologies cannot be used to create summaries of a search result because they are not or only slightly related to the actual documents that are retrieved in a specific search.

Generic ontology models that utilise automatically built semantic representations (formal ontologies) can be used to create semantic representations on the fly. Automatically generated formal ontologies eliminate the process of manually creating formal ontologies. However, generic ontology models cannot be used to provide summaries of search results because the generated formal ontologies do not usually include lexical representations that can be understood by humans.

Semantic web document models are tailored to be used by ontology experts and researchers because only semantic web documents are retrieved. Laymen usually experience difficulties in comprehending semantic web documents. However, semantic web documents that relate to human readable web documents can be used to retrieve human readable documents as presented in [Sah and Wade \(2013\)](#). Such approaches could be used to generate human readable summaries. However, most documents that are available nowadays do not have an ontology attached that describes the content of a document.

**Indexing:** The indexing techniques that are discussed in this section can be used in all general semantic search engine models, which include pre-defined ontology models, semantic web document models, generic ontology models, implicit semantic models, and non-document-related ontology models. However, most pre-defined ontology models instantiate existing knowledge bases. Indexing techniques that instantiate existing knowledge bases assign text elements to concepts in the provided knowledge base.

Generic ontologies automatically generate formal ontologies that emerge out of the documents that are included in the searched document collection. Approaches that implicitly use semantics often utilise language models that express the semantics of terms that appear in a specific document. Implicit semantic techniques, as well as generic ontology techniques, can be used without the need to automatically generate formal ontologies. However, techniques that make implicit use of semantics, as well as generic ontology techniques, cannot be used to summarise search results as discussed in this section. Nevertheless, a combination of an existing knowledge base and generic ontologies could support the indexing and querying process. An existing knowledge base could be used, for instance, to categorise documents and to provide additional, human readable, information next to a search result or instead of a list of search results.

**Querying:** Querying techniques in semantic search engines predominately use traditional query techniques. This shows that most semantic techniques are used in the presentation-phase to provide additional information next to a search result, to implement navigational elements, or to compute summaries.

Semantic search engines that also utilise semantic techniques in the querying process are utilising vector-based or graph-based techniques. Semantic query interfaces eliminate the process of analysing query terms. Semantic query interfaces provide a limited set of query terms that are described in an ontology. The literature about semantic query techniques shows a preference for vector-based or graph-based techniques. Graph-based techniques are a popular solution because formal ontologies can be seamlessly transformed into graph representations. Vector-based techniques can make use of feature vectors that can be extracted out of a formal ontology by utilising ontological components, such as concepts and relations.

Although traditional query techniques are predominantly used in semantic search engines in the literature, the use of semantics could improve the query process. Semantic representations make it possible to reason over a document corpus, which could result in more precise results. However, the use of querying techniques is out of the scope of the research in this thesis.

## 2.4 Automatic Summarisation

Section 2.4.1 provides definitions of the terms ‘automatic summarisation’ and ‘summary’. In Section 2.4.2, the significance of automatic summarisation for researchers, as well as practitioners, is demonstrated. Important terminologies and techniques are discussed in Section 2.4.3 to highlight research gaps, but also to outline recent advances in the automated summarisation of texts. Section 2.4.3 includes the following topics. Firstly, different summarisation process stages are highlighted. These process stages describe the stages that a raw text has to pass through to become a summary. Secondly, context factors are discussed. Context factors influence the design of a specific summarisation approach. Section 2.4.4 delineates different automatic summarisation techniques. Firstly, Section 2.4.4 highlights research gaps in current summarisation approaches. Secondly, Section 2.4.4 provides an overview of automatic summarisation techniques with a focus on abstractive summarisation techniques (see Section 2.4.3 for a definition of the terms ‘extractive summaries’ and ‘abstractive summarisation techniques’). Finally, summary evaluation techniques are discussed in Section 2.4.5. The subsection about summary evaluation techniques defines criteria that will be used to evaluate the purposeful artefact that is presented in this thesis.

### 2.4.1 Definitions

The following section defines the terms ‘summary’ and ‘automatic summarisation’. These definitions will be used throughout this thesis.

**Summary:** There are multiple definitions of the term summary. Lloret and Palomar (2012a, p. 21) defined summary as a “brief but accurate representation of the contents of a document or a set of them”. Radev et al. (2002) defined a summary as a “text that is produced from one or more texts, that conveys important information in the original text(s), and that is no longer than half of the original text(s) and usually significantly less than that”.

These two definitions show the agreement that a summary has to be brief and no longer than half of the original text(s) and usually significantly less than that. Radev et al. (2002) also clearly pointed out that a summary can be produced out of one or more texts and that a summary should convey important information. Lloret and Palomar (2012b), on the other hand, focused more on the accuracy of a summary.

The definitions above focus on textual representations. Whilst there are a number of other representations, such as graphs or images, this thesis focuses on textual summaries. However, the outcome of this work can also be used in other summary representations than textual summaries.

The definition of the term summary, or to be more precise, textual summary, that is used in this thesis is as follows: A textual summary is a brief, textual representation that accurately conveys important information out of one or many original text(s).

To further specify the definition above, the terms ‘brief’ and ‘accurate’ need to be further explained. This thesis refers to [Radev et al. \(2002\)](#) to define the term ‘brief’. [Radev et al. \(2002, p. 399\)](#) defined ‘brief’ as “no longer than half of the original text(s) and usually significantly less”. Nevertheless, this definition is highly dependent on the type of summary that is being created.

**Summarisation:** This paragraph defines the term ‘summarisation’ that is used in this thesis. Summarisation is the process of generating summaries. The term ‘summarisation’ expresses activities that are involved in summarising a specific text. [Sparck Jones \(1999, p. 2\)](#) defined the term ‘summarisation’ as “a reductive transformation of source text to summary text through content reduction by selection and/or generalisation on what is important in the source”. [Saggion \(2014, p. 4157\)](#) defined summarisation, as “the reduction of text to its essential content”.

These two definitions clearly outline a reductive transformation process of text to its essential content. [Sparck Jones \(1999\)](#) further specified that reduction is done by selection and / or generalisation on what is important in the sources.

This thesis uses the following definition for the term ‘summarisation’: Summarisation is a reductive transformation of source text(s) to its essential content.

This definition has been chosen because the definition includes a process - a reductive transformation. Secondly, this definition includes a clear description of what the input looks like, namely one or more source texts. Thirdly, the definition expresses that a summary should contain essential content. In the summarisation of multiple documents, a reductive transformation also includes comparing, matching and contrasting multiple documents to identify content or topics that the summarised documents share. [Oliveira et al. \(2016\)](#) described the summarisation of multiple documents as a budgeted maximisation coverage problem. This means that the most important concepts have to appear in the summary with the minimum number of sentences.

### **Summarisation of Essential Components and Accuracy and Brevity of Summaries:**

As already mentioned in the definition of the term summary, the term ‘essential’, which is related to the term ‘brief’ in the summary definition that is outlined above, has to be further specified. Whether a specific term is essential or not highly depends on the summary that is generated, the audience who reads the summary and the scenario this summary is being used for. Summaries are accurate and brief textual representations of source text(s). A summary should only consist of information that is important to the source. How accurate or brief a summary should be highly depends on the audience, the type of summary, and the scenario the summary is used in. An important point omitted in the definitions that are provided above, but outlined in several citations, is that a summary has to be tailored to a specific scenario and / or audience. These tailored summary specifications then also include a definition in regards to the brevity of a summary, the accuracy of a summary, and a definition that describes what are essential components of a summary.

**Textual Representations of Summaries:** The research in this thesis is based on textual representations of summaries. However, the outcome of this research can also be used to produce summaries that are based on other representations, such as graphs or diagrams.

**Summary Input Types:** A summary can also have many different input types in addition to text, such as pictures and videos. However, this thesis focuses on the summarisation of textual documents.

### 2.4.2 The Significance of Automatic Summarisation

Summarisation is a reductive transformation of source text(s) to its/their essential content as defined in Section 2.4.1. In automatic summarisation, source text(s) is/are automatically transformed to its/their essential content by utilising a variety of techniques (discussed in Section 2.4.4).

Automatic summarisation of text is certainly not a novel topic, but became increasingly important due to various reasons. For instance, [Barzilay and McKeown \(2005\)](#) stated that there is a redundancy in large collections of texts. Such redundancies can be reduced using summarisation techniques. [Barzilay and McKeown \(2005\)](#), [Lloret and Palomar \(2012b\)](#), [Banerjee et al. \(2015\)](#), [Liu et al. \(2016\)](#) and many others agreed that there is a vast number of information available nowadays. Additionally, [Liu et al. \(2016\)](#) stated that there is a large volume of scholarly articles available and [De Ribaupierre et al. \(2016\)](#) predicted that this number will increase due to open access repositories. [Ronzano et al. \(2016\)](#) reported that a new publication is published every 20 seconds and that PubMed, Elsevier's Scopus and Thomson Reuther's ISI Web of knowledge contain more than 171 million papers.

Additionally, [Radev et al. \(2002\)](#) identified that text is difficult to be read by computers. Although this publication is from 2002, the problem is still evident as can be seen in the high activity in this field of research. This is especially so in the identification of redundant text as discussed in [Radev et al. \(2002\)](#) and [Lloret and Palomar \(2013\)](#), but also the creation of abstractive summaries (see Section 2.4.4) are well-known research problems.

The vast number of scientific outlets, the incredible number of scientific publications, and the fact that a new article is published every 20 seconds makes it even more important to support researchers in digesting information in a more efficient, but also effective way (see Section 1.1). Current technologies, such as Google Scholar and Microsoft Academic, are certainly effective in returning search results that provide a list of scientific publications. But these technologies currently do not provide summaries of specific fields.

### 2.4.3 Categorisation of Automatic Summarisation Techniques

Automatic summarisation techniques have to fit a generic process model. Additionally, summaries have to comply with a number of context factors. These

context factors define the type of summary that has to be created, as well as summarisation techniques that are capable of generating a summary that meets the defined context factors.

This section briefly outlines the generic process model and the context factors that are used in this thesis. The next section refers to these process models and context factor to categorise techniques that are described in the literature.

#### 2.4.3.1 Automatic Summarisation Process Model

Models provide a simplified view on a complex problem. This section outlines process models that are used in automatic summarisation. Two models are presented in this section. Firstly, a summarisation stage model is outlined that describes the main stages in automatic summarisation. Secondly, a natural language generation model describes the phases to generate abstractive summaries.

**Summarisation Stage Model:** Sparck Jones (1999) described automatic summarisation as a three-stage model. This three stage model is described by the transitions between these stages. These transitions are as follows: the transition from the source text to a representation of the source text, the transition from the source text representation to the summary text representation, and the transition of the summary text representation to the generation of the summary text. Radev et al. (2002) identified a two-step process by analysing papers in a special issue on summarisation. These two steps are to identify and extract material and to modify, merge, and edit this material using generation techniques. Nenkova and McKeown (2012) identified three tasks that are performed by most summarisers. These tasks include the generation of intermediate representations to score sentences, and to select summary sentences.

Radev et al. (2002)'s approach misses the transition from the source text representation to the summary text representation. Rather than including two different representations in the summarisation process, one for the source text and one for the summary text, Radev et al. (2002)'s model generates a summary right after a model of the source text has been created. The tasks that are identified by Nenkova and McKeown (2012) reflect summarisers that generate summaries that consist of document extracts. However, recent research in automatic summarisers also include approaches that create summaries that are composed out of automatically generated sentences. Such tasks are not reflected in Nenkova and McKeown (2012).

This thesis uses Sparck Jones (1999)'s process model because the three process stages in Sparck Jones (1999) include the transition from a source text representation to a summary text representation. Many summarisation approaches differentiate between source text representations and summary text representations. For example Wang et al. (2011) used a lexical chain method to create a representation of the source document and an ontology to create a representation of the summary. To state another example, Saggion et al. (2016)'s approach creates links between a source document and a referenced paper to

create a source document representation, and then creates a summary model that includes the most important aspects to be used in a summary.

However, many approaches, such as in [Teufel and Moens \(2002\)](#), end at the source representation stage. The returned summaries in such summarisation approaches consist of a number of the highest ranked sentences in the source text representation. Such models are used to create extractive summaries. Extractive summary generation techniques do not include a summary text representation because these techniques solely return excerpts that represent the most important components of the original text.

The following paragraph discusses a natural language generation model that can be used to create abstractive summaries and describes the transition from the summary text representation to the summary.

**Natural Language Generation Model:** Abstractive summaries provide an abstract view on a specific text or texts (see [Section 2.4.3.2](#) for more details on abstractive summaries). Natural language generation automatically creates text in natural language. A research area that utilises natural language generation is the automatic generation of abstractive summaries.

[Bouayad-Agha et al. \(2012\)](#) and [McDonald \(2010\)](#) divided natural language generation into the following tasks: content or information selection, discourse and information structuring or textual organisation, lexicalisation or the choice of linguistic resources, and morpho-syntactic realisation and linearisation.

Automatic summarisation can be divided into three stages ([Sparck Jones, 1999](#)). The last two stages, which include the creation of a summary text representation and the creation of the summary itself, can also be called natural language generation and can be divided into information selection, textual organisation, choice of linguistic resources and realisation. Information selection represents the second stage in [Sparck Jones \(1999\)](#) (the transition from source text representation to summary text representation) whereas the other tasks belong to the third stage in [Sparck Jones \(1999\)](#) (the transition from summarisation text representation to the generation of summary text).

The research in this thesis is concerned with the last two stages in [Sparck Jones \(1999\)](#) and the natural language generation model that is mentioned above. This includes the representation of the summary text as well as the generation and representation of a textual summary (see [Chapter 4](#)).

#### 2.4.3.2 Context Factors

[Sparck Jones \(1999\)](#) outlined context factors that can be used to describe the environment that a specific summarisation approach needs to be tailored to. [Sparck Jones \(1999\)](#) defined three context factors: *input* context factors, *purpose* context factors, and *output* context factors. This thesis utilises the context factors that are specified in [Sparck Jones \(1999\)](#) with a slight adaptation in regards to the output context factor named style, as can be seen below in the paragraph that is titled “Summarisation styles”.

*Input* context factors are concerned with the representation of documents that are used as a source to create a summary. Input context factors can be divided into source text forms, subject types, and units (Sparck Jones, 1999). Source text forms include information about the structure of the source text or the scale of a specific input file. The document structure includes, for instance, headings that are expected in a document, or rhetorical patterns that appear in a specific document type. The scale of an input document expresses the size of a specific input document. Subject types describe the presumed subject knowledge of the reader of a specific source text. The input factor ‘*unit*’ describes the number of input documents that are used to create a summary.

The context factor named *purpose* consists of information about the *audience* of a specific summary, a specific *use* of the summary, and the *situation* that a summary is used in. The *audience* describes the class of readers that a specific summary is intended for. The *purpose* context factor named *use* expresses where the summary will be used, such as for retrieving an overview of a specific topic. The *purpose* context factor *situation* defines whether a specific summary will only be used in a specific situation (tied) or whether a summary can be used in different contexts (floating).

Sparck Jones (1999) identified three major *output* factors, namely *material*, *format* and *styles*. *Output* factors describe properties of a specific summary (the output of a summarisation process). *Material* refers to the coverage of a specific summary. Some summaries, for instance, only capture a major concept whereas other summaries are more comprehensive. *Format* refers to the formatting of a specific summary. Some summaries might only consist of running text whereas others include headings or other tags. The third output context factor in Sparck Jones (1999) is the *style* of a summary, which will be discussed in the paragraph that is titled “Summarisation styles”.

Context factors inform the choice of the summarisation technique that is used to retrieve a certain kind of summary. Thus, context factors express important characteristics of the summarisation process, such as the level of detail or the number of documents that should be processed. Context factors also inform the choice of evaluation techniques that are suitable for a specific context as described in Section 2.4.5.

**Summarisation Styles:** This thesis utilises an adapted version of the *output* context factor in Sparck Jones (1999) that is called *style*. This adapted version introduces three subcategories of summary style context factors. These subcategories reflect important styles that are mentioned in Radev et al. (2002).

The three categories are: *organisational style*, *generation style*, and *transformation style*. The *organisation style* expresses how a specific summary should be organised and what information has to be expressed. The *generation style* is concerned with the technique that a specific summarisation approach utilises to generate a summary. Finally, the transformation style expresses how the source text should be transformed. The next paragraphs provide additional information about each category.

*Organisational styles* include indicative, informative, topic-oriented, and generic summaries. Indicative summaries express that a specific source text covers a specific topic without further describing the content of the source text(s). Informative summaries inform the reader of what the source text says about something. Topic-oriented summaries concentrate on a topic that a reader is interested in and generic (or critical) summaries summarise text from the author's point of view (Sparck Jones, 1999, Radev et al., 2002).

The *generation style* describes the technical aspect of how a summary has been generated. A summary can either be an abstractive summary or an extractive summary. Abstractive summaries are summaries that provide an abstract view of a specific text without using large parts of the original text. True abstractive summaries use terminology that is not explicitly mentioned in the source, whereas abstractive summaries consist of rephrased components that are mentioned in a specific text (Radev et al., 2002).

The *transformation style* of a specific summary is related to the *input* factor named *unit*. However, the difference between the context factor unit and the context factor *transformation style* is that the *transformation style* is related to the summary that is returned by the summarisation approach. One transformation style, for instance, is the aggregative *transformation style*, which means that multiple input documents are aggregated and a unified summary is returned that summarises multiple documents. Another transformation style could be the creation of a summary from multiple documents that only express similar elements.

This thesis focuses on abstractive summaries. Abstractive summaries that are proposed in this thesis utilise an aggregative style to combine information out of artefacts that appear in several publications. More information about the chosen summarisation style in this research can be found in [Chapter 4](#).

#### 2.4.4 Summarisation Techniques

This section introduces different summarisation techniques to provide an overview of automatic summarisation approaches and to highlight potential gaps.

Firstly, general summarisation techniques are discussed and categorised. Summarisation approaches can be categorised by using context factors, which are discussed in [Section 2.4.3.2](#). However, this section only discusses context factors that significantly influence current summarisation approaches. Secondly, techniques that are used in different process stages (see [Section 2.4.3](#)) are discussed. This discussion should highlight similarities and differences of different summarisation approaches and categories.

Although all context factors influence summarisation approaches to a certain extent, some context factors influence the choice of a suitable technique more than others. For instance, the context factor named *input unit* differentiates between one document vs. multiple documents and affects the correct choice of a summarisation technique. Single document summarisation techniques include processing stages that are significantly different to multiple documents summarisation techniques (see [Section 2.4.4.2](#)).

Another important context factor is the generation style of a summary. Abstractive summarisation techniques generate summaries without extracting large pieces of the document that has to be summarised. Extractive summarisation techniques output a set of ranked sentences. Thus, in comparison to extractive techniques, abstractive techniques include processes that generate summaries. Although the context factors ‘*use*’, ‘*situation*’, and ‘*audience*’ can influence a specific summariser, these context factors are currently not used to differentiate between summarisation techniques in the literature. However, that might change in the future because these context factors could influence summarisation approaches because of the different types of summaries that have to be produced when altering the *purpose* context factor that includes the context factors ‘*use*’, ‘*situation*’, and ‘*audience*’.

The following sections are divided into single and multiple document summarisation techniques. Following that, summarisation techniques are discussed that utilise abstractive techniques and summarisation techniques that utilise extractive techniques are delineated. This thesis focuses on abstractive, multi-document summarisers. Thus, this literature review focuses on such summarisers. However, to provide a comprehensive picture, single document and extractive summarisers are also discussed in this section.

Finally, evaluation techniques that are used to evaluate automatic summarisation approaches are highlighted, followed by a discussion of evaluation criteria (the 5Cs) that are used in the evaluation of automatic summarisation approaches.

#### 2.4.4.1 Single and Multi-Document Summarisation Approaches

Summarisers can be categorised into single-document and multi-document summarisers. This categorisation reflects the summarisation context factor named ‘input units’; as described in Section 2.4.3.2.

The differentiation between multi-document and single-document summarisation approaches also influences the output context factor named ‘transformation style’ (see Section 2.4.3.2). The output context factor ‘transformation style’ describes how the source text should be transformed into a summary. Usually, this context factor is more important in multi-document summarisers. In multi-document summarisers, the transformation style can be divided into, for instance, the transformation into aggregative summaries or the transformation into summaries that only expresses features that appear in all documents of the document set that has to be summarised. Single-document summarisation techniques usually only differentiate between organisation style features, such as the capability to create query-based summaries or informative summaries. Although the output style is an important context factor to describe a resulting summary, the general differentiation between multi-document and single document summaries that is expressed in the context factor *input unit* has a bigger influence on the processes that are involved in automatic summarisers.

Examples of extractive single-document summaries can be found in Hennig et al. (2008), Oliveira et al. (2016), and Sarker et al. (2016). Extractive multi-

document summarisers can be found in [Goldstein et al. \(2000\)](#), [Baralis et al. \(2013\)](#), [Wu et al. \(2013\)](#), [Atkinson and Munoz \(2013\)](#), [Christensen et al. \(2013\)](#), [Qiang et al. \(2016\)](#), [Marujo et al. \(2016\)](#), and [Canhasi and Kononenko \(2016\)](#). All mentioned approaches, except the approach that is described in [Marujo et al. \(2016\)](#), firstly create a model of the corpus of documents that have to be summarised, which includes one document in single document summarisers and more than one document in multi-document summarisers. The generated model, which represents the whole document corpus, is then used to identify the importance of the sentences that are expressed in the whole corpus.

[Marujo et al. \(2016\)](#) described one of the few approaches in the literature that firstly summarises each single document and then combines these single document summaries. [Marujo et al. \(2016\)](#) argued that this technique improves the detection of similar concepts in multiple documents. The complexity of identifying similar concepts is caused by the different writing styles of different authors. [Marujo et al. \(2016\)](#) also argued that the separation into a single document summarisation process followed by a multi-document summarisation process improves the performance of summarising multiple documents.

Abstractive multi-document summarisation approaches show a similar distribution to extractive multi-document summarisation approaches when comparing approaches that firstly process and generate a model out of each document and then aggregate these summaries and approaches that build one model out of the whole document set that should be included in a summary. For instance, the approaches that are proposed in [Sun et al. \(2016\)](#), [Rudra et al. \(2016\)](#), [Ganesan et al. \(2010\)](#), [Khan et al. \(2016\)](#), and [Lee et al. \(2005\)](#) are approaches that use the whole document collection to calculate a model of the source texts. All of these approaches generate graphs or trees that are used to identify paths or clusters that are used to generate summaries. These models often resemble algorithms that are also used in abstractive single-document summarisation approaches. Two abstractive single-document approaches that are presented in [Moawad and Aref \(2012\)](#) and [Balaji et al. \(2016\)](#) generate semantic graphs out of single documents before a reduced graph is extracted that can be used as a summary representation.

A few approaches, such as in [Gerani et al. \(2016\)](#), produce representations out of each document that has to be summarised. In [Gerani et al. \(2016\)](#), this representation is called an aspect hierarchy tree. After these aspect hierarchy trees are generated for each document, they are combined to generate a multi-document summary.

It can be said that generic summarisation models for multi-document summarisation approaches and single document summarisation approaches resemble each other if the corpus of documents that has to be summarised is treated as one document. These approaches generate a model that is transformed into a summary text model that can be used to create a summary.

As mentioned earlier, a few approaches generate single-document summary representations for all documents in the corpus. These single-document representations are then aggregated into a multi-document summary representation that can then be used to generate a summary. Such approaches are able to

cope with different writing styles. Different writing styles complicate the comparison of, for example, events that can be extracted out of a document, as highlighted in [Marujo et al. \(2016\)](#). Although the majority of approaches treat the whole document set that has to be summarised as one document, there are important reasons to split this process into a single document summarisation and multi-document summarisation stage.

#### 2.4.4.2 Extractive and Abstractive Summarisation Approaches

**Extractive Summarisation Approaches:** This thesis is concerned with the generation of abstractive multi-document summaries. However, techniques that are used in extractive approaches can also be used in abstractive approaches and are therefore of interest in this thesis.

Extractive summarisation approaches usually select sentences out of the original document and score them. The highest scoring sentences are then used to generate an extractive summary. Modern extractive approaches, such as in [Hennig et al. \(2008\)](#), [Sarker et al. \(2016\)](#), [Goldstein et al. \(2000\)](#), and [Oliveira et al. \(2016\)](#), utilise a variety of scores to select and sort sentences that are then returned as a summary.

Extractive approaches can use bag-of-word models or other statistical models, such as presented in [Goldstein et al. \(2000\)](#) and [Canhasi and Kononenko \(2016\)](#), to identify weights for terms or sentences ([Qiang et al., 2016](#)). These weights are then used to select and rank sentences. The highest ranked sentences are included in the generated summary.

Extractive approaches can make use of semantics to select sentences. Examples of such approaches can be found in [Oliveira et al. \(2016\)](#), [Hennig et al. \(2008\)](#), [Wu et al. \(2013\)](#), [Atkinson and Munoz \(2013\)](#), [Christensen et al. \(2013\)](#), and [Baralis et al. \(2013\)](#). Such approaches firstly generate a model of the source text. This model is then used to rank sentences and to identify the order of the highest ranked sentences in the summary.

Semantic techniques can improve the coherence of a generated extractive summary, as described in [Atkinson and Munoz \(2013\)](#). [Atkinson and Munoz \(2013\)](#), for instance, identified rhetorical roles of sentences, which help to create more coherent summaries. A machine learning approach is used to learn from a manually tagged corpus, which consists of 20,000 sentences. Some rhetorical roles that are used in the approach by [Atkinson and Munoz \(2013\)](#) are, for example cause, effect, problem, and solution. These rhetorical roles are used to create a logical chain of sentences that should present a coherent summary.

[Baralis et al. \(2013\)](#) proposed an extractive summarisation approach that utilises an ontology named YAGO and assigns concepts to sentences. The approach in [Baralis et al. \(2013\)](#) identifies named entities, generates a rank of these entities, and computes scores of these entities to process the rank of a specific sentence. A similar approach is described in [Wu et al. \(2013\)](#). [Wu et al. \(2013\)](#)'s approach utilises an ontology that is provided by domain experts, who also provide keywords to describe each concept in the ontology. These keywords are then used to identify concepts in the source documents. Once a concept can

be identified in a number of sentences in the source documents, these concepts are then used to rank sentences.

Finally, there exist pattern-based extractive summarisation techniques, such as in [Qiang et al. \(2016\)](#). In [Qiang et al. \(2016\)](#), closed patterns are used to identify the weight of a sentence. A closed pattern is a sequence pattern that is not included in another sequential pattern with exactly the same support. The support of a pattern is defined by the number of sentences that use a specific pattern. The more closed patterns can be found in a certain sentence and the higher the weight of such a closed pattern, the more important is a specific sentence. The weight of a closed pattern depends on the number of sentences that include a closed pattern and the number of documents that contain a specific pattern.

Many extractive summarisation techniques utilise semantics. However, all of these approaches only use semantics to calculate the weights of sentences. These weights are used to select and rank sentences that appear in an extractive summary.

**Abstractive Summarisation Approaches:** Abstractive summarisation techniques utilise similar techniques to identify and rank components of source texts as techniques that are used in extractive approaches to rank sentences. In fact, some abstractive approaches firstly rank sentences and then apply techniques, which are described below, to generate abstractive summaries. An example of such an approach can be found in [Sun et al. \(2016\)](#). In [Sun et al. \(2016\)](#), firstly events are extracted out of sentences. These events are used to calculate the similarity of sentences. The calculated similarities are then used to cluster sentences. Then a candidate sentence is selected out of each cluster. These candidates are then compressed to a summary sentence. The approach described in [Khan et al. \(2016\)](#) is another approach that firstly extracts sentences. This approach parses predicate argument structures out of sentences and generates semantic graphs that depict the relationships between the identified predicate argument structures. These graphs are then used to identify sub-graphs to generate a summary.

As can be seen in [Sun et al. \(2016\)](#), and [Khan et al. \(2016\)](#), a group of abstractive summarisers create models out of the sentence structure in the documents that have to be summarised, similar to extractive approaches. Many abstractive techniques identify sentences that should appear in a summary and then compress these sentences or fuse them with other sentences to generate a summary.

Even though there exist abstractive techniques that generate models that are not based on the sentence structure, most techniques extract sentences in the pre-processing stage. [Rudra et al. \(2016\)](#)'s approach, for instance, uses sentences, similarly to [Sun et al. \(2016\)](#), to extract events and concepts. However, [Rudra et al. \(2016\)](#)'s approach uses these events and concepts to build a graph and then utilise integer linear programming to optimise paths in the graph. These resulting graphs are then used to summarise a set of documents. In com-

parison to [Sun et al. \(2016\)](#), [Rudra et al. \(2016\)](#)'s approach does not identify sentences, but generates a model to identify salient components.

Most abstractive approaches generate, in comparison to extractive approaches, a model of the actual source text(s) that has/have to be summarised. The reason for that is that abstractive approaches do not just extract text out of source texts and then present this text as a summary. An abstractive approach needs to create an abstract that, preferably, consists of components that are not syntactically equivalent to the source text. One representation that is frequently used to model source texts are graphs, as can be seen in [Balaji et al. \(2016\)](#), [Moawad and Aref \(2012\)](#), [Gerani et al. \(2016\)](#), [Khan et al. \(2016\)](#), [Ganesan et al. \(2010\)](#), [Rudra et al. \(2016\)](#), and [Sun et al. \(2016\)](#) that are proposed in the literature.

In addition to graphs, there are two other techniques to generate models of source text, such as trees and formal ontologies.

Tree-based representations are essentially unidirectional graphs that only allow one single parent. Thus, approaches that use tree-based representations show similarities to graph-based abstractive approaches. For instance, [Gerani et al. \(2016\)](#)'s approach extracts a tree out of documents, combines these trees into a graph and then reduces this graph to a tree that represents the content that has to be summarised.

Ontology-based models utilise formal ontologies, which can also be expressed as a graph. One major difference to graph-based and tree-based models is that ontology-based models identify parts of a document that can be assigned to a certain concept that is expressed in an ontology. Such ontologies can support the summarisation process if the ontology expresses features that supports the summarisation process. Such features can be, for instance, domain-specific expressions. Examples of ontology-based approaches can be found in [Lee et al. \(2005\)](#), and in [Moawad and Aref \(2012\)](#). [Lee et al. \(2005\)](#)'s approach utilises a domain ontology that describes the domain that a specific summary should summarise. This domain knowledge supports the identification of concepts inside source texts. A domain ontology contains very domain specific concepts and relations. However, approaches, such as in [Lee et al. \(2005\)](#), can also be applied to other domains. However, other domains have to be firstly codified by experts to provide a domain ontology that fits the domain that has to be summarised. [Moawad and Aref \(2012\)](#) proposed an approach that utilises a domain ontology and makes use of a semantic graph to represent source texts. In [Moawad and Aref \(2012\)](#) the domain ontology is used to generate the summary.

**Abstractive Summarisation Techniques - Conclusion:** Abstractive techniques need to model source texts to generate abstractive summaries that do not reuse whole sentences or paragraphs out of the source texts. These source text representations are necessary to either generate sentences via sentence compression and/or sentence fusion. Additionally, these source text representations, in combination with another knowledge base, such as a domain ontology, enable the creation of summaries without the need to reuse the words in the source

texts. Thus, to provide true abstractive approaches, a second knowledge base is important. However, ontologies that are used in abstractive summarisation approaches in the literature can be very domain specific. Formal ontologies that are abstract enough to express a wide range of documents, such as core ontologies, are not discussed in extant summarisation approaches in the literature. Additionally, ontologies that describe core terminology that is discussed in publications that are summarised could support the summarisation process by providing concepts that can be used to generate natural language. However, such an ontology has not been researched yet. The approach that is described in this thesis proposes a set of ontologies that support this feature (see [Chapter 4](#)).

#### 2.4.4.3 Source Text Representations

Abstractive summarisation approaches, as well as most extractive summarisation approaches, create a model of the source text. Source text models support the identification of salient information in the source text. In abstractive approaches, such models can provide information to generate natural language text.

Abstractive as well as extractive summarisation approaches share the same types of source text models. The most common source text models are graph-based or tree-based representations. Other source text models utilise formal ontologies to represent source texts. The next paragraphs briefly introduce each of these approaches.

**Graph-Based Source Text Models:** Graph-based models are the most common source text representations in automatic summarisers.

To generate graph-based representations of source texts, the following steps are executed. The first step identifies the components that should be represented in the resulting graph. These components are extracted utilising the sentence structure in the source text. [Rudra et al. \(2016\)](#), for instance, extracted events and concepts out of sentences. Events are usually presented as verbs, and concepts are represented as nouns in the source text. Once events and concepts have been extracted, semantic similarities are calculated, which are then represented as weights along the edges that connect two vertices. [Sun et al. \(2016\)](#)'s approach also extracts events and clusters these events utilising a graph-based clustering algorithm. In comparison to [Rudra et al. \(2016\)](#), [Sun et al. \(2016\)](#)'s approach only utilises events in the source text model, but no concepts. The edges of the graph consist of weights that represent semantic similarity between two events. The resulting clusters are used to create candidate sentences. In comparison to [Rudra et al. \(2016\)](#), [Sun et al. \(2016\)](#)'s approach does not use the created graph to express a summary structure, but a clustered set of sentences.

Whereas [Rudra et al. \(2016\)](#) and [Sun et al. \(2016\)](#)'s approach assigns weights to edges that represent the similarity between two vertices, [Ganesan et al. \(2010\)](#)'s approach creates graphs that consist of words as vertices and directed edges represent the sentence structure.

[Khan et al. \(2016\)](#)'s approach extracts predicate argument structures. Predicate argument structures are identified utilising semantic role labelling. Each predicate argument structure represents a vertex in the graph and the edges represent semantic similarities. [Moawad and Aref \(2012\)](#)'s approach extracts verbs and nouns and assigns them to vertices in the graph and semantic and topological relations represent the edges of the graph.

As can be seen in the approaches above, most graph-based approaches, such as in [Rudra et al. \(2016\)](#), [Sun et al. \(2016\)](#), and [Khan et al. \(2016\)](#), build a graph that consists of events and concepts that are expressed as vertices. The edges often contain a weight that expresses the similarity between two vertices. These weights can be used to identify salient paths. [Ganesan et al. \(2010\)](#) chose the edges of a graph to express sentence dependencies to extract a coherent set of sentences.

Vertices and edges are extracted utilising natural language processing techniques. After the sentences have been identified, a part-of-speech tagger is used to identify the constituents of a specific sentence. With this information, the nouns and verbs of a specific sentence can be extracted. Some summarisation techniques, such as in [Sun et al. \(2016\)](#) and [Moawad and Aref \(2012\)](#), also use a dependency parser. A dependency parser identifies how specific components or terms are related to other terms in a sentence. A dependency parser is capable of, for instance, identifying subjects, objects, and predicates of a specific sentence. Once these structures have been identified, similarities can be calculated and a graph can be created.

**Tree-Based Approaches:** [Gerani et al. \(2016\)](#) generated tree-based source text representations. This approach utilises a rhetorical model to reveal the rhetorical structure of a text. The rhetorical model should support the identification of rhetorical relations, such as elaboration, explanation, or background. However, [Gerani et al. \(2016\)](#) also implemented a conceptual model in the case that not enough rhetorical relations have been extracted. The generated tree consists of elementary discourse units as vertices and rhetorical relations as edges. Elementary discourse units differentiate between nuclei and satellites. A nucleus is important for conveying the authors' message whereas satellites are less important.

**Ontology-Based Approaches:** Ontology-based approaches utilise ontologies in the source text representation stage. Ontologies guide the source text extraction process. In [Lee et al. \(2005\)](#), an ontology is used to assign concepts that have been identified in the text. [Lee et al. \(2005\)](#) use a dictionary that is constructed by domain experts to identify domain related concepts in the text. Part-of-speech elements are compared to the domain dictionary to identify important terms. [Baralis et al. \(2013\)](#) proposed another ontology-based approach that utilises an ontology that is named YAGO. YAGO is an ontological knowledge-base. [Baralis et al. \(2013\)](#)'s approach assigns concepts to each sentence in the source text. Relations between sentences and concepts are iden-

tified by utilising entity recognition and disambiguation. [Wu et al. \(2013\)](#) also assigned concepts to sentences. The approach in [Wu et al. \(2013\)](#) requires an ontology that contains keywords for each concept that is represented in the ontology. These keywords have to be created by experts. [Hennig et al. \(2008\)](#) built an ontology that is populated with bag-of-words that are constructed from a web search. [Hennig et al. \(2008\)](#)'s approach utilises an ontology that is not domain specific. The authors used the DMOZ taxonomy and created bag-of-words models of the first two levels in the DMOZ taxonomy.

**Source Text Representations - Conclusion:** Most summarisation techniques model the source text before a summary representation is created. These models use graph-based, ontology-based, and tree-based representations. Graph-based approaches belong to the most common source text modelling approaches. However, ontologies and other external knowledge-bases can enhance the summary generation process by providing an additional knowledge base that can support the text generation process. If true abstractive summaries should be provided, a secondary knowledge base is needed to avoid the reuse of components of the source text.

The major challenge in generating ontologies is to assign concepts to either words or sentences in the source text. Keywords that express a certain concept, named entity recognition, or the use of a dictionary can provide more abstract representations to generate true abstractive summaries. However, entity recognition techniques are only capable of identifying a very restricted set of concepts. Keyword or dictionary based techniques, on the other hand, belong to a pre-defined knowledge-base that is expressive enough to paraphrase a concept.

#### 2.4.4.4 Summary Text Representation

Once the source text has been analysed and translated into a simplified model without losing the expressiveness that is necessary to properly summarise the source text, this source text model has to be reduced to a summary model.

The transformation from a text model to a summary model usually consists of a clustering process to identify repetitive components. [Sun et al. \(2016\)](#) propose a clustering technique that uses feature vectors to represent events. A graph-based clustering technique calculates event clusters. [Khan et al. \(2016\)](#)'s approach clusters predicate argument structures with the help of a semantic similarity matrix and WordNet.

Once clusters have been identified, each cluster has to be represented by a text that summarises this cluster. Selected clusters and their representative text, which can be, for instance a sentence ([Sun et al., 2016](#)) or a path in a graph ([Ganesan et al., 2010](#)), are then transformed into sentences of the summary.

Extractive approaches do not need a summary text representation as long as salient sentences can be identified in the text representation model. However, a summary representation can support the identification of sentences that should be included in a summary, such as in [Atkinson and Munoz \(2013\)](#) and [Hennig](#)

et al. (2008). In Christensen et al. (2013), another extractive approach, the summary representation is used to identify coherent sentences.

#### 2.4.4.5 Summary Generation

Extractive summarisation approaches generate summaries by identifying and ranking salient sentences. Abstractive approaches generate natural language text.

In extractive approaches, extracted sentences have to relate to the topic of the summary. Extracted sentences also need to fit within neighbouring sentences to provide coherent summaries. In the summarisation of multiple documents, the identification of salient sentences is complicated due to different writing styles. Finally, a summary should fit a rhetorical structure to provide a coherent summary.

Abstractive summarisation approaches do not consist of a number of sentences that are extracted out of the source text, but should consist of text that has to be generated using natural language generation techniques. Natural language generation includes three tasks: lexicalisation, choosing linguistic resources, and the realisation of a summary (McDonald, 2010).

**Lexicalisation:** Lexicalisation is the first step in natural language generation. The lexicalisation process identifies lexemes for concepts or events that are stored in the summary representation (Bouayad-Agha et al., 2012). Sun et al. (2016), for instance, produce a set of candidate sentences that represent a specific event that has been identified earlier. Out of these candidate sentences word graphs are constructed that store lexemes. Rudra et al. (2016) propose another abstractive technique that identifies tweet paths that correspond to events that have been extracted earlier. Khan et al. (2016) utilised predicate argument structures and their relations to identify salient predicate argument structures. In the lexicalisation process, similar predicate argument structures are merged to identify lexemes.

**Choice of Linguistic Resource:** Linguistic resources serve as knowledge-bases that are used to generate sentences. True abstractive approaches often rely on linguistic resources to avoid reusing text out of the source document. These linguistic resources lead to a surface structure to realise sentences in the summary.

Moawad and Aref (2012), for instance, used WordNet to select synonyms for concepts that are stored in a semantic graph.

However, not all abstractive approaches use linguistic resources. Rudra et al. (2016), for instance, identified paths in existing sentences. These paths are used to generate summaries. Thus, linguistic resources are not necessary to create a summary. However, techniques that do not need a lexicalisation process are not true abstractive summarisation techniques because such summaries solely contain words that were already present in the source text. This also includes

abstractive approaches that utilise sentence compression and sentence fusion techniques, such as in [Sun et al. \(2016\)](#), and [Khan et al. \(2016\)](#).

Domain ontologies, WordNet, or dictionaries are used as linguistic resources. Linguistic resources have to provide the capability to map concepts to lexemes. Lexemes are then transformed to sentences in the summary realisation process.

**Summary Realisation:** The summary realisation process uses summary representations and generated lexemes (if applicable) and applies one of the following summary realisation approaches. A summary can be realised utilising template-based techniques, rule-based techniques, graph path-based techniques, and sentence compression and/or fusion techniques.

A template-based approach can be found in [Gerani et al. \(2016\)](#). Sentence realisation templates are often domain specific. In [Gerani et al. \(2016\)](#), for instance, the sample templates are specific for reviews. Such templates often contain rules to generate grammatically correct sentences and to maintain coherence.

In comparison to template-based approaches that also include rules to generate template-based sentences, there are also fully rule-based techniques. [Khan et al. \(2016\)](#) proposed a rule-base technique to create an abstract summary. This rule-base technique utilises extracted predicate argument structures and applies rules to generate sentences using the predicate argument structures. Another rule-based approach can be found in [Moawad and Aref \(2012\)](#). [Moawad and Aref \(2012\)](#)'s approach takes the output of the lexicalisation process, builds a discourse structure by applying rules to create a specific sentence, and aggregates them into paragraphs. These paragraphs are then transformed into grammatically correct sentences.

[Rudra et al. \(2016\)](#), applied a graph-based method. This graph-based method takes a certain path that has been extracted out of sentences in the source text to generate a summary sentence. [Balaji et al. \(2016\)](#) proposed another graph-based method that utilises a semantic graph to create summaries

Sentence compression and/or sentence fusion techniques can be used to generate summaries. Examples of such techniques can be found in [Sun et al. \(2016\)](#). Even though sentence compression and fusion techniques result in sentences that consist of vocabulary that is present in the source text, the generated sentences are not present in the source text.

**Summary Generation - Conclusion:** The generation of abstractive summaries includes three tasks (lexicalisation, choice of linguistic resources, and summary realisation). However, all three tasks are only necessary in true abstractive summaries. Other abstractive approaches that, for instance, use sentence compression and/or sentence fusion only rely on the summary realisation step because the vocabulary of the original documents is used.

The lexicalisation process and the selection of linguistic resources task usually include external knowledge bases. The lexicalisation process outputs lexemes that are related to previously identified concepts in the source text. An

ontology that includes instances of the stored concepts can be used for such tasks.

The process of the selection of linguistic resources identifies particular words and syntactic constructions, as well as morphological variations (McDonald, 2010). This process relies on information that includes rhetorical, as well as structural information. Rhetorical and structural information are necessary to identify how the sentences are organised. Although ontologies can and are used to perform this task, ontologies do not describe how summaries can be structured or the rhetorical information that is necessary in the summarisation process.

#### 2.4.4.6 Summarisation Techniques - Conclusion

The specification of context factors in automatic summarisation techniques guide the choice of suitable summarisation approaches. However, the differentiation between single and multi-document summaries, and the differentiation between abstractive and extractive techniques are the most important distinguishing features in summarisation approaches in the literature.

Although there is a clear differentiation between single and multi-document summarisation approaches, the techniques that are used in both approaches do not differentiate significantly if all documents in a multi-document summarisation approach are treated as one document. Nevertheless, although rarely discussed in the literature, the separation into a single document summarisation stage and a multi-document summarisation stage can enhance the summarisation process. In particular, different writing styles complicate the identification and comparison of similar concepts if they were not previously assigned to a general set of concepts, which can be achieved in a single document summarisation stage.

Differences between extractive and abstractive techniques are apparent in the summary generation phase. In extractive techniques, summaries consist of salient sentences to provide a concise, but coherent summary. In abstractive approaches, another set of tasks need to be executed to generate an abstractive summary. True abstractive summaries enable the provision of coherent and concise summaries without repeating sentences in the original text. An important step in the generation of abstractive summaries is the choice of linguistic resources. Ontologies that describe core concepts that should appear in a summary could support the summary generation process by providing a guideline for the summarisation process. Although there exists literature that includes ontologies in this process, the support of an ontology that guides the summarisation process is not yet present in the literature.

#### 2.4.5 Evaluation of Automated Summaries

Research demands rigorous evaluation. This section reflects on evaluation techniques that are proposed in the field of automatic summarisation. The evaluation techniques that are discussed in this thesis only assess efficacy and effectiveness criteria. The artefact that is discussed in this thesis has not been

evaluated in terms of efficiency criteria and a discussion of such criteria and techniques has not been included in this thesis.

Firstly, a categorisation of evaluation techniques is proposed, followed by a discussion of each category. Out of this discussion, a set of requirements can be identified that automatic summarisation techniques should fulfil. These requirements result in the 5Cs that are used to evaluate the artefact that is presented in this thesis.

Summaries can be evaluated intrinsically or extrinsically, automatically or manually, and in terms of informativeness or quality (Lloret and Palomar, 2012b). Sparck Jones (1999) also highlighted that the evaluation of context factors that define a specific summarisation approach is of high importance.

**Intrinsic vs. Extrinsic Evaluation:** Intrinsic summarisation evaluation techniques assess summaries in regards to their information content. Extrinsic evaluation techniques determine the summary's effectiveness in other applications. Whether to choose intrinsic or extrinsic evaluations highly depends on context factors (see Section 2.4.3.2 for a discussion on context factors). In particular, the context factor named 'purpose' influences the choice of the correct extrinsic evaluation technique. Audience, use, and situation are three purpose context factors that all influence the extrinsic quality of a summary.

A summary needs to be tailored to the audience that reads this summary (Sparck Jones, 1999). A layman expects a different depth of the generated summary in comparison to an expert who would like to read a summary about a topic within his or her profession. However, the use of a summary also expects different types of summaries. If a summary should provide an overview of search results in a search engine, an expert as well as a layman might only be interested in a summary that mentions the most important concepts and maybe a comparison of them. In this case, the covered depth of the topic in the summary is independent of the audience.

The last context factor that belongs to the context factor purpose is the situation in which a summary is used. The context factor situation, as discussed in Section 2.4.3.2, identifies whether a summary will be used in a specific situation or whether it can also be used in other contexts. If the context can change, the summary should adapt to the actual situation (Sparck Jones, 1999).

To summarise, extrinsic evaluations are important for summarisation techniques that are tailored to a specific purpose. If a summarisation technique is tailored to a specific purpose, all purpose context factors have to be taken into consideration.

Extrinsic evaluations consider the purpose of a specific summarisation approach or summary. An important purpose context factor in summarisation approaches is the audience that a specific summarisation approach is intended for. Because the audience is an important factor, a manual evaluation or an automatic evaluation that utilises gold standards has to be designed. A gold standard should be provided by the audience that a specific summary is intended for.

In comparison to extrinsic evaluations, intrinsic evaluations are used in any context and for most summarisation approaches. Extrinsic evaluations are not necessary if the purpose cannot or has not been identified properly.

There are many summarisation approaches in the literature that generate informative summaries, such as in [Khan et al. \(2016\)](#), [Lee et al. \(2005\)](#), [Moawad and Aref \(2012\)](#), [Balaji et al. \(2016\)](#), and [Qiang et al. \(2016\)](#). Such techniques do not need extrinsic evaluations unless the purpose of the summary has been clearly defined. However, intrinsic evaluations are important because the quality of the information content is crucial.

Additionally, many summarisation approaches are mainly evaluated in terms of intrinsic features because these approaches were evaluated by using corpora that were provided for the Document Understanding Conferences (DUC). One reason for using such corpora is that it is possible to retrieve reproducible evaluation results. However, there are a number of features, especially extrinsic features, that cannot be evaluated using such an approach.

**Automatic vs. Manual Evaluation:** Automatic evaluations often produce more reliable and reproducible results. Additionally, automatic evaluation techniques are more objective than manual evaluation techniques. Most automatic evaluation techniques use the recall-oriented ROUGE technique ([Lin, 2004](#)). This technique compares a generated summary with a hand-written gold standard. This gold standard has to be prepared diligently to reduce the subjectivity of the evaluation result. It measures the number of overlapping units between the gold standard and the summary that needs to be evaluated.

Fully manual evaluation techniques suffer from the subjectivity of test candidates. Additionally, as mentioned in [Lin \(2004\)](#), the time needed to manually evaluate summarisation techniques, as it is done in the Document Understanding Conferences, would be about 3,000 man hours ([Lin, 2004](#)).

Although the evaluation of some intrinsic qualities can be achieved by utilising automatic evaluation techniques, some features can only be evaluated manually. One of them is whether a summary fits a specific context for a specific audience. Other quality aspects in summaries are the presence of tautological sentences, rupture of textual sentences, or linguistic quality criteria, such as non-redundancy, structure, coherence, and focus ([Lloret and Palomar, 2012b](#)). Such features currently have to be evaluated manually.

**Informativeness vs. Quality:** The informativeness of a summary is related to the coverage that is expected by a specific summarisation technique.

Informativeness can be evaluated using quantitative approaches or qualitative approaches. Metrics that are used in quantitative approaches are precision, recall, and the F-measure. A high number of publications in this field use the recall-oriented ROUGE technique ([Lin, 2004](#)) to identify the informativeness of a summary. However, qualitative features, as mentioned in the previous subsection titled “Automatic vs. manual evaluation”, can currently not be evaluated reliably using automatic approaches. [Rudra et al. \(2016\)](#) evaluated summarisation

sation approaches manually by handing out surveys that evaluated information coverage, diversity, and readability. Christensen et al. (2013) evaluated summaries in regards to a gold summary.

Thus, manual evaluation techniques are required to evaluate automatic summarisation approaches.

**Evaluation Criteria:** Summaries can be evaluated regarding the informativeness and the quality of a specific summary (Lloret and Palomar, 2012b), as well as in regards to purpose context factors (Sparck Jones, 1999).

These criteria can be further divided as follows. Murray et al. (2010), for instance, identified the following criteria: general comprehension, coherence, readability, and perceived relevance. All of these criteria, except the perceived relevance of a summary, which is an informativeness criterion, are quality criteria, whereas perceived relevance relates to the context factor *purpose*. Additionally, the identification of tautological sentences and the rupture of textual sentences are also quality criteria that are mentioned in Lloret and Palomar (2012b).

Informativeness expresses whether all concepts are covered that are expected in a specific approach. Whether all concepts are covered properly in the summary varies significantly, depending on context factors.

**The 5Cs:** The literature of summarisation evaluation techniques show that most evaluations evaluate the informativeness aspect by using the ROUGE technique. The ROUGE technique identifies whether concepts that are expected in a specific summary, are included in the summary. This technique can be assigned to the criterion of comprehensiveness.

The quality criteria ‘general comprehension’, ‘coherence’, and ‘readability’ can be translated as follows. To generally comprehend a summary, it has to be written clearly. Thus, the criterion clarity can be assigned to the criterion of general comprehension. Additionally, a summary can only be understood if the summary is also written coherently.

A summary should only contain information that is needed for a certain purpose, which means that the perceived relevance has to be evaluated.

A summary, as discussed in Radev et al. (2002), has to be less than 50% of the original text, which means that a summary has to be concise.

Finally, to fulfil the purpose of a specific summary, the information has to be correct to be of any use.

This results in the 5Cs that a summary should inherit: Comprehensiveness, Clarity, Coherence, Conciseness, and Correctness.

#### 2.4.6 Automatic Summarisation - Reflection and Conclusion

This section outlined the extant literature about the topic of automatic summarisation of texts.

Firstly, definitions of the terms ‘summary’ and ‘summarisation’ introduced the topic of automatic summarisation. Further, the significance of automatic summarisation was briefly highlighted as a research motivation.

The categorisation of summarisation approaches outlined the difference between abstractive and extractive techniques by also delineating and amending the process model in Sparck Jones (1999) with the natural language process model in Bouayad-Agha et al. (2012) and McDonald (2010).

Additionally, context factors in automatic summarisation that are proposed in Sparck Jones (1999) defined important factors that have to be considered in designing summarisation approaches. However, it was also outlined that some context factors are more important than others by analysing automatic summarisation literature.

Different summarisation techniques highlight similarities but also differences in automatic summarisation techniques. It can be inferred that, although there are many similarities in single and multi-document approaches, multi-document summarisation models that firstly treat each document before all single-document representations are combined might have advantages to approaches that treat all documents as one document.

Additionally, the use of ontologies that describe the main concepts or components of a summary could improve the natural language generation process.

Finally, the following evaluation criteria for automatic summarisation approaches, also called the 5Cs in this thesis (Comprehensiveness, Clarity, Coherence, Conciseness, and Correctness) were identified out of extant evaluation techniques in the literature.

## 2.5 Design Science Research

This section covers the research paradigm ‘design science research (DSR)’. There are two reasons to introduce DSR in this publication. Firstly, the proposed architecture (DSRCRSA) focuses on the formalised representation and the automatic summarisation of DSR publication content. Secondly, the research that is presented in this thesis follows the DSR paradigm.

As discussed in [Chapter 1](#), this thesis focuses on the summarisation of DSR publication content. DSR has been chosen because DSR is concerned with the invention and evaluation of purposeful artefacts that address a general problem. In the applied sciences, many publications discuss artefacts to solve general problems. Additionally, this work focuses on DSR publications to limit the scope of this research, but also to potentially include many types of publications, which might also be of interest to a larger group of people. DSR publications might not only be of interest to researchers, but also to lecturers and practitioners. Practitioners in particular can make use of a concise representation of an artefact that is presented in a DSR publication.

Section [2.5.1](#) defines DSR. Section [2.5.2](#) differentiates research and development to separate DSR from standard development processes. Section [2.5.3](#) discusses prescriptive and descriptive design knowledge. Section [2.5.4](#) highlights design theories and discusses important components of a design theory, which are an important output of DSR. Following that, Section [2.5.5](#) discusses DSR concepts in the literature, before Section [2.5.6](#) defines salient DSR concepts that should appear in DSR publications. Finally, Section [2.5.7](#) briefly highlights the DSR methodologies that informed the selection of the research methodology applied to the research that is presented in this thesis.

### 2.5.1 Definition of DSR

DSR is a research paradigm in the field of information systems that has recently been re-emphasised to increase the rigour in carrying out DSR research projects. However, DSR can be applied to any field that designs and evaluates purposeful artefacts ([Venable, 2010b](#)). The Sciences of the Artificial ([Simon, 1996](#)), which was first published in 1969, influenced the foundation of the DSR paradigm ([Hevner et al., 2004](#)).

DSR is a research paradigm that is concerned with the design of purposeful artefacts. [Venable and Baskerville \(2012, p. 142\)](#) defined DSR as “research that invents a new purposeful artefact to address a generalised type of problem and evaluates its utility for solving problems of that type”.

One of the main differences between DSR and other research paradigms is that DSR researches the utility of a generalisable solution whereas behavioural science paradigms research the truth of a specific hypothesis to understand how the world works and to predict how it will behave by altering independent variables.

Design science tries “to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts” ([Hevner et al., 2004, p.](#)

75).

### 2.5.2 Research vs. Development

DSR has often been compared with standard design processes that result in a novel product. Proponents of DSR argue that the generalisability of a specific problem to a class of problems or the development of a design theory indicates the research intent of DSR. Generalisability, novelty of the designed artefact, and significance of the designed artefact are the main research contributions in DSR (Hevner et al., 2004). Other proponents of DSR state that prescribing a design theory is the main research contribution of DSR (Gregor, 2006).

Thus, the main differentiator to other research paradigms is the research of new means to solve problems or make improvements. These new means (purposeful artefacts) should be generalisable. Additionally, design theories can be built that include knowledge about the purposeful artefact, together with a description of its utility. In addition to that, the designed artefact has to be significant and novel.

Artefacts that are developed in industry should be novel in a certain aspect to attract the attention of a customer. Artefacts that are developed in industry should also have practical significance, otherwise people might not want to buy a certain product. Generalisability and the development of a design theory are research specific components. Additionally, theoretical significance and contribution to knowledge does not have to be included in a standard development process. A rigorous evaluation is another research aspect that is not necessarily included in the development process in industry.

However, many successful companies include research departments. For instance, if a company wants to develop a specific product, a development strategy might be researched that does not exist yet.

### 2.5.3 Prescriptive Knowledge vs. Descriptive Knowledge

Gregor and Hevner (2013) divided useful knowledge that can be created in a DSR process into two groups of knowledge:  $\Lambda$  - knowledge (prescriptive) and  $\Omega$  - knowledge (descriptive). Descriptive knowledge is based on observations and classification of phenomena and can be used for sense-making (natural laws, principles, patterns, theories). Constructs, models, methods, instantiations, and design theories make up prescriptive knowledge that result out of a DSR process. Models and methods include prescriptive statements that prescribe how an artefact should behave (models) or be built (methods). Design theories can include prescriptive statements that discuss how a generalised problem could be solved.

Some proponents of DSR limit DSR to the creation of prescriptive knowledge (Walls et al., 1992). Many DSR proponents agree that prescriptive knowledge is undoubtedly an integral component of DSR. However, descriptive knowledge

has gained acceptance as a research outcome of DSR as can be read in [Vaishnavi and Kuechler \(2004\)](#), and [Vaishnavi and Kuechler \(2015\)](#).

Descriptive knowledge can be a research outcome of a DSR project. An example would be to research whether humans are more productive in computer work when they are standing instead of sitting on a chair. This descriptive knowledge can then be translated into an artefact that incorporates the descriptive knowledge that has been generated beforehand. The prescriptive statement would be “to be more productive in computer work, stand”.

Even though descriptive knowledge can also be generated in DSR, DSR should always generate prescriptive knowledge. Whether descriptive knowledge can be published together with prescriptive knowledge depends on, for instance, how much someone wants to underpin the practical significance of the author’s theory. Practical significance can be generated by conducting studies that answer the question of whether someone should stand whilst working on a computer. This would provide practical significance for, for instance, an artefact (a desk) that is capable of changing in height.

#### 2.5.4 Design Theory

[Gregor and Jones \(2007\)](#) proposed the anatomy of a design theory that includes a synthesis of [Dubin \(1978\)](#) and [Walls et al. \(1992\)](#). This section discusses this synthesis and concludes with important DSR concepts that are related to a design theory in DSR. Then, Section 2.5.5 discusses and provides definitions for universally used DSR concepts, while also including design theory concepts that have been discussed in this section. Design theory is an important output of a DSR project. Thus, this section discusses the components of a design theory separately.

The anatomy of a design theory is exhaustively covered in [Gregor and Jones \(2007\)](#). This section provides an overview of the main components of a design theory to further highlight that the components of a design theory describe in large part the main concepts in DSR.

[Gregor \(2006\)](#) stated five types of theory in information systems (analysis, explanation, prediction, explanation and prediction, and design and action). These five types include a combination of the following primary goals of a theory: analysis and description, explanation, prediction, and prescription. The primary goal of the theory of design and action is prescription - the fifth type of theory in [Gregor \(2006\)](#). A prescriptive theory describes the method or structure (or both) of an artefact. A primary goal of many IS research projects is to prescribe the construction of an artefact. However, prescriptive statements about the use of a specific artefact in a certain scenario or to achieve a certain goal can also be assigned to theories of design and action.

Design theory is entailed by the theory of design and action ([Gregor, 2006](#)). The theory of design and action is composed of eight components: “purpose and scope, constructs, principles of form and function, artefact mutability, testable propositions, justificatory knowledge, principles of implementation, and expository instantiation” ([Gregor and Jones, 2007](#)).

The following subsections discuss the eight components that a design theory consists of, according to [Gregor and Jones \(2007\)](#). Additionally, this section concludes by delineating DSR components that are included in a design theory.

#### 2.5.4.1 Purpose and Scope

Purpose and scope are defined in [Gregor and Jones \(2007\)](#) as a set of meta-requirements that specify the type of artefact. These meta-requirements also define the scope or the boundary of a design theory ([Gregor and Jones, 2007](#)). The design theory itself applies to artefacts that fulfil a specific set of meta-requirements ([Walls et al., 1992, 2004](#)).

Purpose and scope are properties that describe a specific artefact. Thus, purpose and scope are not only important aspects of a design theory, but an important aspect of DSR in general.

The concepts purpose and scope can be used interchangeably for meta-requirements that prescribe how to solve a generalised problem. Such prescriptions might influence the scope of a specific artefact. However, there might be features that a specific artefact inherits that are not defined as a requirement. However, there also exist prescriptions of the scope of an artefact that restrict the scope of an artefact, but are not related to the purpose of a specific artefact. An example of such a prescription would be the use of electric engines, which would not alter the purpose of a car, which is to get from A to B. Thus, the concept ‘scope’ and the concept purpose only overlap to a certain extent.

#### 2.5.4.2 Constructs

Constructs are “representations of the entities of interest in the theory” ([Gregor and Jones, 2007](#), p. 322). Such entities can be physical phenomena or abstract theoretical terms. [Walls et al. \(1992\)](#) described constructs as verbal descriptions of bipolar dimensions.

Thus, constructs are statements that a design theory uses, for instance, to categorise a specific outcome. Constructs are the building blocks of a design theory, a design product, a design method, or can be used to describe aspects of the purpose and scope.

#### 2.5.4.3 Principle of Form and Function

Principles describe the form and function of an artefact. Principles are an “abstract blueprint or architecture that describe an IS artifact” ([Gregor and Jones, 2007](#), p. 322).

Principles of form and function describe important aspects of a specific artefact. The difference between principles and constructs are that constructs are the building blocks that can be used to describe principles.

#### 2.5.4.4 Artefact Mutability

Artefacts might be changed over time. [Gregor and Jones \(2007\)](#) proposed two examples to explain artefact mutability. However, these two examples are distinct from each other. The examples are as follows: “The designers consider the effects of team learning that occur over multiple construction cycles and show how the policy will vary over a number of cycles.” The second example from [Gregor and Jones \(2007\)](#) is as follows: “Suggestions for improving the approach are given for further work: one example is that parts of the approach could be packaged as a self-guiding computer-based system.”

These two examples of artefact mutations cover two distinct features. The first example discusses mutations of an artefact during a single research project. In the proposed example the artefact design is designed over multiple construction cycles. The second example states future research opportunities. However, this is usually not a component of a research project, but a set of research ideas that can be added to the conclusion of a DSR publication.

Artefact mutability, as proposed in [Gregor and Jones \(2007\)](#), is a component that can also be expressed as a principle of form and function by adding constraints to either the form or the function of an artefact.

#### 2.5.4.5 Testable Propositions

Testable propositions are “truth statements about the design theory” ([Gregor and Jones, 2007](#), p. 322). A design theory has to be evaluated. Truth statements about a design theory can support the process of validating a specific scenario. However, such truth statements can also be expressed as a set of meta-requirements because meta-requirements have to be testable propositions by definition. A requirement has to be falsifiable to test whether a requirement has been fulfilled.

#### 2.5.4.6 Justificatory Knowledge

[Gregor and Jones \(2007\)](#) disagreed with [Venable \(2006\)](#)’s proposal that justificatory knowledge (also called kernel theories) are optional components. [Gregor and Jones \(2007\)](#) stated that justificatory knowledge is important to provide a basis for the chosen design. However, not all designs need to depend on a specific kernel theory. For instance, an approach to design relational databases does not necessarily need a kernel theory to support the development of a design realisation. This approach only needs to show utility towards the storage and retrieval of data. However, kernel theories can be used to justify that such a relational database can be built by referring to a kernel theory that shows that data can be stored in a relational structure in a computer.

#### 2.5.4.7 Principles of Implementation

“Principles of implementation describe a process for implementing the theory in a specific context” ([Gregor and Jones, 2007](#), p. 322). Principles of implementa-

tion relate to the concept ‘design-method’ in [Walls et al. \(1992\)](#). Principles are important outputs of a DSR process. Principles should be defined at a high level of abstraction to be applicable to a class of problems. Principles incorporate the prescriptive nature of DSR.

#### 2.5.4.8 Expository Instantiation

Expository instantiations are materialised artefacts that are not considered as a necessary part of a design theory ([Gregor and Jones, 2007](#)). However, materialised artefacts can support the justification of a specific design theory. Whereas a materialised artefact can support the evaluation of a design theory, there are also other ways to do that. [Gregor and Jones \(2007\)](#), for instance, proposed the creation of mock-ups of real systems.

#### 2.5.4.9 Design Theory - Conclusion

The eight components of a design theory (that are proposed in [Gregor and Jones \(2007\)](#)) are components that can also be applied to DSR in general. Purpose and scope, constructs, principles of form and function, principles of implementation and justificatory knowledge are important concepts of any DSR project.

Artefact mutability, testable propositions, and expository instantiations are identified in this thesis as optional components to describe a design theory or to specify an artefact design. Artefact mutability can be described by altering the purpose or scope of a design theory. However, mostly, artefact mutability is expressed by updated artefacts that are described in several DSR publications or DSR projects. Thus, in this thesis, artefact mutability does not have to be explicitly expressed. Testable propositions can express the requirements of an artefact design. Thus, testable propositions do not have to be used in the context of this research. An expository instantiation realises a specific artefact design. Such expository instantiations are often used to evaluate the utility of a specific artefact. However, there are other means that can be used to provide evidence for the utility of a specific artefact. Nevertheless, the concept ‘expository instantiation’ serves as an important DSR concept in this thesis because many artefact designs are evaluated by utilising expository instantiations. Additionally, expository instantiations (also called specific solutions) are integrated in a step of the soft design science methodology that was proposed in [Pries-Heje et al. \(2014\)](#).

### 2.5.5 Synthesis of DSR Concepts

Section 2.5.4 concluded that concepts, such as purpose and scope, constructs, principles of form and function, and principles of implementation have to be covered in DSR conceptualisations. Justificatory knowledge (kernel theory) was identified as an optional component. All these concepts revolve around an artefact design. Whereas the previous section discussed the components of a ‘design

theory' as synthesised in [Gregor and Jones \(2007\)](#) and showed that design theory components include concepts that need to be covered in DSR work, this section consists of a synthesis of DSR concepts from the literature.

This section discusses important DSR concepts and different interpretations of these concepts. Section 2.5.6 then defines DSR concepts that are salient for DSR publications.

### 2.5.5.1 Design

The term 'design' can be interpreted as a noun or a verb.

[Walls et al. \(1992, p. 36\)](#) utilised the definition of the concept 'design' that was proposed by [Fielden \(1975\)](#): Design is the "use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency." This definition defines 'design' as a verb.

The noun 'design' is composed of a number of constructs that define the structure of a specific system or constructs that describe the process to design a specific artefact.

Design is a component that is evident in every DSR publication. A design can be expressed as an artefact. Section 2.5.5.2 introduces two artefact designs: the design product and the design method that reflect the interpretations of 'design' as a noun and 'design' as a verb respectively.

### 2.5.5.2 Design Product vs. Design Method

[Walls et al. \(1992\)](#) stated that a design theory has to be comprised of two aspects and seven components. The first aspect is concerned with the design product, which fulfils a set of meta-requirements and implements a specific meta-design. The second aspect is concerned with the design method that describes a way to create a specific artefact (i.e., to instantiate the meta-design).

[Gregor and Jones \(2007\)](#) used these two aspects to provide a basis for the design theory components that were described in the anatomy of a design theory.

[Gregor and Jones \(2007\)](#) adopted and extended [Walls et al. \(1992\)](#)'s definition of a design theory. [Gregor and Jones \(2007\)](#) mapped the component 'purpose and scope' to meta-requirements in [Walls et al. \(1992\)](#). The design theory component 'principles of form and function' ([Gregor and Jones, 2007](#)) relates to the concept meta-design that was proposed in [Walls et al. \(1992\)](#). A design product includes the components meta-requirement and meta-design. The component 'principles of implementation' ([Gregor and Jones, 2007](#)) refers to the concept design-method in [Walls et al. \(1992\)](#). Constructs, as presented in [Gregor and Jones \(2007\)](#), provide the concepts that are needed to describe the design product as well as the design method.

[Walls et al. \(1992\)](#) as well as [Gregor and Jones \(2007\)](#) agreed on the differentiation of design product and design method. Additionally, both agreed that these two aspects are major aspects in DSR.

### 2.5.5.3 Kernel Theory

Design-products and design-methods can be supported by kernel theories. Kernel theories inform the design process and the design of requirements (Walls et al., 1992). However, in this thesis, kernel theories can also be used to inform the design product in general.

Walls et al. (1992) and Gregor and Jones (2007) stated that kernel theories are a compulsory components of a design theory. Venable (2006) disagreed with this proposition. However, Venable (2006) also pointed out that kernel theories might be relevant to the meta-requirements or design-methods. Although kernel theories, as proposed in Venable (2006), are not a compulsory component of a design theory, kernel theories can still be helpful to ground a specific design theory.

### 2.5.5.4 Meta-Requirement vs. Purpose and Scope

Walls et al. (1992) defined meta-requirements as goals that are applied to a specific design. The authors also stated that the prefix ‘meta’ is used to express that meta-requirements are applied to a class of problems, rather than one specific problem.

Gregor and Jones (2007) mapped the concept ‘meta-requirement’ to the concept ‘purpose and scope’ of Gregor and Jones (2007)’s proposed anatomical skeleton of design theory. The concept ‘purpose’ describes the major use cases of an artefact that can be constructed by following a specific design theory. The concept ‘scope’ defines the boundaries of a specific design theory.

Although it is possible to describe the scope of an artefact by describing the purpose of a specific artefact, the scope can include other features than the purpose. The scope can, for instance, restrict a specific artefact. For example, an artefact design could include a constraint that a specific artefact has to obey. For instance, an artefact might have to fit a specific specification, such as being able to run with specific memory constraints, or a resulting artefact should not use more than a certain amount of disk space. However, the purpose or the requirement could be that the artefact needs to be able to run as an embedded system. Thus, the purpose, which can be expressed by a set of requirements, differs from the scope, because the scope includes expressions that might specify restrictions that might enable the artefact design to fulfil a specific requirement.

### 2.5.5.5 Principles of Form and Function vs. Principles of Implementation

As Walls et al. (1992) stated, a design theory should describe the form of the design (design as a noun / meta-design) and the act of implementing a design (design as a verb / design method). Principles of form and function, as proposed in Gregor and Jones (2007), describe the form and function of an artefact that emerges out of the DSR process. Gregor and Jones (2007) also stated that principles of implementation are concerned with the method (design method) that has to be implemented to generate a specific artefact.

Gregor and Jones (2007) stated that design as a noun and design as a verb cannot be separated. Gregor and Jones (2007) explained that a specific kernel theory can be used as a foundation for both a specific design as well as a specific design process. Walls et al. (1992), on the other hand, proposed kernel theories for the design product as well as kernel theories for the design method.

Although there is a clear differentiation between principles that describe the steps to implement a specific artefact and principles that describe the form and the function of a specific artefact, these two sets of principles depend on each other.

### 2.5.5.6 Artefact

Gregor and Jones (2007) referenced Simon (1996) to define the term ‘artefact’. An artefact is “used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally” (Simon, 1996).

Gregor and Hevner (2013) mentioned that an artefact can be readily instantiated without any adaptations whereas a design theory also contributes to knowledge. Gregor and Jones (2007) described two different kinds of artefacts: materialised artefacts and abstract artefacts. Abstract artefacts include design theories (Gregor and Hevner, 2013). Thus, in this thesis, the term artefact is used to denote a design theory, but also other, more specific, kinds of artefacts, such as artefact design, and design realisation.

**Meta-Design vs Artefact:** A meta-design describes a class of artefacts (Walls et al., 1992). Thus, artefacts that belong to a specific class of artefacts are instantiations of a meta-design. There exist artefacts that result out of a design process (Walls et al., 1992). A design process can follow a specific meta-design. Design theories entail meta-designs that describe a class of artefacts. A design theory (according to Walls et al. (1992)) consists of meta-requirements, kernel theories, and testable design process hypotheses in addition to meta-design, design product hypotheses, and a design method. A design theory is also a type of artefact. Thus, a design theory as well as a meta-design denote high-level artefacts.

**Design Theory and Artefact:** A theory for design and action (a type V theory in Gregor (2006)) describes how an artefact can be designed or what the components of a specific artefact should look like. Gregor and Jones (2007) also stated that three outputs (constructs, models, and methods) out of the four outputs identified in March and Smith (1995) (constructs, models, methods, and instantiations) are components of a broader view of theory. Gregor and Jones (2007) describe a theory as an abstract artefact and its instantiation as a material artefact.

Gregor and Hevner (2013) denoted an artefact as something that is materialised or can be materialised to an object or process. A theory is more abstract (non-material existence) than materialised artefacts and contains knowledge as well as a description of a materialised artefact.

Gregor and Hevner (2013) merged the pragmatic and theoretical camp of DSR. The pragmatic camp refers to March and Smith (1995) and Hevner et al. (2004) and sees the artefact itself as a valid research output of DSR. March and Smith (1995) stated that theories are used in natural sciences whereas design science is concerned with building and evaluating an artefact. The theoretical camp sees a design theory as a valid research output of DSR and excludes simple artefacts. This means that both the creation of a construct, model, method, and/or instantiation as well as a design theory can be a contribution to the field of DSR knowledge.

**Artefact and Components:** The term ‘artefact’ is used to describe something artificial, human-made. This can be anything from a design theory to a design product. Even though a design theory might not be materialised, it is still something artificially constructed by humans. Simon (1996) also stated that a complex artefact is a hierarchy composed of semi-independent components.

Subcomponents that can exist independently from the overarching artefact can be seen as another artefact. Moreover, components that can only be used as a part of another artefact can also be defined as an artefact. Such components that only have a purpose in conjunction with other artefacts are still artificial, because such components are still constructed by humans, and can therefore be denoted as an artefact.

**Artefact and Artefact Mutability:** The concept ‘artefact’ is arguably the most important concept of a design theory but also of DSR in general. Without an artefact description, a design theory cannot exist.

Artefact mutability, as discussed in Gregor and Jones (2007), expresses how artefacts can emerge and evolve over time. Artefact mutability can express the changing nature of an artefact.

This is certainly an important aspect of artefacts. However, unless a specific research project is concerned with the evolution of a specific artefact, neither artefact mutability is needed to fully describe a design theory nor is the mutability of an artefact important to express components of a DSR project in general.

Usually, DSR prescribes how a specific artefact can be created and how a specific artefact will look once a specific design theory has been applied. Such literature does not need to discuss the mutability of an artefact.

#### 2.5.5.7 Utility Relationship

DSR assesses the utility of a specific artefact in comparison to identifying the truth in behavioural sciences. A utility relationship expresses whether an artefact design fulfils a set of requirements or its purpose(s). If an artefact design, which further results in a specific artefact instantiation, fulfils the stated requirements and an evaluation that asserts that the relationship between the artefact design and the set of meta-requirements holds, evidence can be provided for the

utility of a specific design theory. Thus, the significance of the utility relationship, including how much utility there is and how significant the problem and improvement, determines the practical significance of a specific DSR project.

The utility relationship was defined in [Venable \(2006\)](#). Another interpretation of the utility relationship is described in [Walls et al. \(1992\)](#), and [Gregor and Jones \(2007\)](#), who defined such a relationship as prescriptive statements that prescribe the nature of a specific artefact.

The relationship between the artefact's purpose (meta-requirements) and a solution (meta-design) expresses such a utility relationship.

In DSR, a utility relationship needs to be described and evaluated to provide evidence for the significance of a specific artefact or design theory.

#### 2.5.5.8 DSR Concepts - Reflection

This subsection introduced a number of concepts that can be found in the literature. Each subsection discussed different interpretations of certain DSR concepts and synthesised them when possible. The concepts that should be described in DSR publications are further defined in the following section (Section [2.5.6](#)).

### 2.5.6 Salient DSR Concepts in DSR Publications

Following the discussion of the main components of a design theory, and a synthesis of certain DSR aspects, this section defines salient components in DSR publications. These concepts will be utilised to provide an ontological account of the domain DSR (see [Chapter 4](#)).

This section narrows the scope and settles on a design decision for the construction of the formal ontology that is named DSRDCO (see Section [4.3.3](#)).

#### 2.5.6.1 Artefact

The concept 'artefact' is an integral concept in the field of DSR (see Section [2.5.5](#)).

An artefact describes something artificial, human made ([Simon, 1996](#)). There exist materialised as well as abstract artefacts ([Gregor and Hevner, 2013](#)). Design theories are abstract artefacts that prescribe design processes and artefacts that result out of such design processes.

Artefacts can contribute to the knowledge of DSR to a certain extent. One factor that influences the contribution to knowledge is the level of abstraction of a specific artefact. More abstract artefacts that prescribe a specific design, such as a design theory, usually contribute more to the knowledge base than lower level artefacts.

A DSR publication can include different levels of artefact abstractions. Materialised artefacts are instantiations of a specific meta-design. A meta-design is an abstract representation of a materialised artefact. A design theory consists

of a meta-design in addition to meta-requirements and design methods, but also other aspects, such as kernel theories and testable hypotheses.

Meta-requirements are assertions that express the goal of a specific design product or potentially of a whole set of different artefacts/design products. Artefacts are “products of artificial character” (Meriam Webster). Meta-requirements cannot be seen as a product because meta-requirements are assertions that a certain artefact has to fulfil. Thus, meta-requirements that are used in the context of DSR are not an instance of the class artefact. However, meta-requirements can be the output of a specific research that identifies a specific set of meta-requirements. If meta-requirements are the product of a specific process, they can be interpreted as an artefact. However, such outputs not only express a set of statements that express the meta-requirements but also include information about how these meta-requirements have been identified, or why these meta-requirements are significant for the design of a specific artefact. This argumentation can also be used for testable hypotheses. Testable hypotheses are usually used in a DSR project to evaluate whether the requirements have been met.

A meta-design, on the other hand, is an artefact because it represents the output of a DSR project.

In comparison to meta-requirements that are part of a specific DSR project, kernel theories are external products and are the output of another piece of research. Thus, kernel theories are artefacts that are utilised in a specific piece of research.

DSR projects often consist of artefacts that describe different levels of abstraction: an artefact that represents a design theory subsumes the artefacts meta-design and design method. A meta-design can consist of artefacts that describe realisations of this meta-design. Each of these artefacts can be split up into sub-components, which are again artefacts.

One reason to use the term artefact for all of these components is that DSR publications discuss research outcomes where each research outcome can result in an artefact that describes a specific level of abstraction. For instance, some publications do not present a design theory at all, but an artefact that solves a more or less extensive class of problems.

Out of this discussion, four types of artefacts can be identified. The most abstract artefacts are design theories. The second and third types of artefacts are meta-designs and design methods. The fourth type of artefacts are materialised artefacts.

### 2.5.6.2 Requirement

A utility relationship entails a requirement. A requirement, or more specifically meta-requirements, are used throughout the DSR literature.

As expressed in the previous subsection, a requirement can be interpreted as an artefact as well as a property. In a DSR project, a requirement that a specific artefact has to fulfil is expressed in the form of statements and represent properties of a specific artefact.

Requirements can be differentiated in several levels of abstraction, similarly to different levels of abstraction in artefacts as discussed in the previous section. Meta-requirements express high level requirements. [Baskerville and Pries-Heje \(2010\)](#) and [Venable et al. \(2012\)](#) named meta-requirements general requirements, and [Gregor and Jones \(2007\)](#) named them purpose and scope.

However, the discussion in Section 2.5.5 showed that the concept ‘scope’ does not necessarily describe meta-requirements. Additionally, there can also be a difference identified between meta-requirements and the concept ‘purpose’. The concept ‘purpose’ expresses the ultimate use of a specific artefact, whereas meta-requirements are requirements that a class of artefacts have to fulfil, but do not necessarily have to state the ultimate purpose of an artefact.

### 2.5.6.3 Purpose

[Gregor and Jones \(2007, p. 325\)](#) stated that the design theory component ‘purpose and scope’ is a “design component [that] says what a system is for”.

[Gregor and Jones \(2007\)](#) referred to Heidegger’s example of a silver chalice. The purpose of the silver chalice can only be identified by knowing the religious ritual that involves the chalice. Thus, the purpose as well as the scope have to include information about the use cases that involve a specific artefact.

The difference between the purpose and the requirement of a specific artefact is that a requirement does not necessarily need to refer to the main aim of an artefact. [Walls et al. \(1992\)](#)’s definition of a meta-requirement states that a meta-requirement describes a class of goals a theory applies to. A goal or a class of goals do not necessarily include use cases that involve a specific artefact that fulfils a certain requirement.

### 2.5.6.4 Scope

The scope of an artefact expresses the boundaries of a specific system. [Gregor and Jones \(2007\)](#) combined the purpose and the scope of a specific artefact into one component. A purpose can express the scope of a specific artefact design by limiting the use of a specific artefact design. However, the scope can also describe other aspects that limit the scope. Thus, the concept scope should be treated separately to the concept purpose.

### 2.5.6.5 Design Theory

Design theories are an important output of a DSR project. A design theory can be interpreted as an abstract artefact and can be described by a utility relationship that expresses that an artefact fulfils a certain set of meta-requirements. A design theory consists of a design product and a design method. A design product includes a meta-design, meta-requirements, kernel theories, and testable design product hypotheses. A design method includes a method design, kernel theories, and testable design process hypotheses ([Walls et al., 1992](#)).

#### 2.5.6.6 Kernel Theory

Kernel theories are theories from natural and social sciences ([Walls et al., 1992](#)). Kernel theories are used to justify or to build the basis of a design theory. Kernel theories are not compulsory for a design theory as discussed in Section 2.5.5. However, if kernel theories are expressed in a design theory, this information provides essential information of the design theory in question.

#### 2.5.6.7 Construct

[Hevner et al. \(2004\)](#) cited Schön (1938) by proposing construct as a language in which problems and solutions are defined and communicated. A construct is a design theory artefact and provides high level conceptualisations that can be utilised to describe a specific set of lower level artefacts such as models methods and instantiations. Constructs entail the concept of an artefact.

#### 2.5.6.8 Evaluation

Evaluation is not a part of a design theory, but a component in a DSR project. Evaluation is a key activity in DSR ([Venable et al., 2016](#)). Thus, the concept ‘evaluation’ should be present in the conceptualisation of DSR.

#### 2.5.6.9 Principles

Principles of form and function and principles of implementation are components of a design theory ([Gregor and Jones, 2007](#)). Principles describe an output of a DSR project. Principles are knowledge contributions in the field of DSR. Thus, principles can be seen as a salient concept in DSR publications.

### 2.5.7 DSR Methodologies

This thesis discusses a DSR project. Thus, a DSR methodology has been selected that fits the research that is discussed in this thesis. This section introduces DSR methodologies.

There are several DSR methodologies proposed in the literature. Some of the literature provides guidelines, such as in [Hevner et al. \(2004\)](#), while some provides more stringent processes, such as in [Peppers et al. \(2007\)](#). There are also more detailed DSR methodologies in the literature, such as in [Pries-Heje et al. \(2014\)](#).

[Hevner et al. \(2004\)](#) proposed seven guidelines that should be considered in developing a DSR project, together with a number of evaluation methods. However, [Hevner et al. \(2004\)](#) did not include a detailed set of methods, except a general life-cycle (build - evaluate) that can be utilised in a DSR project.

[Vaishnavi and Kuechler \(2004\)](#), and [Vaishnavi and Kuechler \(2015\)](#) proposed a general methodology of design research. This methodology includes a number of process steps (awareness of problem, suggestion, development, evaluation,

and conclusion), and an output for each process step. [Vaishnavi and Kuechler \(2015\)](#) emphasised the knowledge generation phase in each iteration.

[Peppers et al. \(2007\)](#) proposed another well-known DSR methodology. [Peppers et al. \(2007\)](#) identified six stages that describe different tasks in a DSR project: the identification of a problem, the identifications of a solution, the development of a design, the demonstration that the developed artefact solves a specific problem, evaluation, and communication.

[Pries-Heje et al. \(2014\)](#) presented a Soft Design Science Methodology (SDSM) that can be used for DSR projects. This methodology is one of the most stringent methodologies and includes eight steps that are divided into real world and design thinking aspects. SDSM proposes an iterative process to conduct DSR.

[Sein et al. \(2011\)](#) proposed a methodology named Action Design Research (ADR). ADR combines components of action research to guide the research process. ADR addresses the problem that in an organisational setting, a researcher can learn from the intervention while addressing a problematic solution. Additionally, ADR describes a BIE cycle. The BIE cycle includes the steps ‘building’, ‘intervention’, and ‘evaluation’.

The following steps are included in many DSR methodologies: identification of a problem, description of a solution, the design of an artefact, and the evaluation of an artefact.

The use of iterations in the research process is another key characteristic that emerges out of the DSR methodology literature. Artefacts cannot reach a refined state after the first iteration. Thus, the process of identifying a solution and developing a design has to be repeated until a publishable outcome has been reached. These iterations can also include several evaluation stages.

### 2.5.8 DSR - Reflection and Conclusion

DSR is concerned with the invention of purposeful artefacts. The output of DSR projects are design artefacts of a specific level of abstraction. Design theories are abstract design artefacts. A design theory should include a number of principles that guide the design process that results in a materialised artefact.

DSR seeks to contribute to knowledge by providing design theories and / or design artefacts that prescribe, propose, or otherwise suggest a solution for a class of problems. Such a solution is preferably rigorously evaluated to identify the utility of a specific artefact.

Salient DSR concepts in DSR publications include the concepts artefact, requirement, purpose, scope, design theory, kernel theory, construct, evaluation, and principles.

There exist a number of DSR methodologies that guide a DSR project. Methodologies that are described in the DSR literature include methodologies that range from a set of guidelines to methodologies that provide a stringent number of stages. Many DSR methodologies also propose the iterative development of an artefact.

## 2.6 Literature Review - Reflection and Conclusion

The literature review section provides an overview of the problem space and the solution space that is discussed in this thesis and arrives at a set of research questions. These research questions are outlined in [Chapter 1](#).

The main research question discusses whether search results that include a set of DSR publications can be automatically summarised into a textual summary that is concise, comprehensive, coherent, clear, and correct.

The problem space includes academic search engines that search repositories of DSR articles. Such search engines do not currently support the summarisation of documents that are contained in a search result.

Literature about automatic summarisation proposes techniques to summarise documents. However, the automatic summarisation literature does not, to the best of the author's knowledge, include literature that is capable of producing automatic summaries that are tailored to DSR publications.

Many automatic summarisation techniques that are proposed in the literature generate extractive summaries. Extractive summaries consist of a selection of important sentences in a document. Abstractive summarisation techniques enable the generation of summaries that express a specific topic of interest in a coherent, but also concise manner. Many abstractive techniques are tailored to a certain topic (such as biographies of painters). Other abstractive techniques utilise models that do not provide clear lexical representations for identified concepts. This complicates the generation of clear summaries. Finally, a comprehensive summary needs to include all important concepts that are expected in a certain summary. Current automatic summarisation approaches are not tailored to the representation of DSR concepts.

The solution space that has been researched includes the use of formal ontologies in automatic summarisation and the identification of salient concepts that are described in DSR publications, as well as cloze text sentences to support the generation of summaries.

Published research in the field of automatic summarisation provides some evidence that formal ontologies can support the summarisation process in certain aspects. However, many summarisation techniques that utilise formal ontologies in the summarisation process include non-expressive formal ontologies. Nevertheless, to generate an abstractive natural language summary (abstractive summaries try to reduce the use of terminology that appears in the original text), additional knowledge bases have to be provided that consist of a vocabulary that can be used to generate abstractive summaries.

It was identified in the literature review that mostly non-expressive ontologies are used in the summarisation process. However, such ontologies do not contain the knowledge to generate summaries that include instantiations of concepts that a reader would expect in such a summary. More expressive formal ontologies were researched and described in this thesis that enable a more-expressive ontology that is capable of generating such summaries.

To the best of the author's knowledge, there is no literature available that is concerned with the engineering of a formal ontology that expresses DSR concepts that appear in DSR publications. However, there is literature available that discusses different aspects of DSR, such as design theory or DSR methodologies. Thus, the research in this thesis is concerned with the identification of salient DSR concepts and the design of a formal ontology that is capable of describing DSR publication content.

Finally, natural language has to be generated in the summarisation process. Template-based systems are discussed in the automatic summarisation literature. However, the sentence generation process is discussed rarely in most publications. Additionally, there do not exist templates or cloze sentences that can be used to generate DSR publication summaries. Thus, a research question emerged that is concerned with the analysis of cloze sentences and a process to fill in the gaps in cloze sentences to generate a summary.

This thesis is concerned with the identification of formal ontologies to conceptualise the topic of DSR publications that are expressive enough to reason over the content of DSR publications to infer concepts on different semiotic layers. This thesis further researches how these formal ontologies can be utilised to summarise single DSR publication content as well as multiple DSR publication content in natural language to answer the main research question that is stated at the beginning of this subsection.

## Chapter 3

# Research Methodology

### 3.1 Research Paradigms and Research Methods

Saunders et al. (2016) divided research into the following layers: philosophies, approaches, strategies, choices, time horizon, and techniques and procedures. These layers are delineated as a research onion that includes the outermost layer named research philosophy. Saunders et al. (2016, p. 126) use the term ‘research philosophy’ to refer to a “system of beliefs and assumptions about the development of knowledge”. A research philosophy is defined by ontological, epistemological, and axiological assumptions that guide a specific piece of research. These assumptions lie on a continuum between objectivism and subjectivism (Saunders et al., 2016). However, Saunders et al. (2016) further differentiated between research philosophies by adding another dimension that describes a continuum between sociology of radical change and sociology of regulation. These two dimensions (the dimension objectivism and subjectivism and the dimension of radical change and regulation) were proposed by Burrell and Morgan (1979) to differentiate research of paradigms.

To summarise, a research philosophy that has been chosen for a specific piece of research is described by ontological, epistemological, and axiological assumptions. A paradigm is composed of a set of basic and taken-for-granted assumptions (Saunders et al., 2016). These assumptions can further be assigned to a specific quadrant that describes one out of four distinct research paradigms that are proposed in Burrell and Morgan (1979). Burrell and Morgan (1979) named these four quadrants respectively radical humanist, radical structuralist, interpretivist, and functionalist. A radical humanist has a subjective standpoint in research and tries to extend sociological limitations by applying a sociology of radical change (Burrell and Morgan, 1979). The sociology of radical change “emphasises the importance of overthrowing or transcending the limitations of existing social arrangements” (Burrell and Morgan, 1979, p. 32). A radical structuralist also believes that research objectives should aim towards the sociology of radical change. Next to the acknowledgement that research should try to extend limitations of social arrangements, a radical structuralist adopts an objective standpoint. A radical structuralist chooses a positivists approach, is a realist, determinist, and nomothetic (Burrell and Morgan, 1979). The interpretivist follows a subjective approach to research, potentially utilising qualitative analysis. However, the interpretivist pursues a regulated approach. An interpretive researcher wants to understand the world as it is at a level of subjective experience (Burrell and Morgan, 1979). The functionalist is interested in a regulative form of research by understanding the world as it is. However, the functionalist follows a positivist approach by empirically testing hypotheses about the world.

In information systems, Hevner et al. (2004) identified two paradigms - the behavioural science paradigm and the design science paradigm. However, the distinction between the DSR paradigm and the behavioural science paradigm is not discussed in Burrell and Morgan (1979), or Saunders et al. (2016).

Both behavioural science as well as design science include research that can be assigned to any of the four quadrants that are proposed in Burrell and Morgan

(1979).

Behavioural science includes qualitative research that subjectively looks at either the world as it is, or qualitative research that wants to extend sociological boundaries. Additionally, there exist behavioural research approaches that objectively look at the world by providing empirical evidence that supports the understanding of the world or provides evidence for hypotheses that extend limitations by researching what is possible. These approaches to research can also be applied to design science.

DSR produces design artefacts and subjectively or objectively evaluates the utility of a specific artefact. For instance, a realisation of a design artefact can be subjectively evaluated by interviewing a small number of users that experience a specific problem that a specific artefact should solve. However, design artefacts can also be evaluated objectively.

Design artefacts in DSR can include artefacts that already exist. Such artefacts obviously do not extend limitations of previously designed artefacts. Research that involves such artefacts is interested in the current state of affairs. Such research can be added to the sociology of regulation. An example of such research could include an evaluation of whether a specific artefact has been successfully applied to an environment that the evaluated artefact was not designed for.

Many publications in DSR present design artefacts that include novel features that are meant to disrupt or extend state-of-the-art research in that field.

Both radical as well as regulatory research can be conducted by utilising objective methods.

Although there exists DSR that fits into any of these four paradigms, most DSR projects focus on the invention of purposeful artefacts. Invention includes the creation of something novel that did not exist beforehand. Thus, DSR tends to utilise paradigms that follow the sociology of radical change.

The behavioural paradigm as well as the DSR paradigm can be differentiated, thus introducing a dimension that is concerned with the researched material.

<sup>1</sup> DSR is concerned with the research of purposeful artefacts. Artefacts have to be artificial, human-made. DSR wants to understand whether a specific artefact has utility for a specific class of problems. Behavioural science strives to understand the nature of the world by researching the sociological significance of a specific hypothesis and whether this hypothesis is true in a given world. Thus, behavioural science does not involve the science of the artificial.

Another definition of the term ‘research paradigm’ is presented in [Kuhn \(2012\)](#) (first published in 1962). [Kuhn \(2012\)](#) used the term ‘unprecedented scientific achievements’, which [Devlin and Bokulich \(2015\)](#) denoted as a paradigm. The definition by [Kuhn \(2012\)](#) describes research paradigms using a disciplinary matrix. The disciplinary matrix in [Kuhn \(2012\)](#) includes the dimensions symbolic generalisations, metaphysical beliefs, values, and shared exemplars.

Values include accuracy, consistency, breadth of scope, simplicity, and fruitfulness ([Devlin and Bokulich, 2015](#)). Shared exemplars are one of the more fun-

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<sup>1</sup>This dimension has been stated in a discussion by [John Venable \(2016\)](#).

damental shared commitments that identify a paradigm (Kuhn, 2012). Shared exemplars are concrete ways of solving a problem that is accepted by the group as paradigmatic.

Symbolic generalisations can be described as formalised components of a paradigm (Devlin and Bokulich, 2015).

DSR includes shared exemplars in the field of information systems that are distinct from other types of research. Shared exemplars in DSR include the invention of a purposeful artefact or the application of a purposeful artefact in a new field. Thus, DSR emerges as a distinct paradigm due to shared exemplars that are agreed on by proponents of DSR.

Whereas behavioural science attempts to find the truth, a scientific contribution in DSR is the identification of the utility of a design artefact to solve a class of problems. This scientific contribution can be called a utility theory Venable (2006) of a specific design for a generalisable problem. Such a utility theory can be expressed as a design theory or a set of principles (Venable, 2006, Gregor and Jones, 2007, Gregor, 2006).

**Applied Research Paradigm:** The research that is discussed in this thesis follows the DSR paradigm. This work is concerned with novel design artefacts and researches the utility of these artefacts in regard to a class of problems. This research can be assigned to the field of information systems and shares the commitment of information systems researchers.

In regard to Burrell and Morgan (1979) this research takes an interpretative approach. This research follows a subjective approach by evaluating the artefacts qualitatively with the help of DSR experts. A subjective approach was necessary because of the subjective nature of summaries. Overview summaries about DSR articles can be interpreted rather differently, as can be seen in Chapter 5. Thus, an interpretative approach was chosen to analyse the differences and similarities of the DSR experts' opinions.

The second dimension of radical change vs. regulation (see Burrell and Morgan (1979)) distinguishes scientific work into whether an interpretative or a radical humanist approach has been chosen. This work strives to support the status quo in providing more effective techniques to search, retrieve, and summarise DSR publications. Thus, the work that is presented in this thesis describes research that fits into the quadrant regulation and is therefore interpretative.

## 3.2 Selection of DSR

This thesis discusses a solution for a class of problems. This class of problems is concerned with the representation of scientific content in an information object. This representation can be used to convert natural language text into a structure that supports automated reasoning processes. The artefacts that are presented in this thesis could support researchers and practitioners (if faithfully applied)

to more efficiently review the literature and to identify and compare different scientific results.

This thesis provides a design theory that can be used for systems that require knowledge that is presented in DSR articles in a formal, concise, comprehensive, coherent, clear, and correct way.

Realisations of the proposed design artefacts have been evaluated to identify whether the design artefacts enable the summarisation of DSR articles.

Thus, this research includes the design of a design artefact that solves the above mentioned class of problems and can therefore be categorised into the paradigm of DSR. This research invents “a [new] purposeful artefact to address a generalised type of problem and evaluates its utility for solving problems of that type” (Venable and Baskerville, 2012, p. 142).

The research that is presented in this thesis predominantly creates prescriptive knowledge. Section 2.5.3 describes the difference between descriptive and prescriptive knowledge. The artefacts that are presented in this thesis prescribe a general solution as well as design principles that enable the development of a specific solution. DSR is a research paradigm that is concerned with such artefacts. Thus, this thesis follows the DSR paradigm and utilises a DSR methodology.

The guidelines that were presented in Hevner et al. (2004) were adhered throughout the project. Table 3.1 depicts the implementation of each of these guidelines in this research.

Guideline	Implementation
Guideline 1: Design as an Artefact	This research resulted in a set of artefacts. These artefacts are comprised of a model, a method, and instantiations.
Guideline 2: Problem Relevance	This research identified a solution for a relevant problem (see <a href="#">Chapter 1</a> ).
Guideline 3: Design Evaluation	The utility has been evaluated by identifying whether the instantiations (the summaries) are useful for DSR experts. The quality of the artefacts was evaluated summatively, the efficacy of the design artefact was evaluated formatively.
Guideline 4: Research Contributions	The identification of two design principles that improve the use of formal ontologies to structure and summarise DSR articles, but also the design artefact DSRCRSA, which include the formal ontologies DSRDCO and DSRKBO, are a research contribution.
Guideline 5: Research Rigor	SDSM was chosen as the DSR methodology of the research that is presented in this thesis. The methods that were applied in each of the steps can be found in <a href="#">Section 4.2</a> .
Guideline 6: Design as a Search Process	<a href="#">Section 4.2</a> and <a href="#">Section 4.2.4.3</a> describe the search process for the general solution design, the specific solution design, and the specific solution implementation. This search process was implemented in an iterative manner.
Guideline 7: Communication of Research	This research was communicated to technology-oriented but also management-oriented audiences in a number of conferences. This thesis was written to be read by both types of audiences.

Table 3.1: Implementation of [Hevner et al. \(2004\)](#) guidelines

A predominantly inductive approach has been chosen for this research.

This research utilises qualitative methods to provide evidence for the efficacy of the proposed design artefact.

The outcome of this work follows a predominantly interpretative philosophy.

This research followed the DSR paradigm because firstly, prescriptive knowledge was created in this research (see [Section 2.5.3](#)). Secondly, artificial artefact designs were researched. The researched artefacts are part of a utility relationship between the artefacts and the meta-requirements these artefacts have to fulfil (see [Section 2.5.5.7](#)). The socio-technical nature of the artefact itself is another indicator for the use of DSR as a research paradigm. The resulting design theory includes all mandatory components of a design theory, as discussed in [Section 2.5.4](#). Finally, two design principles have emerged.

Even though the topic of DSR was also researched in these studies, this research followed the DSR paradigm and utilised SDSM as a research methodology. The topic of DSR was researched to identify structures that can be used in the researched artefacts. Thus, researching the topic of DSR was not the

main objective of this thesis. Therefore, the use of a DSR methodology was appropriate for the presented research.

### 3.3 Applied DSR Methodology

The previous section identified DSR as the optimal paradigm for the kind of research that is presented in this thesis. Research usually follows a set of methods that are arranged utilising a research methodology. Due to the selection of DSR, a DSR methodology is used.

A research methodology has to align with the intention of a specific piece of research. A research methodology should enable a research output that is expected in a specific piece of research. Additionally, depending on the type of research, a research methodology should provide more or less stringent guidance through the research process.

Most DSR methodologies in the literature include the evaluation of a specific artefact. Often, the artefacts that are evaluated are instantiations of a design artefact. If these design artefact instantiations evaluate against a set of criteria, it can be concluded that artefacts that follow the design of a given design artefact fulfil the requirements that are expressed in the set of criteria.

Another important aspect in the selection of a suitable DSR methodology is the iterative aspect of a specific piece of research. Nevertheless, many methodologies in the literature include an iterative aspect in the design of a specific artefact.

The DSR methodology that has been chosen for the research in this thesis follows the Soft Design Science Methodology (SDSM) presented in [Pries-Heje et al. \(2014\)](#).

There are many research methodologies proposed in the DSR literature, as can be read in Section 2.5.7.

SDSM is a more stringent research methodology that is split up into the ‘real world’ and the ‘systems thinking’ world. It contains iterations in three phases that are included in SDSM. SDSM consists of eight phases. Although the phases and iterations are more stringent than in other DSR methodologies, there are no explicit methods proposed for any of these phases.

This research includes (as in most other DSR projects) a learning process to identify a specific problem and subsequently a phase to identify a general solution. SDSM reflects that in step one, step two, and step three.

After identifying a general solution, a specific solution for a specific problem has to be developed that implements the general solution. By designing a specific solution for a specific problem, the general solution needs to be updated, which again reflects on the design of the specific solution. An iterative process is needed (and proposed in SDSM) to refine the general solution that influences the specific solution. When an update of the general solution design does not trigger an update of the specific solution and the specific solution does not have to be altered to fit a specific problem, the iterative process ends and the specific solution can be constructed. Each iteration between the design of the specific

solution and the design of the general solution includes a process that assesses the alignment of the specific solution design to the general solution design.

Once the design of the specific solution has been finished, the construction of the specific solution begins. In the research that is presented in this thesis, formal ontologies have been created that represent a solution for the problem of presenting formalised representations of DSR articles. These specific solutions are used as evaluands for the specific design. The evaluation of the specific solution triggers whether another iteration between the specific solution design and the specific solution is necessary.

Finally, the specific solution has to be evaluated towards a specific set of requirements. This may then result in an adaptation of the specific solution if the previously identified set of requirements cannot be fulfilled.

All of the steps that are described above and presented in [Pries-Heje et al. \(2014\)](#) have been carried out in the research presented in this thesis (see Section 4.2). The phases that are presented in [Pries-Heje et al. \(2014\)](#) have enabled the research of a design artefact realisation that fulfils the identified requirements, and generates a generalisable design artefact to solve a class of problems. In particular, the iterations between the general solution and the specific solution design, between the specific solution design and the construction of a specific solution, and the construction of a specific solution and the identification of a specific problem have enabled a more fine-grained research process. All of the proposed SDSM steps (see Section 2.5.7, Section 4.2, and [Pries-Heje et al. \(2014\)](#)) have been implemented in this research. The iteration between the design thinking world and the real world that is presented in [Pries-Heje et al. \(2014\)](#) was identified as an important aspect of this research to research solutions that fit the identified requirements. Iterations between the general design and the specific design and iterations between the specific design and the specific design solution supported the refinement process of the identified artefacts.

### 3.4 Ontology Engineering Methodology

This research includes the design and development of two formal ontologies (DSRDCO and DSRKBO; see Section 4.3.3 and Section 4.3.4). The DSR methodology that has been applied in this research is described in Section 3.3. However, this DSR methodology does not include guidelines for the design of formal ontologies.

The ontology engineering methodology that has been applied in this thesis emerged out of a synthesis of ontology engineering methodologies, which are described in Section 2.2.6.

The utilised ontology engineering methodology includes three main tasks. These three tasks include the identification of a terminology, the creation of a taxonomy, and the identification of predicates.

Other tasks that have been applied in this research are the creation of a domain glossary, the identification of reusable ontologies, and the identification

of complex classes.

Finally, competency questions are defined to evaluate the designed ontology.

The utilised ontology engineering methodology incorporates the following phases:

1. Initialisation phase (Suárez-Figueroa et al., 2016), which includes the identification of requirements. The reuse phase (Suárez-Figueroa et al., 2016), which includes the identification of reusable ontologies.
2. Design and implementation phase (Suárez-Figueroa et al., 2016), which includes the following tasks:
  - (a) Create taxonomy
  - (b) Develop domain glossary
  - (c) Define predicates
  - (d) Define complex classes
  - (e) Define competency questions

Each iteration in the applied DSR methodology includes all phases of the proposed ontology engineering methodology tasks.

The identified ontology engineering methodology has been designed by defining the three cornerstones for scheduling, which are presented in Suárez-Figueroa et al. (2016). These cornerstones for scheduling include the identification of an ontology engineering life cycle model, a scenario, and a set of activities.

**Engineering Scenario:** Suárez-Figueroa et al. (2016) proposed to firstly identify the ontology engineering scenario. The research that is presented in this thesis conceptualises the topic of DSR. Formal ontologies do not exist in the literature that covers the topic of DSR publication content and nor did formal ontologies existed at the beginning of this research that cover the field of publications or documents in general. Thus, scenario one in Suárez-Figueroa et al. (2016) has been chosen. Scenario one in Suárez-Figueroa et al. (2016) is named ‘from specification to implementation’. The ontology has not only been developed from scratch, but the requirements had to be firstly described, because the representation of content out of scientific publications (especially DSR publications) has not been covered in the literature.

Suárez-Figueroa et al. (2016) stated that scenario one has to be applied in any ontology engineering process. The authors also stated that more than one ontology scenario might be used in the design of a single ontology. Even though no formal ontology fulfilled the identified requirements exactly, there are some formal ontologies that include components that can be reused to fulfil the identified requirements. Thus, scenario three (‘Reusing ontological resources’) has also been applied in this work. The author of this thesis proposes that scenario three should be included in scenario one and become a compulsory phase. The reason for that is that research into existing formal ontologies should be

conducted to identify whether other formal ontologies already fulfil the requirements before a new formal ontology is designed. This would save “reinventing the wheel”. The importance of identifying reusable ontologies is also proposed in [Noy et al. \(2001\)](#).

To summarise, scenario one and scenario three have been chosen from [Suárez-Figueroa et al. \(2016\)](#). However, these two scenarios have been merged into one scenario because both scenarios include tasks that highly depend on each other.

**Engineering Life Cycle Model:** [Suárez-Figueroa et al. \(2016\)](#) discussed two life cycle models: a waterfall model and an iterative model. The authors defined several variations of these two models to cover most ontology engineering needs. Each variation includes several scenarios that are involved in the design process. The activities that are involved in the waterfall model are the same as the activities that are involved in the iterative model.

This research utilises an iterative ontology life cycle model because the applied DSR methodology includes an iterative DSR process. Many iterations of this iterative DSR process include ontology engineering tasks and therefore, this research also utilises an iterative ontology life cycle model.

**Activities:** [Suárez-Figueroa et al. \(2016\)](#) proposed a six-phase model in the case that scenario three (‘Reusing ontological resources’) is included in the development process. This six-phase model consists of the following phases: initiation phase (divided into a general and a specific initiation phase), a reuse phase, a design phase, an implementation phase, and a maintenance phase. Each phase can include a number of activities.

The initiation phase includes the identification of requirements. Additionally, a development team needs to be identified in this phase, which was not necessary in this research as this is a one person research project. The requirements are adapted in each iteration to reflect changes that have been identified in a previous iteration. The identified requirements informed the development of competency questions. The competency questions are then transformed into formalised queries that utilise the structure of the designed ontologies.

The second phase includes the identification of formal ontologies that can be included in the design of the researched ontologies.

The design phase and the implementation phase (phase three and four) include the creation of a model that satisfies the requirements that have been identified in the research phase ([Suárez-Figueroa et al., 2016](#)). [Suárez-Figueroa et al. \(2016\)](#) mentioned that these two phases can be executed in concert, which is the case in this research project.

The design phase and the implementation phase include major activities, which are outlined at the beginning of this section. These activities include the creation of a taxonomy, the creation of a domain glossary, the definition of predicates, the definition of complex classes and the definition of competency questions. The definition of complex classes, which is also proposed in [Bošnjak and Podgorelec \(2016\)](#), is essential to reason high-level concepts from low-level

concepts. The development of competency questions is discussed in [Grüninger and Fox \(1995\)](#) and is used to evaluate the resulting formal ontologies.

The last phase that is proposed in [Suárez-Figueroa et al. \(2016\)](#) is the maintenance phase, which includes activities to maintain quality and to extend the formal ontology if missing knowledge is detected. However, this phase was not included in this research, because the designed ontologies have not been used in a productive environment yet.

## Chapter 4

# Artefact Design

## 4.1 Introduction

The artefact designs that are presented in this chapter support the conceptualisation of DSR publication content. Such DSR conceptualisations enable the automatic summarisation of DSR content and the comparison of multiple DSR projects. DSR conceptualisations can be described and stored with the help of formal ontologies. Formal ontologies enable reasoning techniques, such as the identification of higher-level concepts. The reasoning process supports the summarisation of single and multiple DSR documents.

This chapter presents the DSR process that was used to generate artefact designs that enable the automatic summarisation of DSR publications. The main artefact design (DSRCRSA) prescribes an architecture that can guide the development of systems that support the storage and retrieval, as well as the summarisation of DSR publications. DSRCRSA is based on two design principles that prescribe how systems can be developed that enable the conceptualisation and extraction of DSR knowledge. “A design principle represents knowledge that is codified, explicit knowledge, readily accessible as prescriptive statements” (Chandra Kruse et al., 2016, p. 39). The first design principle prescribes the use of semiotic layers in formal ontologies to express concepts in formal conceptualisations. The second design principle prescribes the use of complex classes that include axioms to describe concepts at each semiotic layer by utilising concepts that are described in the lower layer. More information about the design principles that have emerged out of this project can be found in Section 6.1. Design realisations that follow these principles support the automatic generation of summaries.

The following subsections are structured as follows.

Section 4.2 provides a brief introduction to the DSR methodology that was utilised in this research. Section 4.2 also highlights the design iterations that were involved in the design of the artefact designs.

Section 4.3 delineates the researched artefacts in more detail. First, the architecture is introduced. Then the components of the proposed architecture are discussed. DSRCRSA includes two core ontologies (DSRDCO and DSRKBO). DSRDCO and DSRKBO are further discussed in regards to the ontology engineering methodology that was applied in this research (see Chapter 3 for more information about the applied ontology engineering methodology). The ontology engineering methodology included tasks to identify requirements, to research ontologies that can be reused, to provide a concept hierarchy, to create a glossary of concepts and relations, and to design competency questions that were used to formatively evaluate the designed ontologies.

Section 4.4 discusses the retrieval of information that users of a system that implements DSRCRSA expect in order to generate single document and multi-document summaries. This research is concerned with the representation of DSR publications and the summarisation of DSR publications. Thus, the indexing process is beyond the scope of this research. Nevertheless, manual conceptual representations had to be created to generate and evaluate single document and multi-document summaries. However, the main focus of this thesis lies in the

automatic summarisation of DSR publications that makes use of the proposed DSRCRSA and the ontology repository that is included in DSRCRSA.

Section 4.5 discusses the summarisation process. This section includes a discussion of several algorithms that were used to generate natural language overview summaries of single or multiple DSR publications.

Complete formal ontologies that are represented in an OWL format can be found in the appendix (6.3) of this thesis.

The design realisations were summatively (ex-post) evaluated with the help of DSR experts. The evaluation is discussed in Chapter 5.

## 4.2 Applied Research Methodology

This section summarises the research methodology that was applied to the research that is presented in this thesis. The research process followed the soft design science methodology (see Section 3.3).

Section 4.2.2 outlines the specific problem, which is an outcome of SDSM step 1 (Learn about specific problem). A more extensive discussion of the problem can found in Chapter 1 (Introduction).

Section 4.2.3 discusses the general problem and the general requirements (or meta-requirements). The general problem, as well as the general requirements, represent outcomes of SDSM step 2.

Section 4.2.4 delineates the general design solution and the specific design solution to solve the previously identified problems. The identification of the general design solution and the specific design solution were carried out in a number of iterations. Through these iterations, a specific solution can be refined until a general design solution emerges (and subsequently refined) to fulfil previously identified meta-requirements. Each iteration is briefly highlighted and includes statements in regards to the feasibility of the presented approach.

The identification of the general problem, the general requirements, as well as the identification of the general and specific design solution take place in the design thinking world (Pries-Heje et al., 2014). These steps guided the design process and were mainly executed on the drawing board.

The design of a specific solution is usually evaluated by providing evidence that an instantiation of the solution design fulfils the identified requirements in the real world.

The general design solution should include all components that are needed to sufficiently inform the development of a specific solution that fulfils the identified meta-requirements. However, a general design solution should not be over-specified to remain applicable to a class of problems.

A specific design solution not only needs to be sufficiently described by a general design solution, it also needs to be capable of creating the artefacts that the design is meant to produce. Thus, the design of the specific solution can finally only be evaluated by identifying whether an instantiation of the specific design solution solves a specific problem and fulfils the general requirements.

### 4.2.1 Applied Methods in SDSM

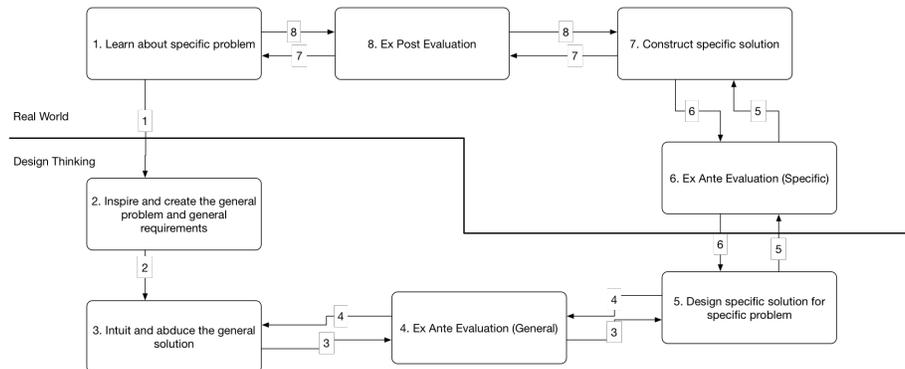


Figure 4.1: SDSM adapted from Pries-Heje et al. (2014)

SDSM is divided into eight steps. However, Pries-Heje et al. (2014) do not describe methods that can be used in each of these steps. This section introduces the methods that were chosen for this research. Section 4.2.1.1 to Section 4.2.1.4 provide an overview of the methods that were used in each step of SDSM.

#### 4.2.1.1 Specific problem

Firstly, a specific problem was identified. Such problems can emerge out of experience, out of discussions with practitioners, or through analysis of real world implementations.

Personal experience, discussions with fellow researchers, but also the analysis of current state of the art academic search engines lead to the identification of the described specific problem, which were noted as a number of user stories (see Section 4.2.2.1).

The specific problem that has been identified in this thesis is the lack of automatically generated summaries and the lack of significant search results due to the vastness of available literature.

#### 4.2.1.2 General problem and general requirements

A general problem followed by the definition of general requirements was abstracted out of the specific problem.

The general problem has been abstracted from the specific problem through logical reasoning. The requirements could then be derived from the general problem.

The general problem included the lack of formal representations of DSR articles. The lack of formal representations of DSR complicates the extraction of information that should appear in a summary.

### 4.2.1.3 Design of general and specific solution and construction of specific solution

The general solution has been identified utilising an iterative process. This iterative process includes five SDSM steps: Intuit and abduce the general solution, ex ante evaluation (general and specific), design specific solution for specific problem, and construct specific solution. As the steps already imply, this iterative process includes an intuitive process of identifying a general solution, a design process to identify specific solutions that incorporate all aspects of the general solution, an evaluation of whether the general solution can be transferred into the design of a specific solution. Finally, the design of the specific solution was evaluated to see whether the design can be transferred into an implementation that fulfils the identified general requirements.

**Evaluation of design and implementation:** An artificial evaluation has been applied in each iteration. An artificial evaluation was used because a real system has not existed. Additionally, subsystems needed to be evaluated, which comprise DSRCRSA. These subsystem could not be tested with real users. Specific solutions were evaluated artificially to identify whether all aspects of the general solutions were incorporated in the specific solution (step 4: general ex ante evaluation).

An implementation of the specific solution was used to identify whether the specific solution design enables the implementation of a specific solution that fulfils the previously identified requirements.

**General solution design:** The general solution has been identified intuitively. This process was supported by a rigorous literature review, but also by an analysis of academic search engines in practice. Additionally, the ontology engineering methodology that is proposed in Section 3.4 was utilised in the design process.

**Specific solution design:** Once a general solution was identified a specific solution was designed, which incorporated aspects of the general solution. This specific solution was evaluated artificially to identify whether all aspects of the general solution were incorporated.

**Specific solution implementation:** Once the specific solution design was evaluated, the specific solution was implemented. This enabled the identification of whether the identified requirements were fulfilled by the implementation, which further implies the ability of the specific solution design to fulfil the requirements that are also incorporated in the general solution design.

### 4.2.1.4 Ex post evaluation

The last step of SDSM is the ex post evaluation. A qualitative method was chosen to identify whether the output of the specific solution fulfils the identified

requirements. Therefore potential real users were asked to participate in a series of interviews.

DSR experts were asked in a series of three interviews whether they can agree that the generated summaries fulfil 5 criteria, which were identified as requirements for overview summaries as described in Section 2.4.5.

## 4.2.2 The Problem

Many research projects are concerned with the automatic generation of summaries (see Section 2.4). However, the automatic summarisation of search results is rarely discussed in the literature nor implemented in state-of-the-art search engines (see Chapter 1).

Nevertheless, automatically generated summaries in the form of overview summaries about academic search engine results that contain a list of DSR publications could equally support researchers and practitioners. The following subsection discusses user stories that were identified for the user group of researchers. Researchers are the major user group for such overview summaries. Thus, this thesis concentrates on the user group of researchers. The following subsection delineates how researchers can be supported by the provision of overview summaries.

The problem that is approached in this research is described by the need of novel search result presentations that provide automatically generated overview summaries of search results. Such overview summaries should facilitate the search through a number of DSR publications by providing overview summaries about topics that are expressed in search queries.

### 4.2.2.1 User Stories

“A user story describes functionality that will be valuable to either a user or purchaser of a system or software.” (Cohn, 2004, p.4) In this research, several user stories have been identified. The identified user stories have emerged out of discussions with experienced DSR researchers. Although there is no guarantee that a complete set of user groups and user stories have been identified, three major user groups have emerged. The following user groups could make use of conceptualisations of DSR content and the presentation of search results of DSR publications: researchers, lecturers, and practitioners. Researchers review literature on a daily basis. Researchers require a comprehensive picture of a specific topic or in regards to a specific query. Lecturers teach students about state-of-the-art research. Therefore, lecturers have similar requirements to researchers. However, lecturers often only need to retrieve an overview of a specific topic. Practitioners, on the other hand, might prefer a solution to a problem at hand.

The identification of the general problem and especially the identification of general requirements included the development of user stories.

The process of identifying user requirements includes three steps. (1) A description of each user group needs to be developed. These descriptions support the identification of similarities and dissimilarities between user groups. (2) User

groups are involved in events that are concerned with the retrieval of information from DSR publications. These events are identified to specify the requirements of the involved user group. (3) Use cases are created to identify functions that a system has to provide in extracting information out of DSR publications.

**Stakeholders :** Researchers, lecturers, and practitioners were identified as stakeholder groups. This is not a complete list of stakeholder groups that might be interested in retrieving scientific work; however, these three stakeholder groups are primarily addressed in DSR publications.

Lecturers as well as researchers are potentially interested in acquiring in-depth knowledge about a topic of interest. Practitioners, on the other hand usually search for a design solution that solves a specific problem at hand.

Researchers usually search for a more comprehensive description about a specific topic than lecturers do. This means that researchers are interested in in-depth knowledge that can be acquired by studying a comprehensive account of literature about a specific topic. Lecturers are interested in providing students with a comprehensive overview of a specific topic.

Practitioners might often be interested in design artefacts that solve a specific problem. However, practitioners are also potentially interested in acquiring new knowledge to study a specific topic.

All stakeholder groups can make use of comprehensive summaries that provide overviews of a specific topic that are coherent, correct, and concise.

**Aspects:** Three aspects of DSR publications were chosen to support researchers, lecturers, and practitioners in searching and reviewing the DSR literature. These three aspects should appear in summaries of single and multiple DSR publications. These three aspects are also identified in [Teufel and Moens \(2002\)](#).

(1) Lecturers, researchers, and practitioners want to see the benefits and descriptions of a specific solution.

(2) Lecturers and researchers want to retrieve statements about the novelty of a specific artefact.

(3) Lecturers and researchers want to retrieve the literature that a specific publication relates to.

[Teufel and Moens \(2002\)](#) differentiated between rhetorical status and relatedness among articles. Rhetorical status includes terms about problem solving (which is related to aspect 1), and terms of intellectual attribution (which is related to aspect 2). Finally, the relatedness among specific articles ([Teufel and Moens, 2002](#)) relates to aspect 3.

**Summary:** All stakeholder groups can make use of a brief overview of a set of DSR publications to cope with the vast amount of publications that are available today. Additionally, (as discussed in Section 2.4) summaries have to fulfil the 5Cs. This means that a summary:

- has to include a comprehensive overview of the text that needs to be summarised.

- should be concise to reduce the workload that is involved in the literature review process.
- should be coherent to reduce the amount of time that is needed to review a publication.
- should be correct to be of any use to the reader.
- should be clear to reduce any misunderstandings in order to provide a proper account of what is written in the text.

**Search Results:** Overview summaries can provide an overview of a specific topic, but also an overview of a set of search results. Current academic search engines provide links to scientific publications, together with metadata about each retrieved publication. Lists of scientific publications and their metadata, in comparison to overview summaries, can complicate the comparison and synthesis of publications because each publication needs to be reviewed to identify whether the content fits a specific objective.

A literature review process includes a careful study of publications. However, the vast amount of publications complicates the manual comparison and synthesis of search results.

**Researchers' User Stories:** Based on the scope of the research that is presented in this thesis, only user stories that are concerned with the user group of researchers were considered. However, most aspects that are described in the paragraph named 'Aspects' are aspects that apply to multiple user groups. Additionally, the main aspect of this research is to prescribe an architecture that enables formalised representations of DSR publications. These representations support the summarisation and combination of DSR articles.

DSR experts can provide sufficient evidence in regards to the proposed research outcome.

The following user stories are of concern to the user group of researchers.

A researcher wants an answer to the following questions in regards to a DSR publication:

- What are the components that an artefact design consists of?
- What are the requirements / problems that are proposed in the DSR publication?
- Is it feasible to apply a solution to a different problem?
- Can an artefact design be replaced by another artefact design and does the new artefact design deliver the same result, but with better evaluation results?
- What is the practical significance and the theoretical significance of the DSR artefacts that are presented in a specific paper?

Most questions that are mentioned above can be answered in the form of a summary that includes the most salient concepts of a specific DSR article. However, an abstract of an article should already include this information; nevertheless, not all abstracts provide summaries that include all the components that researchers expect in a summary. Additionally, an automatically generated summary can, in comparison to abstracts, be tailored to a specific scenario that is identified by certain expectations that a user might have. However, every automatically generated summary should provide a comprehensive picture in regards to the queried topic of a specific search.

In addition to single document summaries, the proposed architecture should also be capable of summarising multiple publications. Such a set of publications could be returned by an academic search engine.

In regards to multiple DSR publications, a researcher wants an answer to the following questions.

A researcher would like to:

- identify artefacts that solve a specific problem.
- find artefacts that use related artefact components.
- find all publications that propose similar artefacts.
- determine how extant approaches that solve a similar problem relate to each other.
- determine how well extant approaches solve the problem.
- retrieve a comprehensive list of publications that are similar in a specific aspect / artefact component / requirement.
- retrieve a concise conceptualisation of articles that are similar in a specific aspect / artefact component / requirement.
- retrieve a coherent conceptualisation of articles that are similar in a specific aspect / artefact component / requirement.
- retrieve a correct conceptualisation of articles that are similar in a specific aspect / artefact component / requirement.

#### 4.2.2.2 A Typical Search Query

In this thesis, the intent of an overview summary is to summarise multiple DSR publications to provide an answer to a search query. The most important DSR publications that are returned by a search query are used to generate an overview summary. Thus, a summary should include answers to concepts that are expressed in a search query. This section discusses a typical search query of a researcher.

**Search Query and Search Strategy:** Although search engines strive to provide a searcher with the best answer to a given search query, search results can be improved significantly if a searcher understands how the utilised search engine works. For instance, searchers can generate search queries that make use of additional features that are built into a specific search engine. An optimal search query integrates terms that clearly state what the expected result should look like. A search strategy can include information about the expected search result. However, searchers often do not know how a system processes a certain query. Additionally, search engines might implement different non-transparent search strategies to deal with different search queries. This limits the options for a searcher to influence the search process.

The interpretation of search queries in natural language is beyond the scope of the research that is presented in this thesis. Thus, the architecture (DSRCRSA) that is presented in this thesis is designed to be integrated in a search engine that returns a set of documents.

This work focuses on the presentation of search results. Such presentations should provide a comprehensive picture by not leaving out any information that might be of importance to the searcher. A search result should be concise so as not to overload the searcher with too much information. A coherent search result supports a searcher in understanding a specific search result. A list of search results are often hard to follow without reviewing each returned result. A search result should also be correct, at least in accordance with the information that is represented in a specific document that is returned in the search result.

Although the search process is not discussed in detail in this thesis, a search strategy needs to be defined and outlined to specify the output of a summary. A search strategy enables the retrieval of information that is then used in the generation of a summary.

**A Typical Search Query:** A search strategy revolves around a search query. The search query of a researcher might express the wish to identify artefacts that fulfil a specific set of requirements. A standard search engine can be used to execute such a query. A search query might include keywords that describe the solution or keywords that describe requirements that the solution has to fulfil. Search results then might include documents that contain keywords that relate to keywords of the search query. However, these keywords might be found in a paragraph that describes the solution rather than the requirements that the solution fulfils. A conceptualisation of the document can solve this problem. If the conceptualisation of the document instantiates the concept requirement with terms that appear in the document, the keywords that are expressed in the query should only search instantiations of the concept that the keyword in the query belongs to.

A natural language search query might look as follows: “I want to know all solutions that fulfil the requirement of categorising scientific documents.” A more detailed search query might be: “I want to get a comparison of all solutions that solve the question of categorising scientific documents” or “I want

to know all algorithms that categorise scientific documents”, or “I want to get a comparison of all algorithms that are utilised to categorise scientific documents”.

A common issue in stating a search query is that a user might not know how to correctly query a search engine in order to feed the search engine with information that the search engine can understand and that enables the search engine to return results that the searcher expects.

**A Typical Search Strategy:** A typical search strategy has been identified in this research. This search strategy emerged out of discussions with DSR researchers and expands on the user stories that were discussed in Section 4.2.2.1. Additionally, the following search strategy components are comprised of major aspects of search engines. Section 2.3 includes a discussion of search engines and their components.

A search strategy has to include the following components to process a search query. For each component, an example will be depicted that relates to a search query that searches for artefacts that fulfil the requirement of categorising search results:

1. Type of user: The type of user helps identify the depth and breadth of search results. In this example the type of user is a researcher. A researcher is more likely to be interested in a more comprehensive set of results than a practitioner.
2. Type of returned information: In this example, the information that should be returned consists of solution spaces. A solution space includes a conceptualisation to describe a specific solution.
3. Querying space: A search process can generate better results if it knows what parts of a document have to be queried. Results can be even more exact if the search can be limited to a certain set of concepts. In this example, the search space consists of instantiations of the concept ‘requirement’ to find solutions that are capable of categorising scientific articles.
4. Search result presentation: The architecture that is presented in this thesis enables novel presentations of search results, compared to just a list of documents. Therefore, a search strategy needs to know the appropriate presentation of the extracted result. This can be a list of artefacts that fulfils a requirement or a summary that additionally compares the retrieved artefacts.
5. Level of detail of search result: Some users might be interested in a more detailed description of a search result, whereas others are only interested in a brief overview of the returned articles.
6. Limitations: Depending on the artefact, there might be a number of properties that are within a certain range. Thus, metrics need to be defined. These metrics and ranges are used during the search process to identify whether a specific artefact fulfils these requirements.

These are basic components of a search strategy. However, components 2, 3, and 4 are only needed in search engines that retrieve more than just the name of a specific document.

This thesis is concerned with the comparison and summarisation of formalised DSR publication content. A comprehensive conceptualisation of DSR content enables the comparison of instantiations of DSR concepts. This thesis focuses on the generation of natural language summaries. Thus, a search strategy needs to describe all six components, except component 4.

A semantic search engine that utilises formal ontologies (as proposed in this thesis) can perform a more targeted search because of the possibility of restricting the returned information by utilising formal conceptualisations.

**A Typical Search Result:** A search result should answer a specific query and is the product of a search strategy. A search engine analyses a specific query to develop a search strategy that fits a given search query. However, a user could also define a search strategy to retrieve a more personalised search result.

In comparison to a ranked list of documents, the proposed architecture (DSRCSRSA) could provide results that can be tailored to a search strategy and includes more specific information than a ranked list of documents. DSRCSRSA is capable of returning summaries that belong to a specific result set. However, DSRCSRSA can be used to extract any kind of information that is expressed in the formal ontologies that are utilised in the ontology repository that is part of DSRCSRSA.

The answer or search result to the question “I want to know all solutions that fulfil the requirement of categorising scientific articles” would look as follows.

A search result would include a list of solutions that propose to categorise scientific documents. Although such a result only consists of a list of solutions, this list can include additional information about each solution, and the result set is more related to the search query because of a more targeted search. For instance, only information is extracted that fits the term ‘scientific documents’ or semantically similar expressions such as ‘scientific articles’, ‘scientific books’, ‘research articles’, etc. Additionally, the search is restricted to instantiations of the concept ‘requirement’. Such a strategy can remove false positives in the search result. In addition to these advantages, DSRCSRSA is also capable of comparing DSR publications and providing overview summaries of a result set.

**Research Outcome:** This section discussed a typical query to depict an example of what the proposed architecture (DSRCSRSA) is designed for.

This thesis focuses on the formal representation of DSR articles and the generation of natural language summaries out of these formal representations. However, the search process itself is outside the scope of this research.

Nevertheless, the feasibility of generating natural language summaries (see [Chapter 5](#)) shows that search result presentations can be generated if DSRCSRSA

is properly implemented, if a search strategy is properly defined, and if the search is executed to retrieve a number of documents.

### 4.2.3 General Problem and General Requirements

**General Problem:** The lack of automated summaries that summarise DSR content is a specific problem that affects researchers in their literature review process, as discussed in [Chapter 1](#). This is a specific problem because it is only concerned with researchers and DSR publications; however, this specific problem can be generalised.

Most current state-of-the-art search engines do not include semantics in their search process. However, there are a number of approaches in the literature that make use of semantics both in the search process and in the search result presentation. Most of these approaches utilise non-expressive ontologies to support the search process. There are currently no search engines available that conceptualise DSR publications and make use of formal ontologies. Thus, an architecture is needed (and provided in this thesis) that introduces repositories of formal ontologies of DSR content and semantic techniques to reason over DSR content.

The general problem that emerges out of the specific problem is that formal representations of DSR content are needed to support semantic techniques that, for instance, enable the summarisation of scientific articles. Nevertheless, formal representations of DSR content can support many other techniques, such as the identification of novel artefacts, by automatically combining different kinds of artefacts, or evaluating all components that are included in the knowledge base, to achieve a certain goal by interpreting other DSR outcomes that are stored in the formalised conceptualisation of DSR. To summarise, formal representations enable a plethora of possibilities for computer systems to process DSR content.

**General Requirements:** General requirements to solve a general problem include the design of an architecture that enables the formalised storage and retrieval of DSR content with the help of formal ontologies. Additionally, a set of formal ontologies needs to be designed that includes axioms to reason over instantiations of these ontologies. These formal ontologies need to reflect the domain of DSR, the domain of scientific publications, and knowledge bases that formalise DSR content.

Further, a set of axioms needs to be identified that enables reasoning over formal ontologies, and processes need to be defined, to combine a set of DSR publications, which then enables the summarisation of single and combined DSR articles.

Finally, a set of principles should emerge that support the development of systems that provide an ontological representation of DSR content.

The design artefacts, once implemented, have to produce design realisations that fulfil the 5Cs (comprehensiveness, clarity, conciseness, coherence, correctness) (as identified in [Section 2.4.5](#)). The 5Cs should not only ensure that the

summary is of use to researchers, but should provide evidence that the most important components of DSR publications are available in the ontology repository in a formalised form.

#### 4.2.4 The Solution

This section discusses the general solution that was designed. Additionally, the specific solution is briefly outlined before the design process is explained.

The design process includes a number of iterations. These iterations include the development of a specific solution design as well as the construction of a specific solution and the formative evaluations that guided the design process.

##### 4.2.4.1 The General Solution

The specific solution fulfils the requirement of automatically generating summaries of DSR content. The generalised solution includes an architecture and processes that enable a user or a system to utilise formalised DSR content. Such a general solution can be applied to databases of scientific publications, as well as to any information system that processes DSR publications. Additionally, the proposed general solution includes an ontology repository that provides formalised conceptualisations of DSR content. Such formalised conceptualisations and the reasoning capabilities that are provided by such conceptualisations can be utilised in any information system that stores and / or utilises DSR content. Finally, the proposed architecture can potentially be used to store and compare any form of conceptualisation if a core ontology is provided that describes the genre that needs to be stored. This can be ensured by the division of ontological reasoning capabilities into different semiotic layers.

Many automatic summarisation processes that exist in the literature generate summaries by identifying and returning salient sentences (see Section 2.4.4). Automatic summarisation techniques that produce structured summaries about a number of key concepts need to identify instantiations of these key concepts. Formal ontologies enable the formal representation of DSR content. A formal representation of DSR content improves searchability. However, more importantly, a formal representation provides conceptualisations that support the identification of higher-level concepts. Higher-level concepts enable the classification of DSR content. Such classifications support the generation of summaries. Nevertheless, formal ontologies that support the process of generating automatic summaries need to be expressive enough to support such reasoning processes.

**Architecture:** This thesis proposes an architecture as a general solution. This architecture is called the DSR content representation and summarisation architecture (DSRCRSA). DSRCRSA includes an ontology repository and processes to retrieve and summarise DSR content. Additionally, the ontology repository makes use of a set of core ontologies that provide a structure that enables the comparison of several DSR publications. DSRCRSA should be capable of guid-

ing the process of developing systems that fulfil the previously specified general requirements. A detailed discussion of DSRCRSA can be found in Section 4.3.1.

**Formal Ontologies (DSRDCO and DSRKBO):** DSRCRSA includes an ontology repository that consists of two formal ontologies; the design science research document core ontology (DSRDCO) and the design science research knowledge base ontology (DSRKBO).

The design science research document core ontology (DSRDCO) is a formal ontology that consists of a terminology box (T-Box) that is needed to conceptualise DSR content. DSRDCO also makes use of the DoCo ontology that is presented in [Constantin et al. \(2016\)](#) to describe rhetorical elements.

The design science research knowledge base ontology (DSRKBO) conceptualises DSR knowledge. DSRKBO enables the comparison and combination of DSR work.

These two formal ontologies support the storage of formalised representations of DSR work. Further, these ontologies enable to reason over assertion boxes that contain instantiations of both DSRDCO and DSRKBO. Such reasoning capabilities enable the generation of summaries and the combination and comparison of DSR content. A detailed discussion of these formal ontologies can be found in Section 4.3.2.

#### 4.2.4.2 Specific Solution

The specific solution that is presented in this thesis is capable of transforming a set of formalised DSR publications into a summary that provides a comparison of DSR components. Manually created summaries guided the process of identifying specific solutions that fulfil the requirement of summarising and comparing DSR content. These specific solutions informed the design of a general solution.

The specific solution can utilise the output of a search engine that understands a specific search query, then retrieves documents out of the result set, and lastly ranks them before the search result presentation generator creates a representation of a search result.

In order to support the search process, a semantic index can be maintained that is stored in the ontology repository. This ontology repository stores semantic representations of all documents that have been identified in the search process.

#### 4.2.4.3 Research Process

This research included seven iterations to create the design of the final artefact design. Each iteration was concerned with the identification of specific designs and solutions that implement a general design. If all aspects of the general design can be transferred into a solution design and solution implementation and if these solutions can be evaluated by DSR experts, the general design solution fulfils its requirements.

Iteration 1 identified whether state-of-the-art repositories can be used to implement the general solution. Iteration 2 was concerned with the feasibility of the identified general solution in terms of the involved data structures. Iteration 3 was concerned with the identification of similar concepts. Iteration 4 was concerned with the identification of salient concepts. Iteration 5 researched logical representations to represent and compare DSR concepts that appear in DSR publications. Iteration 6 was concerned with the generation of the ontology. Iteration 7 included the creation of summaries as well as the development of a prototype that automatically creates such summaries.

All iterations were concerned with the identification of specific solutions that enable the general solution of utilising formal ontologies to represent and summarise DSR content. The next paragraphs describe these iterations to provide an overview of the research process.

**Iteration 1:** The first iteration was concerned with research on repository systems or digital libraries that support the ontological representation of DSR content. Although some repositories, such as Fedora Commons<sup>1</sup> or Greenstone (Hinze et al., 2009), provide semantic capabilities, these semantic capabilities are limited to metadata. Both systems can store metadata by the use of formal ontologies. However a formalised representation of DSR content is not supported. Nonetheless, the integration of formal ontologies, especially in the Fedora Commons repository, is possible.

The outcome of this iteration included the identification of whether formal ontologies can be integrated in state-of-the-art document repositories. However, a proper formal representation of DSR content needed to be identified to store DSR work that is represented in one or many documents.

**Iteration 2:** The objective of the second iteration included the creation of an ontological representation of DSR content. As a first step, a semantic network was created to represent DSR content. This semantic network consisted of relations that were extracted from DSR publications.

Although the creation of such semantic networks was possible, but these semantic networks became too extensive to employ reasoning capabilities. In particular, the representation of complete sentences as they appear in a DSR publication proved to be too complex.

**Iteration 3:** The third iteration was concerned with the combination of DSR content. Firstly, three example publications were chosen and a semantic network was created. Then, concepts that were related were combined and the similarity between these concepts was depicted, which enabled the representation of similarities.

The representation and identification of the similarity between two concepts is a difficult task. Even though concepts might look similar, they might be interpreted differently in another context. Thus, contexts have to be defined to

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<sup>1</sup><http://fedorarepository.org/features>

describe where a specific concept belongs to. In this research, it was additionally identified that the semantic networks that were created rarely expressed the most salient concepts of a DSR publication.

**Iteration 4:** The fourth iteration was concerned with the identification of salient concepts. Thus, the most salient concepts that appear in scientific publications needed to be identified. This was achieved by focusing on a specific research area. In this case, DSR publications were chosen. A number of DSR articles were reviewed to identify the most salient concepts.

However, only a subset of components of scientific publications were identified. Although a number of concepts were identified, these concepts could not be categorised as DSR concepts or concepts of scientific publications. Thus, although concepts that were specific to a specific article were identified, these concepts were not properly categorised.

**Iteration 5:** The outcome of iteration four led to further research on argumentation, rhetorical categories, and the structure of scientific publications. Thus, iteration five was concerned with a literature review about the structure of scientific publications. Additionally, content representations were researched to support the conceptualisation of scientific publications. Finally, logical representation was researched and applied to identify how the content of scientific publications can be captured and conceptualised into DSR concepts.

Logical representations were created by utilising the lambda-calculus as discussed in [Partee and Hendriks \(2011\)](#), as well as first-order logic and description logic. Description logic was sufficient to state axioms to describe complex classes. Montague grammar, on the other hand, was used to translate publications into formal representations. This did not work as intended. However, the use of description logic has proved to be useful. Additionally, description logic is the logic that OWL (the web ontology language) is based on.

**Iteration 6:** After the identification of concepts that represent argumentation in scientific articles, such as the AIF ([Rahwan et al., 2007](#)), rhetorical categories as discussed in [Teufel and Moens \(2002\)](#), and the structure of scientific publications as discussed in [Groza et al. \(2007\)](#), it was necessary to reduce the designed DSR conceptualisation to a manageable set of concepts.

The field of DSR was chosen to limit the conceptualisation to concepts that are specific to DSR. DSR can cover a large area of scientific research. DSR concepts are more important in regard to the summarisation of DSR publications than are rhetorical categories or arguments. However, some rhetorical categories are still reflected in the DSR ontology. A set of cloze sentences were identified to evaluate whether the identified DSR conceptualisation was sufficient.

**Iteration 7:** The seventh iteration included the creation of a specific solution. Thus, a number of real world articles were converted into an ontological representation and an algorithm was developed and applied to create a summary of

one article and a combined summary of three articles. These summaries were then evaluated. The evaluation of these summaries is discussed in [Chapter 5](#).

**Research Process - Conclusion:** Many iterations were concerned with the design and development of formal ontologies. Thus, the ontology engineering methodology that is described in [Chapter 3](#) was applied from iteration three onwards. The Soft Design Science Methodology (SDSM) ([Pries-Heje et al., 2014](#)) was applied throughout this research. The SDSM includes iterations between the real world and the design thinking world in all iterations. However, it was not possible to apply these ideas to a real world system because there do not exist real world systems that include the fully-automatic concept extraction process that is needed to populate the formal ontologies that were designed, researched and presented in this thesis. Thus, simulations and manual examples were created to reflect the real world. These manual examples include single and multi-document summaries that follow cloze-text templates that were researched in this thesis. Additionally, a prototype was developed to generate single and multi-document summaries automatically from a provided set of ontology instantiations.

### 4.3 The Design Artefact Products

This section delineates in more detail the design artefacts that resulted out of the research process.

Section [4.3.1](#) delineates the design science research content representation and summarisation architecture (DSRCRSA). DSRCRSA can be used in systems that store and describe DSR content.

Section [4.3.2](#) discusses the ontology repository, which is a core component of the architecture. The ontology repository enables a formalised representation of DSR content.

Section [4.3.3](#) and Section [4.3.4](#) describe the output of the ontology engineering process of DSRDCO and DSRKBO respectively. Both sections include requirements for each core ontology (DSRDCO and DSRKBO), a discussion about the reuse of ontologies, a concept hierarchy, a glossary of concepts and properties, and competency questions.

#### 4.3.1 DSRCRSA

The design science research content representation and summarisation architecture (DSRCRSA) (see [Figure 4.2](#)) has two purposes. Firstly, the architecture provides a framework to formalise and to store DSR content. Secondly, DSRCRSA provides formal ontologies to reason within formalised DSR content that is stored in systems that implement this architecture.

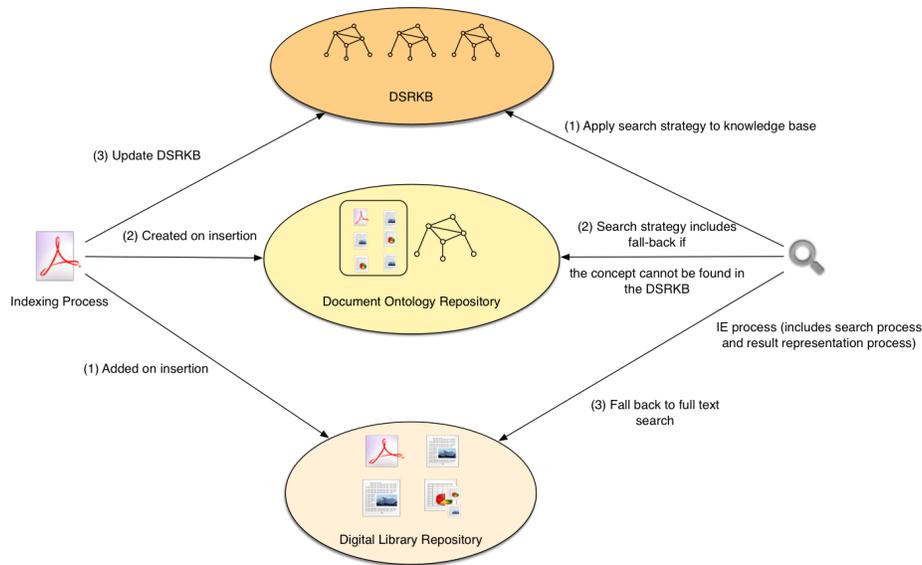


Figure 4.2: DSRCRSA

**General Components:** The main components of DSRCRSA are an ontology repository, two ontology designs (DSRDCO and DSRKBO), and processes to retrieve and summarise DSR content that is represented in the ontology repository. The ontology repository includes a DSR knowledge base, a DSR document ontology, and a document repository (see Figure 4.2). In addition to that, DSRCRSA includes two processes: the information retrieval process and the summarisation process. This section is concerned with design products. Thus, design methods, such as the information retrieval process and the summarisation process are not discussed in this section. Please refer to Section 4.4.3 and Section 4.5 for a discussion on the design methods that are included in DSRCRSA.

The main components and processes are defined in detail in order to build design realisations utilising this architecture, yet abstract enough to apply this architecture to a class of systems that make use of DSR content.

The next paragraphs provide an overview of the DSR knowledge base, the document ontology repository, and the processes involved. This architecture stores DSR publications. Thus, a repository system needs to be implemented to reflect the storage needs. The last paragraph in Section 4.3.1 describes the digital repository that was utilised in this research.

**DSRKB:** The design science research knowledge base (DSRKB) is based on DSRKBO (the design science research knowledge base ontology). DSRKBO provides a conceptualisation (T-Box) of DSR knowledge base features. DSRKBO is an application ontology, which means that it fulfils internal, system specific

requirements.

The knowledge base ontology is concerned with the storage of concepts that have a certain level of support. In the proposed indexing process, a concept has to be mentioned in more than one publication. However, the support of a specific concept, which expresses the number of instantiations of a certain concept, can be set to a higher value, which should increase the confidence in an identified concept.

Whereas DSRKBO provides a T-Box, DSRKB consists of assertions between individuals (A-Box) and assertions between individuals and classes of DSRKBO.

DSRKBO also includes the simple knowledge organisation system (SKOS)<sup>2</sup>.

A detailed discussion of DSRKBO can be found in Section 4.3.4.

**Document Ontology Repository:** Another essential repository of DSRCRSA is the repository of design science research document ontologies (DSRDOs). DSRDOs are A-boxes that instantiate the design science research document core ontology (DSRDCO). DSRDCO is a T-Box that includes essential DSR concepts that typically appear in DSR publications. Thus, DSRDCO represents the topic of DSR, but focuses on DSR publications.

Each document that is added to this repository is formalised and stored in a DSRDO. These formalisations of DSR publication content can be generated manually, semi-automatically, or automatically. However, the correctness of these formalisations is essential to further process and reason over these ontologies.

Concepts that show similarities to other DSRDOs are stored in DSRKB. In DSRCRSA, the combination and comparison of DSRDOs takes place in the indexing phase. Because the combination and comparison of DSRDOs takes place in the indexing phase, the information extraction process solely needs to retrieve common components from DSRKB to extract similarities between different DSRDOs.

DSRDCO also includes concepts to represent documents. Besides a conceptualisation of DSR, DSRDCO also has to cover a conceptualisation of scientific documents or documents in general.

A detailed description of DSRDCO can be found in Section 4.3.3.

**Digital Library Repository:** The digital library repository stores DSR publications and has two purposes. Firstly, a full text search is possible in the case that the knowledge base does not retrieve useful information. Secondly, this repository can be referenced by DSRDOs and DSRKB. These references can support the extraction of original texts that refer to specific concepts that are stored in a specific DSRDO or DSRKB. Fedora Commons<sup>3</sup> is an example of a digital repository in which RDF is natively built in and enables the storage

<sup>2</sup><https://www.w3.org/2004/02/skos/>

<sup>3</sup><http://fedorarepository.org/features>

of formal ontologies. Fedora Commons also provides web services that provide functionalities to access formal ontologies.

This thesis focuses on the information extraction and summarisation process of DSR publications by utilising DSRDOs and DSRKB. Thus, this thesis does not include an extensive discussion of digital library repositories. However, a feasibility study was conducted to identify whether this architecture can be combined with a digital repository platform named Fedora Commons<sup>4</sup>. It could be identified that there are several digital libraries, such as in [Kruk and McDaniel \(2008\)](#), [Kruk et al. \(2009\)](#), [Buchanan \(2006\)](#), [Hinze, Buchanan, Bainbridge, and Witten \(Hinze et al.\)](#), and digital repositories, such as Fedora Commons, that include semantic capabilities. Some of these digital libraries and digital repositories integrate formal ontologies to describe meta-data. A test installation of Fedora Commons showed that semantics about documents can be added and retrieved from the system. Each item that is stored in the system consists of the document itself together with instantiations of arbitrary formal ontologies. However, only formal ontologies were integrated in the repository that were used to describe relations between a set of documents with the help of meta-data. Thus, no semantics were stored about the content of a specific document.

### 4.3.2 DSR Ontology Repository

Figure 4.3 delineates the ontology hierarchy that is used in the ontology repository of DSRCRSA. The two main formal ontologies that describe a core component of DSRCRSA are DSRKBO and DSRDCO. DSRKBO and DSRDCO describe T-Boxes that are used in the knowledge base (DSRKB) and document ontologies (DSRDOs) respectively. Thus, this section focuses on the introduction of these two ontologies (DSRDCO and DSRKBO).

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<sup>4</sup><http://fedorarepository.org/features>

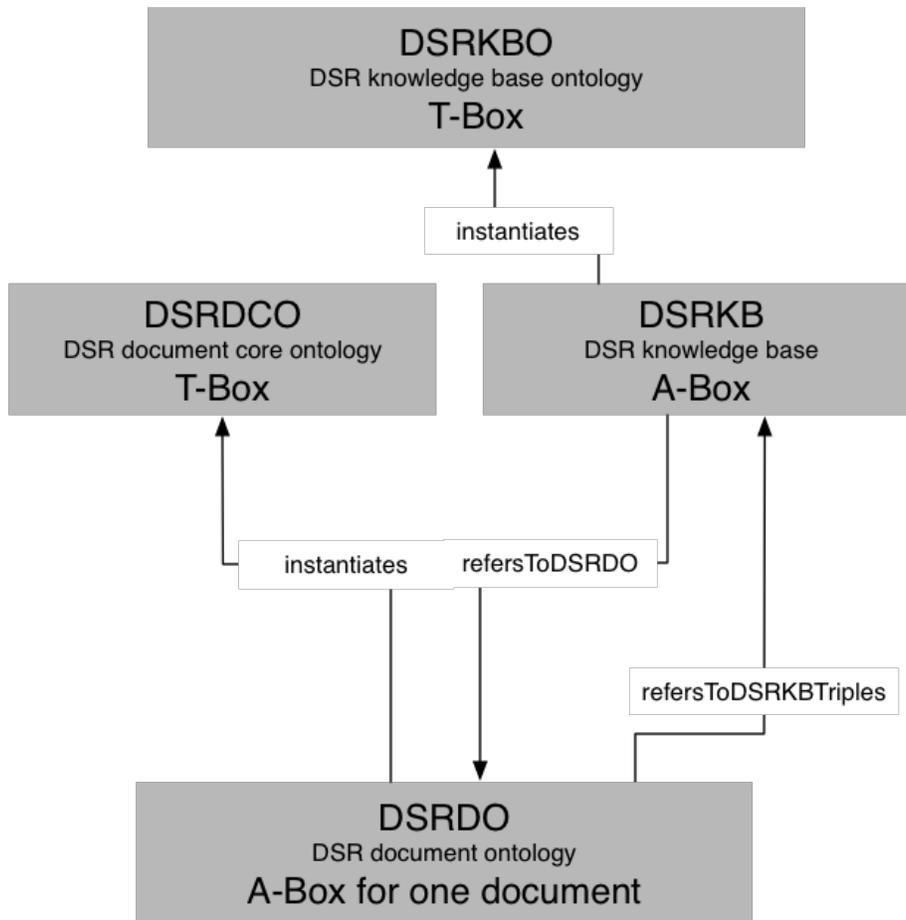


Figure 4.3: DSRCRSA ontology repository

#### 4.3.2.1 Architecture Structure

The proposed ontology repository utilises several ontology layers. Section 2.2.2 discussed the general differentiation between top-level ontology, core ontology, and domain ontology. This differentiation expresses different levels of detail, but also different uses of an ontology. The ontology repository follows a similar approach.

However, in this thesis, another set of layers are introduced. These layers are used to describe different properties of signs. These layers are a subset of the properties of signs that are discussed in Stamper et al. (2000). These properties are introduced to formally represent DSR publication content. The categorisation that is used in this thesis is based on the semiotic framework in Stamper et al. (2000), the rhetoric categories in Teufel and Moens (2002), as well as the semiotic triangle that is discussed in Sowa (2000) and originates from

Peirce.

The main intent of the proposed ontology repository architecture is to store formalised DSR content. To formalise DSR content that can be used to denote objects, the semiotic triangle (Sowa, 2000) needs to be expressed in the formal ontology. The semiotic triangle expresses that an object can be described by a symbol if a concept exists that connects the symbol with the object. Thus, an ontology repository that describes DSR publication content should be capable of describing concepts, as well as symbols to represent these concepts.

Burton-Jones et al. (2005) derived four qualities of ontologies that are based on the semiotic framework that is presented in Stamper (1996), Stamper et al. (2000), and Falkenberg et al. (1998) (see Section 2.2.8). This semiotic framework consists of six layers and each layer represents a certain property of signs. These six layers describe physical, empiric, syntactic, semantic, pragmatic, and social properties respectively. Sowa (2000) divided the field of semiotics (the study of signs) into three branches: syntax, semantics, and pragmatics.

This work focuses on the representation of DSR content that is presented in publications. Thus, social aspects that are represented in the social layer are not of interest in the representation of DSR publication content. A major aim of any publication is to affect the reader and ensure the reader makes use of the information that is presented in a DSR publication. However, this thesis focuses on the representation of single and multiple DSR publications, which excludes social aspects. Nevertheless, the ontology repository could be extended in future research projects to reflect the social aspects of signs.

The physical layer contains the written document itself (Falkenberg et al., 1998). Because the physical document itself does not have to be represented in the ontology that describes a DSR publication, this semiotic level is not of importance in this thesis.

Textual patterns, and statistics, which belong to the empirical level (Falkenberg et al., 1998), express and describe certain features that can be used to reason over conceptualisations that belong to the semantic level and therefore should be expressed in a design science research document core ontology (DSRD CO).

The syntactic level, semantic level, and pragmatic level are used to express the structure, the meaning of signs, and the usage of signs respectively.

Thus, the ontology repository architecture and the formal ontologies that are used in this architecture must be able to represent empirical properties of signs, syntactic properties of signs, semantic properties of signs, and pragmatic properties of signs.

#### 4.3.2.2 DSR Ontology Repository Design

The ontology repository architecture (see Figure 4.3) consists of four formal ontology components. These four ontology components are separated into A-Boxes and T-Boxes. DSRKBO and DSRDCO describe T-Boxes. These T-Boxes include axioms to provide reasoning capabilities. Additionally, the structures that are expressed in these T-Boxes are used to categorise individuals by as-

signing concepts that are described in the T-Boxes to individuals that appear in the text. These individuals are stored in separate ontologies that only consist of A-Boxes.

The concept hierarchies that are expressed in DSRKBO and DSRDCO serve as a structure that is utilised to categorise concepts that are expressed in a specific document. These concepts are then stored as individuals of concepts that are expressed in DSRDCO and DSRKBO. These individuals, together with the axioms and the concept hierarchies that are expressed in DSRDCO and DSRKBO, are used to reason high-level concepts out of low-level concepts. A high-level concept is inferred out of axioms that refer to lower-level concepts. Each DSRDO includes an A-box that describes a specific DSR publication and refers to classes in the T-Boxes (DSRDCO and DSRKBO).

Once a specific DSRDO has been created, DSRKB can be updated with concepts that are shared between a number of publications. Concepts that are shared between a number of publications appear in multiple DSRDOs.

This architecture includes a clear separation between A-Boxes and T-Boxes. This means that DSRDOs that contain assertions about specific publications refer to DSRDCO, but are stored in separate ontologies. This separation has the advantage that it is not necessary to include the whole T-Box of DSRDCO in all DSRDOs. Additionally, different versions of DSRDCO can be maintained at the same time.

This ontology repository enables the storage and development of a knowledge base that includes concepts that are shared between a number of publications. Such a knowledge base allows the comparison of ontologies at indexing time, which reduces the processing time in the information retrieval process.

Finally, the proposed T-Box ontologies are expressive enough to enable reasoning capabilities to deduce high-level concepts from low-level concepts (see Section 4.4).

**Ontologies Repository Components:** The ontology repository that is presented in Figure 4.3 consists of four components.

DSRKBO and DSRDCO provide the terminology that the other ontologies (DSRKB and DSRDOs) utilise to define the assertions.

DSRKBO provides the terminology that is used to define different contexts. Each context consists of a conceptualisation that can be identified in at least two publications.

DSRDCO conceptualises the topic of DSR and includes a conceptualisation to describe the content of publications. The purpose of this ontology is to provide a structure that can be instantiated with the content of a specific DSR publication. DSRDCO not only provides a terminology to conceptualise DSR content, but also consists of reasoning capabilities that can be used in the indexing process, and also in the information extraction process.

DSRKB and DSRDO solely consist of assertions. These assertions refer to DSRKBO and DSRDCO respectively.

DSRKB stores assertions that describe different contexts. Once a context

can be identified, the conceptualisation that describes this context is moved from the document ontology into the knowledge base. Nevertheless, all assertions that previously existed in the document ontology are preserved by creating the same assertions in the knowledge base. This enables a comprehensive knowledge base that covers the most important DSR concepts that are discussed in the corpus of publications.

DSRDO is designed to store DSR content that appears in a specific DSR publication. Besides DSR concepts, this ontology also stores document structure-related information.

### 4.3.3 DSRDCO

This section describes the design of the design science research document core ontology (DSRDCO). The structure of this section follows the applied ontology engineering methodology.

First, the requirements are described. Requirements usually consist of statements that are then converted to competency questions.

Second, the literature that consists of formal ontology publications but also formal ontology specifications is reviewed to identify formal ontologies that describe the content of documents.

Third, the concept hierarchy is described. This concept hierarchy should comprehensively describe the topic of DSR publications.

Fourth, a glossary is presented to provide definitions of the concepts that have been identified.

Fifth, predicates are described to highlight the relations this formal ontology can express.

Sixth, complex classes are discussed that enable the identification of higher-level concepts. Each level includes concepts that correspond to the specific property layer of signs.

Lastly, competency questions are discussed. These competency questions are based on the identified requirements and can be used to evaluate the formal ontology.

#### 4.3.3.1 Requirements

DSRDCO has to fulfil two requirements. Firstly, DSRDCO has to be able to describe DSR publication content. Secondly, DSRDCO has to represent the topic of DSR.

A formalised representation, if generated correctly, enables reasoning over DSR content. Reasoning capabilities enable search capabilities, but more importantly, reasoning capabilities enable the comparison and combination of multiple DSRDOs.

The representation of DSR is needed to summarise salient DSR concepts in DSR publications.

### 4.3.3.2 Ontology Reuse

Formal ontologies are reused to provide interconnectivity between different systems. Ontology reuse also reduces the amount of formal ontologies that can be found on the semantic web. In addition to that, the same conceptualisation does not have to be reinvented. However, sometimes there exist reasons for reinventing a specific conceptualisation as discussed in Section 2.2.6.

The design of DSRDCO included the search for document ontologies that enable the formal conceptualisation of publication content. A discussion of different document ontologies in the literature can be found in Section 2.2.7.

Section 2.2.7 discussed the DoCo ontology (Constantin et al., 2016). The DoCo ontology includes a conceptualisation to describe documents, which can also be used for scientific publications. Thus, the DoCo ontology was integrated into DSRDCO. However, only concepts that express rhetorical information, such as ‘contribution’, ‘discussion’, ‘evaluation’, and ‘scenario’, are reused in this thesis.

### 4.3.3.3 Concept Hierarchy

The concept hierarchy of DSRDCO serves two purposes. (1) The concept hierarchy needs to be able to sufficiently describe DSR content that is presented in DSR publications. (2) The concept hierarchy of DSRDCO needs to conceptualise components of generic scientific articles.

A conceptualisation of DSR solves the problem of generating coherent DSR summaries. Such a DSR concept hierarchy (in combination with a set of axioms) enables the generation of overview summaries that discuss the most important DSR concepts. DSRDCO concept hierarchy has to support the population of DSR concepts that frequently appear in DSR publications.

The concept hierarchy that describes the structure of scientific articles is used to represent the syntactic representation of signs. This representation supports the extraction of higher-level concepts.

**DSR Concept Hierarchy:** The DSR concept hierarchy was analysed by utilising a top-down as well as a bottom-up approach. The following paragraphs with the headings “Top-Down Approach” and “Bottom-Up Approach” describe these two approaches and discuss the final version of DSRDCO. Both steps were executed in a number of iterations.

**Top-Down Approach:** In the top-down approach, concepts were identified from the DSR literature that discusses various aspects of DSR. Some important examples of DSR literature include Vaishnavi and Kuechler (2015), Hevner et al. (2004), Peffers et al. (2007), Walls et al. (1992), Gregor and Jones (2007), Gregor and Hevner (2013), Baskerville and Pries-Heje (2010), and Sein et al. (2011). Further information about the literature review process can be found in Section 2.5.

Important DSR concepts were identified by extracting salient concepts out of DSR publications that discuss DSR concepts. If these concepts are frequently used or discussed in other authors' work, a concept was identified as salient in regard to DSR. Additionally, several informal discussions with DSR experts concluded the identification of DSR concepts. Finally, a summative evaluation showed (see Section 5.2) that DSR experts predominantly agree on the choice of DSR concepts.

The top-down approach resulted in a list of important DSR concepts. Figure 4.4 delineates these DSRDCO concepts. This figure was presented at the DESRIST 2015 conference in Dublin / Ireland.



The following paragraphs briefly highlight salient DSR concepts before they are described in more detail in Section 4.3.3.4.

DSR involves the design of purposeful artefacts. Thus, most DSR literature mentions the concept ‘artefact’ as an integral component of DSR projects and DSR publications. However, an artefact can be more or less abstract (see Section 4.3.3.4). Design theory, artefact design, and design realisation are all subclasses of the concept ‘artefact’. A design theory describes a more abstract form of an artefact, a specific artefact design is a more concrete instantiation of the concept ‘artefact’, whereas a design realisation is a concrete instantiation of the concept ‘artefact’. There is much discussion amongst proponents of DSR on whether the main output of a DSR should be an artefact design or a design theory. However, there is an agreement between proponents of DSR that an artefact design is a less abstract output of DSR than is a design theory.

Another salient concept is the concept ‘design’. A design can be described by concept ‘artefact’. A design can express a method that creates a certain design realisation or a product that describes what a certain design realisation should be composed of to fulfil a set of requirements.

The concept ‘requirement’ is another essential concept that is used to describe the requirements that a specific artefact should fulfil. A design theory can be expressed by describing a utility relationship between an artefact design and a set of meta-requirements. The DSR literature differentiates between requirement and meta-requirements, which is further discussed in Section 4.3.3.4.

‘Kernel theory’ is another concept that created disagreement amongst DSR proponents. Some researchers treat kernel theory as an optional component of DSR, other researchers see kernel theory as a mandatory aspect in a DSR project. However, researchers that do not necessarily see kernel theory as a mandatory component of a DSR project do agree that ‘kernel theory’ can be used to justify a certain DSR outcome if, and only if, the ‘kernel theory’ has a significant influence on the artefact design. If a kernel theory is used to justify a specific design theory, it should also be mentioned in a conceptualisation of DSR publication content.

Most DSR literature that discusses research that follows the DSR paradigm describe design realisations that provide evidence for the utility of a specific artefact design. Design realisations are instantiations of artefact designs. Design realisations showcase the feasibility of the proposed artefact designs. Design realisations are often used as evaluands in an evaluation that should provide evidence that the artefact design fulfils the requirements that were identified in the requirements phase.

Finally, any piece of research should include a rigorous evaluation. Thus, the concept ‘evaluation’ has to be expressed in any DSR project and has to be included in a conceptualisation of DSR. However, as discussed in the following paragraph titled “Bottom-Up Approach”, the concept ‘evaluation’ does not suffice to properly describe the evaluation of a specific artefact.

**Bottom-Up Approach:** The bottom-up approach was used to extract salient DSR publication concepts out of nine DSR publications.

The nine publications had to meet the following selection criteria. All articles discuss an artefact that was proposed as a solution to a general problem. Each article was published in a quality journal or in the proceedings of a quality conference. The articles did not necessarily have to refer to DSR as a research methodology. The papers that were chosen were [Reiterer \(2013\)](#), [Bloehdorn et al. \(2007\)](#), [Pries-Heje and Baskerville \(2008\)](#), [Alani et al. \(2003\)](#), [Castells et al. \(2007\)](#), [Ding et al. \(2004\)](#), [Giannakopoulos et al. \(2014\)](#), [Holub et al. \(2014\)](#), and [Völske et al. \(2014\)](#).

Figure 4.5 delineates the bottom-up extraction process.

## Bottom - Up Approach

DSR conceptualisation based on literature that follows DSR

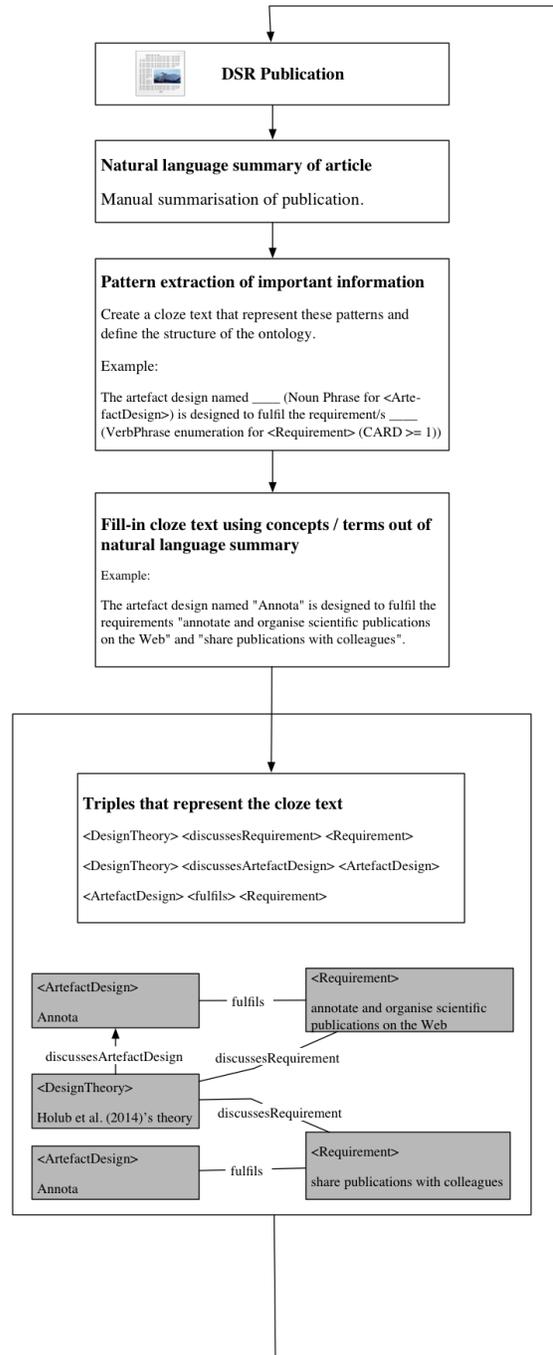


Figure 4.5: DSRDCO design - bottom-up approach

Natural language summaries were manually generated out of these nine publications. These manual summaries were filled into a number of predefined cloze text sentences. These cloze text sentences include gaps that were required to be filled by instantiations of concepts that were previously identified in the top-down approach. If there was no cloze text sentence available to express a specific statement that appeared in the manual summary, concepts as well as cloze text sentences needed to be identified and added to DSRDCO.

This process uncovered the fact that concepts were missing that describe interactions between artefact components, but also that concepts were missing that further describe the evaluation of a specific design artefact.

Interactions between artefacts or artefact components can be expressed by the output or input of the involved artefacts. Such interaction artefacts are themselves of the type ‘artefact design’. Thus, there was no need to add another concept to DSRDCO. However, it is possible that specific artefact designs need to appear in a certain sequence. Both artefact inputs and outputs as well as sequences can be expressed by data properties.

In regards to the evaluation of a specific artefact, several concepts needed to be added to DSRDCO to sufficiently describe evaluation settings as well as the evaluation results and evaluation techniques. Additionally, evaluation criteria had to be clearly identified and expressed to relate these criteria to the requirements of the artefact design. Evaluation results express a certain outcome that is of use to describe quantitative evaluation results as well as qualitative evaluation results. Lastly, evaluations are executed in a specific setting. An evaluation setting includes an evaluation technique, evaluation criteria, evaluation metrics, as well as evaluation results.

**Scientific Publication Conceptualisation:** A formal ontology that conceptualises DSR content that is expressed in scientific publications can include information about the document structure as well as rhetorical categories. Such information can, as presented in this thesis, support the identification of higher-level concepts, such as the instantiations of DSR concepts. Additionally, such low-level expressions provide a structure that higher-level instantiations (i.e. instantiations of DSR concepts) can use to refer to the actual document that a specific instantiation has been extracted from.

The development of conceptualisations of scientific documents has been executed in multiple iterations. Throughout these iterations, new work in the field of document ontologies has been published. One publication that is closely related to the conceptualisation of scientific publication content is described in the work by [Constantin et al. \(2016\)](#). However, the first iterations of the artefact design process were concerned with the development of a new formal ontology to express information in scientific publications. This work resulted in a conceptualisation that focuses on the description of things, objects, and properties that appear in a certain document. Things, objects, and properties are low-level concepts to express information that is presented in a certain article. The document ontology DoCo ([Constantin et al., 2016](#)) includes higher-level

concepts, such as evaluation, discussion, and motivation, which can be defined by expressions that involve lower-level concepts.

Additionally, rhetorical aspects have been identified to describe claims and to provide support for these claims, including warrants and backings, as described in [Toulmin et al. \(1984\)](#). Nevertheless, the rhetorical categories in DoCo are sufficient to answer the competency questions of a formal ontology that is used to identify and describe DSR concepts. Nevertheless, future research might extend this conceptualisation to increase the accuracy of identified instances of DSR concepts or lower-level concepts.

DoCo also serves as a structure to formalise the content of publications that is stored in a PDF format. The process that is published in [Constantin et al. \(2013\)](#) extracts DoCo concepts that cannot be used in the approach that is discussed in this thesis. However, DoCo was chosen in this research to enable the exchange of information between different systems that support or integrate DoCo.

#### 4.3.3.4 Glossary

A formal ontology has to contain a terminology of classes and properties that are unambiguous to the user. Unambiguous components increase the correct use of the proposed ontology. This section provides definitions of main components of DSRDCO. Definitions of these components can be found in the OWL DSRDCO representation that can be downloaded from the prototype web page <sup>5</sup>. This section contains definitions of salient DSRDCO concepts. DSRDCO object properties (or predicates) are discussed in Section [4.3.3.5](#).

#### DSR Aspects:

**Artefact Hierarchy:** Instantiations of the concept ‘artefact’ represent either more abstract or more concrete artefacts. Three important subclasses of the concept ‘artefact’ in DSR express artefacts at different levels of abstraction. These subclasses of the concept ‘artefact’ are ‘design realisation’, ‘artefact design’, and ‘design theory’. Figure [4.6](#) delineates the artefact hierarchy that is used in this research.

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<sup>5</sup><https://git.et-innovations.org/java/dsrcrsa-curtin/tree/master/rdf/v2.2>

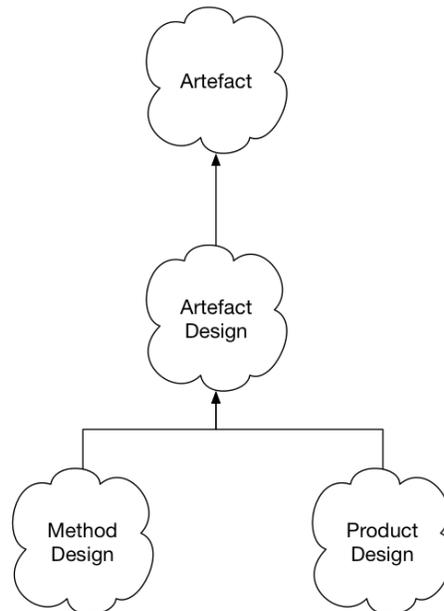


Figure 4.6: Artefact hierarchy

**Artefact:** An artefact describes a tangible concept of something that is artificial, human made. Merriam-Webster defines an artefact as “something characteristic of or resulting from a particular human institution, period, trend, or individual”<sup>6</sup>.

An artefact is something artificial, human made. It can be a product or a method. An artefact should have utility. Hevner et al. (2004) described IT artefacts as constructs, models, methods, and instantiations. Constructs include important vocabularies and symbols. Models include abstractions and representations. Methods include algorithms and practices. Instantiations include prototype systems. All of these four components can be expressed utilising DSRDCO.

Artefacts have to have utility and a purpose. Artefacts need to fulfil a set of requirements to provide evidence for the utility of an artefact. Whether an artefact fulfils its requirements has to be evaluated in an evaluation.

Gregor and Jones (2007) defined an artefact as a technological product or managerial intervention. However, in this thesis, an artefact can describe anything that results from a human institution.

An artefact is used to describe something that is artificial or constructed by humans as opposed to something that occurs naturally (Simon, 1996).

<sup>6</sup><https://www.merriam-webster.com/dictionary/artifact>

Gregor and Jones (2007) applied Aristotle's four causes to any artefact. Aristotle's four causes include the *causa finalis*, the *causa formalis*, the *causa materialis*, and the *causa efficiens* (Gregor and Jones, 2007). Gregor and Jones (2007) interpreted the *causa finalis* as the final cause of an artefact, the *causa formalis* as the formal cause or essence of an artefact, the *causa materialis* as the material an artefact is made from, and the *causa efficiens* as the creator of an artefact. These four causes should be included in the description of an artefact and are expressed in DSRDCO.

**Design Theory:** In DSR, a design theory expresses a theory that prescribes the form and functions of an artefact. Additionally, a design theory prescribes how a design realisation can be implemented. Design theory belongs to one of the five theories in Gregor (2006), which they termed 'theory for design and action'. A design theory is more valuable if it can be applied to a wider class of system. However, design theories that are too abstract and that include a vague set of meta-requirements might be too generic to be of any value.

Form and function, and implementation prescriptions can be expressed as design principles. Principles are prescriptive statements (Chandra Kruse et al., 2016).

Besides principles of form and function, and principles of implementation, a design theory includes components that do not directly describe the design artefact.

The design theory components that are used in DSRDCO are a subset of the eight components that are expressed in Gregor and Jones (2007).

However, DSRDCO does not include the components 'artefact mutability' and 'construct' that are proposed in Gregor and Jones (2007). DSRDCO provides a conceptualisation that should be capable of identifying artefact mutability by identifying differences between artefacts in different DSR publications. Thus, it is possible to generate this information from DSRDCO. However, this is a limitation of this research and a suggestion for further research on this topic.

Constructs are "representations of entities of interest in the theory" (Gregor and Jones, 2007). Such representations can be expressed utilising DSRKBO (see Section 4.3.4) and are therefore not represented in DSRDCO.

Design theory components that are included in DSRDCO are purpose and scope, testable propositions, kernel theories, and expository instantiations. Statements about purpose and scope provide information about the boundaries of the artefact. Testable propositions express a set of meta-requirements that an artefact design has to fulfil. Kernel theories can be used to justify a certain theory. Expository instantiations are design realisations that are often utilised as evaluands in an evaluation.

**Artefact Design:** An artefact design is a subclass of the concept 'artefact'. An artefact design is an abstract artefact that describes the design of a product or a method. An artefact design should have utility. A utility relationship

describes a relation that expresses that an artefact design fulfils a set of meta-requirements.

As a specialisation of the concept ‘artefact’, an artefact design needs to express a design rather than a theory or a design realisation. A design theory depicts a more abstract artefact than an artefact design. However, a design theory can include an artefact design in the discussion. An artefact design can be used to, for example, express some limitations of a theory. For instance, a theory might express that it is only applicable to artefact designs that describe moving objects. A materialised artefact (design realisation) is a concrete implementation of an artefact design. A design realisation can be the evaluand of a certain artefact design.

An artefact design includes statements about the implementation of a design realisation or statements that describe the form and function of a specific design realisation. Such statements are called design principles.

**Method Design:** A method design is a subclass of the concept ‘artefact design’ and describes principles of implementation. Principles of implementation prescribe steps that have to be carried out to create a specific design realisation.

**Product Design:** A product design is a subclass of the concept ‘artefact design’ and describes principles of form and function. Principles of form and function prescribe components and functions that a design realisation has to implement. It is only if these principles of form and functions are properly implemented in a design realisation that a design realisation can be said to have successfully implemented a product design.

**Design Realisation:** A design realisation is an instantiation of a specific artefact design. A design realisation has to follow prescriptive statements of form and function and implementation. A design realisation that has been correctly implemented can be used as an evaluand that provides evidence for the utility of a specific artefact design.

**Requirement:** A requirement can be expressed as a statement that states what an artefact design should fulfil. A requirement describes a class of goals or a specific goal that has to be met by the design artefact. A theory applies to a class of goals or meta-requirements. In a DSR project, artefacts need to be evaluated against a set of requirements. A purpose, on the other hand, describes a general goal that a specific artefact is invented for. A requirement is a goal that becomes an objective of a specific research project, which is not necessarily the purpose of a specific artefact.

**Kernel Theory:** A kernel theory is a theory in natural science or behavioural science that justifies the artefact design (Gregor and Jones, 2007). In a DSR publication, a kernel theory is usually expressed as a reference to another artefact or observation that is included in another publication.

**Evaluation Scenario:** Rigorous evaluation is a key aspect in DSR. In DSR, the utility of an artefact is evaluated against a set of criteria. In a DSR project, there might exist one or more evaluation scenarios. Each evaluation scenario evaluates a specific set of criteria. Each scenario might also use a specific evaluation method. Each criterion evaluates a specific requirement of the researched artefact design.

**Evaluation Method:** An evaluation method is used to systematically acquire and assess information about an artefact. An evaluation method is applied in a specific evaluation setting. An evaluation method assesses whether a set of criteria are met and returns an evaluation result.

**Evaluation Criterion:** An evaluation criterion is described by an assertion that should provide evidence of the utility of an artefact towards a specific requirement.

**Evaluation Result:** An evaluation result consists of a statement that includes evaluation criteria and a discussion on why these criteria have been met. Such a statement might include measurable results, as in quantitative methods, or conclusions that can be deduced out of a qualitative method.

**Evaluation Metric:** Most DSR projects are evaluated qualitatively. Thus, evaluation metrics are not as important as in other areas of research. However, DSR can also include quantitative components. Evaluation metrics further specify an evaluation criterion.

**Scientific Publication Concepts:** DSRDCO includes three concepts that represent concepts of the syntactic layer. These syntactic layer concepts can be used to refer to content in DSR publications. These concepts are the concepts ‘argument’, ‘predicate’, and ‘property’.

**Argument:** The root element of a formal ontology is called ‘thing’. A ‘thing’ can be syntactically expressed utilising a predicate argument structure. At concept extraction time, a document consists of a set of predicate argument structures. A predicate is a function over a set of arguments.

**Property:** A property is a predicate argument structure that describes characteristics of a subject that has been identified in a specific document. Such characteristics further define a specific object that appears in a document and can be an argument in a specific argument structure. A property can be an adjective as well as complete predicate argument structures that express a certain property.

**Predicate:** Predicates are used in statements to express the relation between a number of arguments. Predicates can help to identify a certain concept. For instance, machine learning or pattern identification techniques could be used to identify predicates that enable the identification of a specific higher-level concept.

#### 4.3.3.5 Properties

In formal ontologies, properties are expressions that describe relations in regards to objects (object properties) or literals (data properties).

The identification of object properties was executed in two steps. Firstly, object properties were identified that describe relations between DSR concepts that were identified in the literature. Secondly, indexing and information extraction related object properties were identified to support these two processes.

The discussed object properties below depict a selection of the object properties in DSRDCO. A list of all object properties can be found in the OWL ontology on the prototype web page <sup>7</sup>. Inverse object properties were defined for all object properties in DSRDCO.

Data properties are not described in this section. Data properties in DSRDCO were defined to store, for instance, sequences of concepts, or lexical representations of sentences and terms. The data properties of DSRDCO can be found on the prototype web page <sup>8</sup>.

#### DSR Specific Object Properties:

**fulfilsRequirement:** This object property describes the utility relationship between an artefact design and a set of requirements.

A utility relationship states the utility of a specific artefact. Only if an artefact fulfils its predefined requirements does an artefact design show utility in regards to these requirements.

**designTheoryIncludesArtefact:** This object property describes the relationship between the artefact and the design theory that the artefact belongs to. A design theory presents a theory that involves a specific artefact design.

**designTheoryIncludesRequirement:** A design theory is valid within a certain scope. Such a scope can be expressed by a set of meta-requirements. Thus, a design theory includes a set of requirements.

**includes:** The includes relationship is used to represent part-whole relationships. The object property includes and its sub-properties are used to describe artefact components or sub-requirements.

<sup>7</sup><https://git.et-innovations.org/java/dsrcsa-curtin/tree/master/rdf/v2.2>

<sup>8</sup><https://git.et-innovations.org/java/dsrcsa-curtin/tree/master/rdf/v2.2>

**Competency Question Related Relations:** Several object properties were added as a result of evaluations. These evaluations included the identification of whether the ontology can answer a set of competency questions. The competency questions that evaluate DSRDCO are discussed in Section 4.3.3.6.

Below are some examples of object properties and data properties that have to be added to DSRDCO to sufficiently answer the competency questions that are defined in Section 4.3.3.6 and Section 4.3.4.5.

In addition to part-whole relationships, the object properties ‘broader’ and ‘narrower’ were included in DSRDCO. The object properties ‘narrower’ and ‘broader’ were introduced to present a hierarchy of concepts. These object properties are defined in SKOS, the simple knowledge organisation system<sup>9</sup>.

Object properties, such as ‘isInstantiatedIn’ and ‘isEvaluatedIn’, were introduced to relate design realisations, and evaluations to a specific artefact.

Data properties were added to enable the summarisation and combination of a specific component.

A full list of object properties can be found on the prototype web page<sup>10</sup>.

#### 4.3.3.6 Competency Questions

Competency questions are requirements that a specific ontology has to fulfil. If a formal ontology can answer its competency questions, it can be used within the defined scope that is expressed by these competency questions. However, competency questions should not result in a simple search query; rather, they should include queries that involve different axioms of a formal ontology.

This work is concerned with the extraction of information from formal ontologies, as well as the identification of higher-level concepts that are assigned to different semiotic layers.

The requirements of DSRDCO are determined by the identified requirements and user stories of researchers. These requirements include the retrieval of information out of DSR publications, as well as the combination of information that then result in a natural language summary.

This section covers competency questions that identify information that is related to a single DSR article because DSRDCO is meant to be used to represent a single document.

**Thesis Statement:** The thesis statement is a main component of a DSR article and should be included in a summary. The thesis statement includes the most salient concepts of a DSR publication.

The competency question can be phrased as follows: “What is the thesis statement of this document?”

This competency question searches for artefacts and the requirements that a specific artefact fulfils. A thesis statement also includes a brief description of the artefact. Finally, a thesis statement includes statements about the practical and theoretical significance of a specific artefact.

<sup>9</sup><https://www.w3.org/2004/02/skos/>

<sup>10</sup><https://git.et-innovations.org/java/dsrcsa-curtin/tree/master/rdf/v2.2>

A SPARQL query that extracts the thesis statement of a specific document includes three components: a utility relationship between artefact and requirement, the first-level components of an artefact design, and statements about the significance of an artefact.

Algorithm 4.1 delineates the SPARQL query to select an artefact and its requirements.

---

**Algorithm 4.1** SPARQL query to select an artefact and its requirements

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco:
  <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

SELECT ?artefact ?requirement WHERE
{
  ?artefact rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?artefact dsrdco:isResearchedArtefact ?rootArtefact .
  ?requirement rdf:type dsrdco:Requirement .
  ?artefact dsrdco:fulfills ?requirement .
  filter(regex(?rootArtefact, "true"))
}

```

---

SPARQL queries that extract significance statements or the components of an artefact can be found below.

**Artefact Description:** A brief description of an artefact is often included in the thesis statement. A brief artefact description includes a high-level description of a specific artefact. A high-level description includes the name of the artefact in addition to high-level properties.

The competency question to retrieve an artefact description is as follows: “What is the high level description of an artefact?”.

Algorithm 4.2 presents the SPARQL query to extract arguments that further describe a specific artefact. These arguments can be used to construct the description of an artefact.

---

**Algorithm 4.2** SPARQL query to select artefact components

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

SELECT ?artefact ?p WHERE
{
  ?p rdf:type dsrdco:Property .
  ?p dsrdco:isPropertyOf ?artefact .
  ?artefact rdf:type/rdfs:subClassOf* dsrdco:Artefact
}

```

---

**Significance:** A statement about the significance of an artefact is comprised of a claim that expresses the importance of a specific piece of work. A practical significance statement expresses the importance of a specific artefact in practice, whereas the theoretical significance refers to the literature to identify advantages in comparison to other artefacts that serve a similar purpose.

The competency question is as follows: “What is the importance of the proposed artefact (or artefact component)?”

Algorithm 4.3 delineates the SPARQL query to extract significance statements in relation to an artefact component.

---

**Algorithm 4.3** SPARQL query to select significance statement

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

Select ?artefact ?claim where
{
  ?ts rdf:type/rdfs:subClassOf* dsrdco:TheoreticalSignificance .
  ?ts dsrdco:refersTo ?artefact .
  ?artefact rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?ts dsrdco:includesTSClaim ?claim
}

```

---

**Components:** The components of an artefact describe the structure of an artefact in more detail.

DSRDco has to answer the following competency question: “What are the components of the artefact?”

Algorithm 4.4 presents the SPARQL query to answer this competency question is.

---

**Algorithm 4.4** SPARQL query to retrieve artefact components
 

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

SELECT ?parent ?child WHERE
{
  ?parent rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?child rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?child dsrdco:partOfArtefact ?parent
}
order by ?parent

```

---

**Evaluand:** In DSR, an evaluand is often expressed as a design realisation. An evaluation method evaluates the design realisation (or evaluand). A design realisation is a subclass of the concept ‘artefact’.

DSRDco should be able to identify an evaluand of a specific evaluation method in a specific evaluation setting.

The competency question is as follows: “What are the evaluands that were used in a specific evaluation settings and a specific evaluation method?”

Algorithm 4.5 depicts the SPARQL query that answers the competency question.

---

**Algorithm 4.5** SPARQL query to extract evaluands
 

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

SELECT ?artefact ?setting ?method ?evaluand WHERE
{
  ?artefact rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?artefact dsrdco:isEvaluatedIn ?setting .
  ?setting dsrdco:hasEvaluand ?evaluand .
  ?setting dsrdco:utilises ?method
}

```

---

**Evaluation Result:** A DSR project yields certain results. The main DSR project results are artefact designs, principles, or design theories. An evaluation result should confirm or reject that the artefact design fulfils its requirements. Evaluation results are usually returned in the form of statements that express why the requirements have been fulfilled.

The competency question is expressed as follows: “What are the evaluation results in this research?”

Algorithm 4.6 depicts the SPARQL query that returns evaluation results for a specific artefact, and evaluation setting.

---

**Algorithm 4.6** SPARQL query to extract evaluation results

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>

SELECT ?setting ?result WHERE
{
  ?artefact rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  ?artefact dsrdco:isEvaluatedIn ?setting .
  ?setting dsrdco:producedResult ?result
}

```

---

#### 4.3.4 DSRKBO

The design science research knowledge base ontology (DSRKBO) is designed to store and aggregate knowledge that is encoded in design science research document ontologies (DSRDOs). The design science research knowledge base (DSRKB) and DSRDOs instantiate concepts of the design science research knowledge base ontology (DSRKBO) and the design science research document core ontology (DSRDco).

DSRKB’s intent is to conceptualise different interpretations (world states) of concepts. Each interpretation is described by a context.

DSRKBO uses the relations ‘broader’ and ‘narrower’, which are included in the SKOS (Simple Knowledge Organisation System) ontology. A concept (C1) is ‘broader’ than another concept (C2) if C1 includes C2. C1 is a more abstract presentation of the lower-level concept C2. The relation ‘narrower’ is the inverse of the relation ‘broader’.

SKOS, as well as DSRKBO, are designed to organise knowledge. However, this thesis provides a structure that can be used to describe concepts utilising layers of the semiotic framework. Additionally, DSRKBO enables the representation of contexts to state different interpretations of a specific concept. Thus, SKOS was extended to allow a more fine-grained concept organisation. For in-

stance, the introduction of concepts that can be used to describe different layers of the semiotic framework (Stamper, 1996) is not possible with SKOS. However, these layers are crucial concepts in DSRCRSA to support the reasoning process.

#### 4.3.4.1 Requirements

Chapter 5 (Artefact Evaluation) provides evidence that shows that DSRCRSA is designed to store formal conceptualisations of DSR publications and to provide a knowledge-base of DSR project concepts. Additionally, the evaluation chapter also shows that DSRCRSA is capable of providing search result presentations. Section 4.5 supports this claim by delineating that this architecture is capable of providing automatically generated natural language summaries of single and multiple documents.

DSRCRSA maintains a knowledge-base that is capable of describing and combining several formal conceptualisations of DSR publications. Thus, it was necessary to design a formal ontology that is capable of describing relations between DSR conceptualisations (DSRDOs).

Thus, the requirements of the proposed DSR knowledge base ontology (DSRKBO) are as follows. DSRKBO should

- be capable of expressing relations between concepts that are stored in different DSRDOs.
- be capable of describing different contexts. Each context is included in multiple DSRDOs.
- be capable of describing probabilities that express the likelihood that a reference concept or a context fits to a concept in a DSRDO.

#### 4.3.4.2 Concept Hierarchy

The purpose of DSRKBO is twofold. Firstly, DSRKBO provides the terminology to maintain a DSR knowledge base. Secondly, DSRKBO provides the terminology to express reference concepts or contexts that can be used to refer to DSRDOs.

The concept ‘context’ is used to describe a specific interpretation of a specific concept. Each context is represented by a sub-graph of DSRKB.

To describe a certain context, the concepts ‘context’, ‘reference concept’, and ‘reference concept assertion’ were introduced.

A reference concept is part of a specific context. The concept ‘reference concept’ can also be used to express the root concept that is defined within a certain context. A root concept represents a certain context. The concept ‘context’ includes elements that belong to a specific context. Reference concepts can be included in multiple contexts.

The concepts ‘context’ and ‘reference concept’ are subclasses of the SKOS concept ‘concept’.

A reference concept relates to concepts in DSRDOs. There are two ways to describe such relations in DSRKBO.

The first technique to describe relations between reference concepts and DSRDO concepts is to utilise the concept ‘reference concept assertion’. The concept ‘reference concept assertion’ can be used to express a relation between a reference concept and a certain concept in a DSRDO. In addition to the relation between a reference concept and a DSRDO concept, a probability can be expressed. This probability describes the likelihood that a specific concept in a DSRDO equals a specific reference concept in DSRKB.

The second technique to store relations between reference concepts and DSRDO concepts is to use the SKOS concepts ‘broader’ and ‘narrower’. These two concepts enable the expression of narrower transitives and broader transitives between two concepts. In comparison to the first technique, the second technique does not need a metric to express the similarity between two concepts. However, the second technique cannot be as exact as the first technique. Nevertheless, in many applications the SKOS relations ‘broader’ and ‘narrower’ sufficiently describe relations between reference concepts and DSRDOs, such as in the summarisation of multiple DSR publications.

#### 4.3.4.3 Glossary

This glossary describes the most important concepts in DSRKBO. Concepts that appear in the SKOS <sup>11</sup> ontology are not included in this glossary.

**Context:** The concept ‘context’ is a subclass of the SKOS concept ‘concept scheme’.

A context describes a world state of a specific concept. The concept ‘context’ consists of a number of reference concepts. These reference concepts refer to concepts in DSRDOs.

Each context includes a reference concept that expresses the global concept that is described in a certain context.

A context in DSRKBO needs to be reflected in at least two DSRDOs. However, each DSRDO only refers to a context to a certain degree.

Thus, a level of uncertainty has to be defined to express how likely it is that a certain reference concept (or context) relates to a DSRDO. This information is stored in instantiations of the concept ‘reference concept assertion’.

**Reference Concept:** The concept ‘reference concept’ describes concepts in the knowledge base that have a counterpart in at least two DSRDOs.

Reference concepts have to be broader than concepts in a DSRDO.

Reference concepts are the building blocks of a specific context. Each context consists of a number of reference concepts. Each reference concept is of type ‘ReferenceConcept’. However, each reference concept is also an instantiation of a concept in DSRDCO, such as ‘ArtefactDesign’ or ‘Requirement’. DSRDCO type has to conform to the type of the instantiation in a specific DSRDO that a specific reference concept refers to.

<sup>11</sup><https://www.w3.org/2004/02/skos/intro>

‘Reference concept’ is a subclass of the SKOS concept ‘concept’.

**Reference Concept assertion:** A reference concept assertion relates a specific reference concept to a concept in a DSRDO. A reference concept assertion also expresses the probability that defines the likelihood that a reference concept is related to another concept in DSRDO.

**DSRDCO Terminology:** DSRKBO imports DSRDCO. This means that the whole terminology of DSRDCO can be utilised in the knowledge base.

#### 4.3.4.4 Properties

The following object properties were defined to express the relations between a DSRKBO and a DSRDCO.

Firstly, relations between reference concepts and their counterparts in the DSKBO have to be created. The object properties that are capable of providing this information are the SKOS object properties ‘narrower’ and ‘broader’. A more detailed definition of such a relation can be achieved by the use of the concept ‘reference concept assertion’. Reference concept assertions include a data property that expresses how well a reference concept and concepts that are expressed in a document ontology are related to each other. In addition to instantiations of the concept ‘reference concept assertion’ the object properties ‘narrower’ and ‘broader’ describe another way to relate two concepts. However, reference concept assertions open up other reasoning capabilities. A reference concept assertion defines the similarity between two concepts. The object properties ‘narrower’ and ‘broader’ express a more general relationship between a reference concept and a DSRDCO concept.

The object property ‘narrower’ is used to refer to concepts that are narrower in scope. A reference concept that refers to a concept in a DSRDO has to be broader in scope. A DSRDO concept refers to a reference concept using the object property ‘broader’, whereas a reference concept relates to a DSRDO concept using the inverse object property ‘narrower’.

Secondly, all object properties that can be used in DSRDCO are also available in DSRKB. This enables the conceptualisation of contexts.

The data property ‘hasProbability’ can be applied to a reference concept assertion concept.

#### 4.3.4.5 Competency Questions

The specification of DSRKBO includes competency questions that are related to indexing and information extraction (IE) processes that affect the knowledge base. This section focuses on the IE process. However, due to the semiotic framework that is used in the proposed ontologies (see Section 4.4), the proposed competency questions also reflect the indexing process to some extent. For instance, a literal cannot be extracted if the reasoner is unable to retrieve literals out of syntactic information in the ontology.

The IE process involves DSRKB in the identification of similar and dissimilar concepts. Competency questions that are related to the IE process can be expressed as multi-document summaries. However, answers to IE related competency questions can be adapted and / or reused by other applications.

DSRKB has to be able to answer the following competency questions.

**Shared Artefact Components:** This competency question aims to identify artefact components that are shared between a number of artefact designs. These components can be used to summarise similarities between several artefact designs or DSR document ontologies.

The competency question, expressed in natural language, is stated as follows: What are the artefact design components that are shared between a number of artefact designs?

Similar concepts can be identified by utilising reference concepts. The SPARQL query that returns similar artefact components can either make use of the `skos:narrower` object properties (and its inverse object property ‘`skos:broader`’) or make use of similarity assertions.

The following SPARQL query (Algorithm 4.7) makes use of the `skos` object property ‘`narrower`’.

---

**Algorithm 4.7** SPARQL query to retrieve shared concepts utilising `skos:narrower`

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>

SELECT ?refConcept ?simDesign WHERE
{
  ?refConcept rdf:type/rdfs:subClassOf* dsrdco:Artefact;
              rdf:type dsrkbo:ReferenceConcept .
  ?refConcept skos:narrower ?simDesign
}
ORDER BY ?refConcept

```

---

The following SPARQL query (Algorithm 4.8) extracts similar concepts by utilising the class ‘reference concept assertion’ that was introduced into DSRKBO.

---

**Algorithm 4.8** SPARQL query to retrieve shared concepts utilising the class ‘ReferenceConceptAssertion’

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDCO#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>

SELECT ?refConcept ?artefact ?prop WHERE
{
  ?refConcept rdf:type/rdfs:subClassOf* dsrdco:Artefact;
              rdf:type dsrkbo:ReferenceConcept .
  ?refConcAssertion rdf:type dsrkbo:ReferenceConceptAssertion .
  ?refConcAssertion
    dsrkbo:refConAssertionIncludesReferenceConcept ?refConcept .
  ?refConcAssertion dsrkbo:includesArtefact ?artefact .
  ?refConcAssertion dsrkbo:hasProbability ?prop .
  FILTER (?prop > 0.8)
}

```

---

Algorithm 4.8 searches for reference concepts in the knowledge base. These reference concepts refer to concepts in DSR document ontologies. If a reference concepts has a similarity of over 80% in the example shown in Algorithm 4.8, this reference concept will be returned.

**Shared Context:** A DSRKB should be able to extract all reference concepts that belong to a specific context. In comparison to the previous competency question, this competency questions retrieves the whole structure or concept hierarchy that is shared by a number of DSRDOs.

The competency question can be expressed as follows: “What are the contexts that are shared by DSRDOs in the ontology repository? and What are the components that belong to a certain context?”

The SPARQL query that provides an answer to this question is described in Algorithm 4.9.

---

**Algorithm 4.9** SPARQL query to retrieve contexts out of DSRKB

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDCO#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>

SELECT ?context ?describingConcept ?referenceConcept WHERE
{
  ?context rdf:type dsrkbo:Context .
  ?context dsrkbo:includesDescribingReferenceConcept ?describingConcept .
  ?context dsrkbo:contextIncludesReferenceConcept ?referenceConcept
}

```

---

Algorithm 4.9 searches for contexts and returns the root reference concept and its components. The root reference concept includes terms that can be used to present a certain context. Further, it is possible to extract the name of the ontologies and the concepts in DSRDOs to return artefact designs, together with their components that appear in more than one DSRDO.

**Shared Requirements:** Researchers might be interested in identifying whether specific requirements are fulfilled by other artefact designs.

The competency question that DSRKB needs to be able to answer is as follows: “What are the artefacts that fulfil Requirement X?” Algorithm 4.10 delineates this query and anticipates the IRI of a specific artefact.

---

**Algorithm 4.10** SPARQL query to extract shared requirements

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDCO#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>

SELECT ?refConcept ?pubRequirement ?publicationRequirement WHERE
{
  ?refConcept rdf:type dsrdco:Requirement; rdf:type dsrkbo:ReferenceConcept .
  ?refConcept dsrkbo:narrowerRequirement ?pubRequirement .
  FILTER (STR(?pubRequirement) = "<IRI of requirement in DSRDO>") .
  ?refConcept dsrkbo:narrowerRequirement ?publicationRequirement
}

```

---

The SPARQL query in Algorithm 4.10 returns all artefact designs that fulfil the requirement that matches the identifier (IRI) of a certain requirement.

**Shared Evaluation Techniques:** DSRKBO has to be able to return similar evaluation techniques. This information can help identifying evaluation techniques that have been applied to evaluate similar artefact designs in the literature.

The competency question is as follows: “What evaluation techniques have been used to evaluate a specific shared artefact design component?”

Algorithm 4.11 depicts the SPARQL query that answers the identified competency question.

---

**Algorithm 4.11** SPARQL query to identify shared evaluation techniques

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDCO#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>

SELECT ?artefactDesign ?evalTechnique ?pubTechnique
WHERE
{
  ?artefactDesign rdf:type/rdfs:subClassOf* dsrdco:Artefact .
  Filter(STR(?artefactDesign) = "<IRI of artefact design in DSRDO>") .
  ?artefactDesign dsrdco:isEvaluatedIn ?evalSetting .
  ?evalSetting dsrdco:utilises ?evalTechnique .
  ?evalTechnique dsrkbo:evaluationTechniqueBroader ?referenceConcept .
  ?refConcept dsrkbo:narrowerEvaluationTechnique ?pubTechnique
}

```

---

This query retrieves all artefact designs that match the IRI of a certain artefact design that is described in the ontology. Additionally, all evaluation methods are returned that evaluated a certain artefact.

**Evaluation Results:** Evaluation results describe how an artefact performed in a specific evaluation that utilised a specific evaluation method in regards to a specific artefact design. In DSRDCO, evaluation results are represented as statements that express evaluation claims. The query to extract evaluation results is similar to the query that is stated in Algorithm 4.6. However, in this case, evaluation results should be retrieved that belong to evaluation scenarios that are concerned with artefact designs that belong to a specific reference concept. Thus, evaluation results are returned that belong to a similar artefact design.

Algorithm 4.12 depicts the SPARQL query that is able to extract the evaluation results of a number of related artefact designs.

**Algorithm 4.12** SPARQL query to retrieve evaluation results

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBo#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>

SELECT ?refConcept ?artefactDesign ?evalResult WHERE
{
  ?refConcept rdf:type/rdfs:subClassOf* dsrdco:Artefact;
  rdf:type dsrkbo:ReferenceConcept .
  FILTER (STR(?refConcept) = "<IRI of reference artefact design in DSRKB>") .

  ?refConcept skos:narrower ?artefactDesign .
  ?artefactDesign dsrdco:isEvaluatedIn ?evalScenario .
  ?evalScenario dsrdco:producedResult ?evalResult
}

```

---

The SPARQL query in Algorithm 4.12 returns evaluation results and makes use of reference concepts, evaluation scenarios, and reference concepts that express an artefact, such as DSR methodologies.

**Evaluands:** In an evaluation, the artefact design is often instantiated by a specific design realisation that faithfully implements a specific artefact design. These design realisations are the evaluands in a specific evaluation setting.

The competency question should provide an answer to the following question: “What design realisations have been used to evaluate a specific shared artefact design?” Algorithm 4.13 provides a SPARQL query that answers this specific question.

---

**Algorithm 4.13** Query to retrieve evaluands for a specific shared artefact design

---

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dsrdco: <http://www.et-innovations.org/ontologies/2015/7/DSRDco#>
PREFIX dsrkbo: <http://www.et-innovations.org/ontologies/2015/7/DSRKBO#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>

SELECT ?refConcept ?artefactDesign ?evaluand WHERE
{
  ?refConcept rdf:type/rdfs:subClassOf* dsrdco:Artefact;
  rdf:type dsrkbo:ReferenceConcept .
  FILTER (STR(?refConcept) = "<IRI of reference artefact design in DSRKB>") .
  ?refConcept skos:narrower ?artefactDesign .
  ?artefactDesign dsrdco:isEvaluatedIn ?evalScenario .
  ?evalScenario dsrdco:hasEvaluand ?evaluand
}

```

---

The SPARQL query in Algorithm 4.13 retrieves all evaluands that were used to evaluate a specific shared artefact design that is expressed as a reference concept.

**Dissimilarities:** All of the proposed competency questions in this section describe how to extract similarities. Dissimilarities can be extracted in a similar manner. The main difference to SPARQL queries that extract similarities is that SPARQL queries that extract dissimilarities identify concepts in DSRDOs that do not relate to a certain reference concept and are therefore not shared amongst other DSR publications. This, however, can only be achieved by utilising a closed world assumption. In order to not violate against the open world assumption of the ontology, the extraction can only be temporary and can only reflect the state of the ontology at a specific point in time. Every change to the ontology can result in assertions that are added to the ontology, which could introduce similarities between concepts that have been previously identified to be dissimilar, due to the open world approach of OWL.

## 4.4 Indexing and IE Processes of DSRCRSA

The indexing process of DSRCRSA includes the generation of a document ontology for a specific DSR publication and an update of the knowledge base. The creation of the document ontology (DSRDO) and the update of the knowledge base (DSRKB) includes the definition of axioms that support the identification

of higher-level concepts.

The information extraction (IE) process returns summaries of single and multiple documents that fulfil the 5Cs. The 5Cs are discussed in Section 2.4.5. The IE process utilises DSRKB, which can represent concepts in different contexts. The IE process utilises reasoners and axioms to infer higher-level concepts. The syntactic layer can be used to reason concepts that belong to the semantic layer. The pragmatic layer provides concepts that can be used to create natural language summaries. A reasoner, axioms, rules, and SPARQL queries can extract concepts that the summarisation process (see Section 4.5) uses as an input.

This architecture and the principles that guide the development of information systems that support the conceptualisation of DSR publications are capable of creating overview summaries of a set of documents (see Evaluation Chapter 5).

Expressive ontologies are an important component of DSRCSA in order to provide natural language summaries of search results. Additionally, such ontologies could support the use of formal representations of DSR publication content in information systems.

An expressive ontology includes a rich set of axioms (assertions and rules). These axioms are used by reasoners to deduce high-level concepts, but also by other software to extract information on a more fine-grained level. This thesis shows how expressive ontologies that conform to the principle of utilising semiotic layers can be utilised to automatically generate natural language summaries of DSR content.

The next subsections (1) discuss the processing layers that are used in the discussed ontologies. These processing layers make use of the semiotic framework of Stamper (1996). (2) Examples will delineate how the semiotic framework was applied to DSRDCO, the indexing process, and the IE process. Lastly, (3) summary components and algorithms are discussed that are capable of generating natural language summaries.

#### 4.4.1 Processing Layers

The research in this thesis adapted the framework of Stamper (1996) and included the layers that can also be found in Dale (2010). Additionally, the semiotic triangle (Sowa, 2000) was applied to the ontologies that are proposed in this thesis. The indexing and information extraction processes were aligned to the layers of the semiotic framework of Stamper (1996).

The layers that are used in this work are a subset of the layers that are presented in the semiotic framework of Stamper (1996). These layers include the empiric layer, the syntactic layer, the semantic layer, and the pragmatic layer.

The empiric layer is not represented in DSRDCO and DSRKBO. However, information from the empiric layer, such as the frequency of terms, part of speech information, or the dependency graph, are used in the syntactic layer.

Thus, the empiric layer includes results from processes that empirically analyse natural language.

The syntactic layer includes predicate argument structures and properties of terms that could be identified in the text. Syntactic information represents low-level interpretations of DSR publication content.

The semantic layer is used to identify the meaning that is expressed in argument structures and properties that have been instantiated in the syntactic layer. This includes the identification of concepts, such as Artefact, Requirement, EvaluationMethod, and so on.

Finally, the pragmatic layer includes concepts that are of use to the user in a certain context. In the summarisation of a single document, concepts, such as thesis statement, artefact decomposition, and so on, are identified. In regards to the summarisation of multiple documents, concepts that provide enough information to identify the similarity of, for instance, artefacts are part of the pragmatic layer.

The syntactic, semantic, and the pragmatic layer is expressed by a number of axioms. An open world assumption can complicate reasoning processes due to limitations in regard to, for instance, intersection, or negation axioms. Only if a concept is closed off with the help of axioms, intersection or negation axioms can be used. Without such axioms, external tools need to be applied to extract such information. However, such tools can only create a snapshot of a conceptualisation at a specific point in time; otherwise, it might invalidate a formal ontology if rules that violate the open world assumption are permanently added to a formal ontology.

#### 4.4.2 Indexing Process

This section depicts the manual indexing process that was used to populate the ontologies that are described in this thesis. Although the indexing process is beyond the scope of this thesis, manually created ontologies needed to be created to evaluate the artefact.

This section will introduce the manual ontology engineering process and the creation of axioms.

Although the indexing process was executed manually, axioms can be potentially generated with the help of properties that are provided by POS taggers, dependency parsers, frequent pattern analysers, and / or machine learning algorithms. However, this topic is beyond the scope of DSRCRSA that is presented in this thesis.

This thesis is concerned with the generation of natural language summaries from correctly instantiated formal ontologies that cover a syntactic representation of salient content that appears in DSR publications.

The following manual indexing process depicts steps to create syntactic representations from DSR content by utilising the concepts that are described in Section 4.3.3.4.

The evaluation of the proposed DSRCRSA (see [Chapter 5](#)) provides evidence that the generation of natural language summaries can be achieved if a correct

syntactic representation of DSR content exists.

### **Identification of Artefacts and Requirements in the Indexing Phase:**

The applied manual indexing process includes the following steps:

1. Generation of a formal syntactic representation of salient predicate argument structures of a DSR publication.
2. Identification of the meaning that is expressed in these predicate argument structures by identifying context specific concepts in each semiotic layer. In DSR, this includes the identification of artefacts, requirements, claims, evaluation specific statements, and so on.
3. Identification of constructs that can be used in a specific context, such as the identification of an artefact description, artefact components, and so on, to generate summaries.

The first step includes the extraction of syntactic representations of salient components in a DSR publication.

A syntactic representation of a document consists of a set of predicate argument structures from sentences in a DSR publication.

Each statement consists of a predicate and its arguments. Arguments are meaningful terms that can be expressed by a noun phrase. The predicate consists of a verb that relates to a number of arguments.

Properties are predicate argument structures that express certain features of a specific argument.

Below are some statements and properties that enable the identification of an artefact and requirements.

- Stmt 1: propose(we, solution)
- Stmt 2: requires(solution, method)
- Stmt 3: aims(method, building)
- Stmt 4: aims(method, learning)
- Property 1: called(solution, ADR)
- Property 2: building(artefacts)
- Property 3: learning(from intervention)

These six statements enable the identification of an artefact as well as a set of requirements. The relation between an artefact and its requirement is called a utility relationship. The identification of the artefact and its requirements can be achieved by utilising a set of axioms as well as Semantic Web Rule Language (SWRL) rules.

Statement 1 describes an artefact design named ‘solution’. The term ‘solution’ can be identified as an artefact design because of the predicate ‘propose’ and the personal pronoun argument ‘we’.

Statement 2 states that the solution requires a method. It can be inferred that the term ‘solution’ needs to include a ‘method’.

Statement 3 and statement 4 describe requirements of the concept ‘method’. Thus, the term ‘aims’ can be replaced with the term requirement. Because this is a manual process, the human brain makes automatic connections to other parts of the document that validates this expression.

Finally, Properties 1 to 3 describe aspects of an identified concept. In this example, property 1 provides a name for the proposed solution, namely ‘ADR’. Property 2 and property 3 further describe each requirement. This example discusses parts of the manual conceptualisation of the DSR publication “Action Design Research” by [Sein et al. \(2011\)](#).

**MainArtefactDesign:** Due to the open world assumption in OWL, axioms that express negations are more complex to create. To infer negations, a class must be closed off by introducing a set of axioms that, for instance, express that a certain property is explicitly not included. This makes it possible to properly infer a negation that a property is missing. A missing property alone does not enable the deduction that a property is missing because such a property could be added at any time.

Thus, a richer set of axioms enables more sophisticated reasoning processes. A main artefact could be inferred by identifying that an artefact is the top-most component of an artefact hierarchy. However, due to the open world assumption such an information has to be expressed explicitly in the ontology. A missing ‘partOf(Artefact, Artefact)’ object property would infer, in a closed world assumption, that a specific artefact is the main artefact. In an open world assumption, axioms have to be introduced to express this information.

Thus, in DSRDCO, the data property ‘isResearchedArtefact’ was introduced, which enables the identification of a main artefact in a DSR publication.

The manual indexing process has to ensure the proper identification of this information in order to make correct assumptions.

**Requirement:** A utility relationship can be expressed by the relationship ‘fulfils(ArtefactDesign, Requirement)’. Thus, the identification of the requirement of an artefact is straight forward if the ‘fulfils’ relationship can be identified reliably.

In a case in which the ‘fulfils’ relationship can be identified in the text, the definition of a domain and a range for the object property ‘fulfils’ is sufficient to reason that the individuals are instances of the concepts ‘artefact design’ and ‘requirement’ respectively.

Finally, a semantic web rule language (SWRL) rule expresses that the requirement of a component of a specific artefact becomes a requirement of the main artefact design. The SWRL rule is described in [Algorithm 4.14](#).

---

**Algorithm 4.14** SWRL rule to identify requirements of artefacts

---

```

DSRDCO:fulfils(?artefact, ?requirement) ^
  DSRDCO:partOfArtefact(?artefact, ?artefact2)
-> DSRDCO:fulfils(?artefact2, ?requirement)

```

---

Referring to the example in this section, the resulting utility relationships is as follows: ADR fulfils building artefacts.

### 4.4.3 Information Extraction Process

The information extraction process implements the principle to utilise semiotic layers in the reasoning process and the principle to use adjacent semiotic triangles to delineate the hierarchy between the syntactic, semantic, and pragmatic layer. Additionally, contexts were introduced to describe similarities between several DSR publications.

The syntactic, semantic, and pragmatic layer can be described by two adjacent semiotic triangles. Figure 4.7 provides an example of such a set of adjacent semiotic triangles. Each concept in one of these semiotic triangles is defined by a set of axioms. Each adjacent semiotic triangle uses this set of axioms to express an object that inherits this set of axioms. Each set of axioms utilises concepts from the lower-layer of the semiotic framework. The paragraph “Semiotic Layers” depicts an example of how these two principles were used in this thesis. The paragraph “Reference Concepts and Contexts” discusses another important feature of the ontology repository. This feature describes the use of contexts to present similarities between conceptualisations that appear in a number of DSR publications.

**Semiotic Layers:** The use of semiotic layers is discussed utilising the concept ‘artefact decomposition’. The concept ‘artefact decomposition’ belongs to the pragmatic layer of the ontology repository as it represents a concept that is of use to a certain user in a certain context. However, most pragmatic layer concepts were not added to the formal ontology because they usually extract utilising software and also depict the state of an ontology at a specific point in time to apply a closed world assumption. An artefact decomposition includes all components and sub-components of the main artefact that is discussed in a DSR publication. Additionally, an artefact decomposition includes ‘is a’ relationships of subcomponents to allow different interpretations of a specific artefact.

The following paragraphs introduce an example that delineates the use of the semantic layers to identify the concept ‘artefact decomposition’. Figure 4.7 depicts this process.

## Semiotic Triangles For Artefact Desomposition

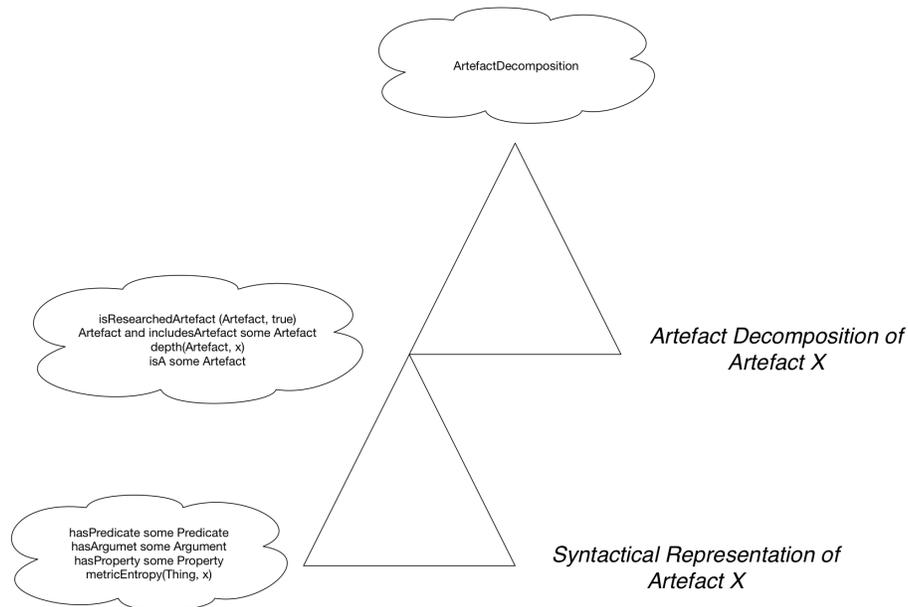


Figure 4.7: Adjacent semiotic triangles for the concept 'Artefact Decomposition'

**Pragmatic Layer:** The pragmatic layer includes an instantiation of the concept 'artefact decomposition'. The pragmatic layer describes a concept in regards to the context it is used in. The concept 'artefact decomposition' can be expressed utilising the following set of axioms. These axioms make use of the semantic layer of the ontology repository.

1. `isResearched(Artefact, true)`
2. `Artefact and includesArtefact some Artefact`
3. `depth(Artefact, x)`
4. `Artefact and isA some Artefact`

Each of these four axioms consists of relations that express the meaning between concepts of the semantic layer. The first axiom expresses that the data property 'isResearchedArtefact' can be used to identify the root artefact of an artefact decomposition. The second axiom identifies artefact components that should be included in an artefact decomposition. The third axiom describes the depth of a certain artefact in the artefact hierarchy. The fourth axiom describes 'is a' relationships between artefacts.

**Semantic Layer:** A concept of the semantic layer has to be described utilising concepts of the syntactic layer. All concepts that are identified on the pragmatic layer need to be expressed utilising concepts of the semantic layer.

In this example, the concept ‘Artefact’ has to be expressed on the semantic layer utilising syntactic layer concepts. The following syntactic layer concepts describe any concept of the semantic layer.

1. hasPredicate some Predicate
2. hasArgument some Argument
3. hasProperty some Property
4. metricEntropy(Thing, e)

Any semantic layer concept can be described by a set of predicates and arguments. Further properties, which also consist of predicate argument structures, can be defined to further describe a specific concept on the syntactic layer. Entropy metrics can be defined for properties to express whether a specific concept, together with its properties, sufficiently describes a certain concept. Entropy metrics can be defined for each concept and are multiplied with the entropy metrics of a parent concept to identify whether a specific concept is sufficiently described utilising a number of properties.

**Reference Concepts and Contexts:** DSRKBO enables the combination of several conceptualisations of DSR publications. DSRKBO provides concepts to represent assertions that describe whether a specific reference concept is related to a concept in a DSRDCO. Such assertions are named ‘reference concept assertions’. Reference concepts relate to concepts in a design science research document ontology (DSRDO), which reflects concepts in DSR publications that utilise DSRDCO. Reference concept assertions can express the similarity between a reference concept and a concept that appears in a DSRDO.

Reference concepts can be used to represent different contexts. Each context is described by a conceptualisation of reference concepts that relate to concepts in DSRDOs.

Concepts and contexts in DSRKB, which populate DSRKBO and DSRDCO, can be identified manually, semi-automatically, or automatically. In this thesis, DSRKB was generated manually.

A context is a conceptualisation that uses DSRDCO terminology. Such a context is aligned to a root concept and relates to a concept in a specific DSRDO. Such a main concept is of type ‘reference concept’. All reference concepts (also reference concepts that are not the root concept in a context) can be used to refer to specific concepts in a DSR document ontology.

Reference concepts that are not root concepts of a context can become a reference concept in another context once new information from DSR publications has been collected and the knowledge base has been updated.

The identification of reference concepts should be done in the indexing phase. In the information extraction phase, these reference concepts can be accessed

to identify similarities between a number of artefacts, requirements, or other DSR concepts. Section 4.5 provides additional information in regards to the summary generation process.

## 4.5 Summary Artefact Design

A prototype was developed to realise the design of DSRCRSA. This prototype was written in Java and uses OWLAPI<sup>12</sup> to access ontology components and the Pellet reasoner (Sirin et al., 2007) to enable reasoning capabilities.

The prototype consists of four components.

The first component handles the ontology access. This component firstly loads the knowledge base. The knowledge base (DSRKB) imports a DSRDO for each DSR publication. The knowledge base utilises the terminology of the core ontologies DSRDCO and DSRKBO. These two core ontologies enable the representation of DSR content on a syntactic, semantic, and pragmatic level.

The second component includes reasoning capabilities to reason higher-level concepts (as described in Section 4.4.3) from lower-level concepts.

The third component consists of processes to identify semantic layer components that express pragmatic layer concepts. The pragmatic layer includes concepts that are of interest in the generation of overview summaries. Due to the open world assumptions that are used in the proposed ontologies, and limitations in reasoning capabilities in generating individuals that are composed out of a number of other individuals, algorithms were designed to execute pragmatic layer functions of the ontology. These algorithms, which are further described below, identify pragmatic layer concepts, such as thesis statement, artefact description, artefact decomposition, evaluation, and the identification of similarities or dissimilarities between DSR conceptualisations.

The fourth component is concerned with the lexicalisation of the identified individuals. This process makes use of the syntactic layer, which utilises predicate argument structures. After the identification of individuals in the semantic layer, summaries can be generated utilising a template based system. The templates or cloze sentences that were used are depicted below each algorithms in this section. This template based system consists of cloze texts for each salient DSR concept (see Section 2.5.6 for a discussion on salient DSR concepts in DSR publications).

To be able to extract and generate the terminology that appears in a summary, syntactic layer concepts need to be extracted. Such syntactic layer concepts can be generated manually, or semi-automatically, in the indexing process. In this thesis, which is concerned with the representation and summarisation of single and multiple DSR publications, the indexing process was performed manually by identifying passages that discuss salient DSR concepts in conceptualised DSR publications (see Section 4.4.2).

The vocabulary that is used to build a sentence follows a predicate argument syntax, whereas the first argument is often the subject of a cloze sentence.

---

<sup>12</sup><http://owlapi.sourceforge.net>

This prototype differentiates between first-level arguments and arguments that depend on other arguments or second-level arguments. In this thesis, such dependent arguments are called ‘properties’. Such properties are used to reduce the entropy of a specific argument. If a concept falls below a certain entropy level, it can be seen as unambiguous and sufficiently defined in a certain context. Initial metric entropies of a term can be manually inserted or generated automatically. A metric entropy is expressed as a real value between 0 and 1. The lower a metric entropy is, the more unambiguous is a specific term.

For instance, a predicate argument structure of the sentence, “The dog goes swimming in a pool that contains water.”, would appear as follows: goes swimming (the dog, in a pool, that contains water). However, in this thesis, another relation between “the pool” and “contains water” is expressed to describe properties. This enables the use of “the pool that contains water” in other contexts.

This structure enables the extraction of meaningful word compounds that can be inserted in a set of cloze text sentences. However, the pragmatic aspect, as well as the semantic aspect of the ontology has to be analysed first to retrieve the components that are necessary to generate a summary. Thus, the next paragraphs describe how a pragmatic model can be generated utilising semantic aspects, as well as how the syntactic information can be retrieved, to finally extract a lexicalisation of compounds that can be filled into the cloze text overview summaries.

**Thesis Statement:** A thesis statement briefly highlights the main components of an artefact, the requirements of a specific research project that are fulfilled by the artefact, the significance of the proposed artefact, as well as important evaluation results. The next paragraphs describe the algorithms that are involved in extracting such information.

Algorithm 4.15 generates a high-level description of the artefact. The extraction of significance statements can be found in Algorithm 4.16, while the extraction of artefact components is described in Algorithm 4.17.

Algorithm 4.15 depicts the extraction of a high-level description of an artefact. This algorithm can be used with any input type, such as requirements. This algorithm shows the calculation of an entropy value that serves as a threshold to limit the level of detail of an artefact description. If the calculated entropy value falls below a certain threshold the information is printed out.

If this algorithm has been executed for a specific artefact and a set of requirements that this artefact fulfils, the following cloze sentence can be filled and returned to the user: “This article describes an artefact named [high-level description of artefact]. The proposed artefact fulfils the requirements to [enumeration of requirements].” The extraction of requirements can be achieved by querying the ontology for artefacts that are related to requirements via the ‘fulfils’ relation.

---

**Algorithm 4.15** Extraction of high-level descriptions of artefacts

---

**Require:**  $a$  is an individual of type Artefact

**Require:**  $onto$  is an ontology of type DSRKB

```

1: function RETRIEVEARTEFACTDESCRIPTION( $a, onto, maxEntropy$ )
2:    $e = \text{getTermEntropy}(\text{getPredicateAndFirstArgument}(a))$ 
3:   while hasNextPropertyArguments( $a$ ) do
4:      $p = \text{getNextPropertyArgument}(a)$ 
5:      $e = \text{getTermEntropy}(p) * e$ 
6:     if  $e > maxEntropy$  then
7:       print( $p$ )
8:     else
9:       break while loop
10:    end if
11:  end while
12: end function

```

---

Algorithm 4.16 describes the extraction of a significance statement. Significance statements consist of claims that either compare two concepts and express that one artefact implements something that the other artefact does not, or claim that a certain artefact is novel. Both claims include a set of artefacts that are involved in a specific claim, together with a claim that addresses each of these artefacts.

Cloze sentences that provide a natural language representation for a comparison claim are as follows: “[Artefact] [Claim], whereas [Artefact2] [Claim2]”.

A novelty claim can be expressed by the following cloze sentence: “[Artefact] offers the possibility [Claim].” This cloze text is used if there is no novelty item involved in a claim. In the case that there is a novelty item expressed, the cloze sentence is as follows: “[Artefact] adds a [novelty item] to the body of knowledge.”

The selection of a cloze sentence depends on the type of claim that can be extracted as well as on the level of detail that can be extracted. If a specific novelty claim can be extracted, this information can be formally described in the ontology.

---

**Algorithm 4.16** Extraction of significance statements

---

**Require:**  $a$  is an individual of type Artefact**Require:**  $onto$  is an ontology of type DSRKB

```

1: function RETRIEVESIGNIFICANCESTATEMENT( $a, onto, maxEntropy$ )
2:    $ts = \text{querySignificanceStatement}(a)$ 
3:    $c = \text{querySignificanceClaims}(ts)$ 
4:   if isComparisonClaim(type( $c$ )) and size( $c$ ) = 2 then
5:      $(a_1, a_2) = \text{extractInvolvedArtefacts}(ts)$ 
6:     printComparison( $c, a_1, a_2, maxEntropy$ )
7:   else if isNoveltyClaim(type( $c$ )) then
8:      $a_1 = \text{extractInvolvedArtefact}(ts)$ 
9:      $ni = \text{extractNoveltyItems}(ts)$ 
10:    printNoveltyClaim( $c, a_1, ni, maxEntropy$ )
11:  end if
12: end function

```

---

**Artefact Description:** Algorithm 4.15 extracts an artefact description up to a certain level of detail. An artefact description includes properties that describe an artefact, whereas artefact decomposition delineates the components of a specific artefact.

The lexical representation of an artefact description includes the name of an artefact and a number of properties that further define an artefact. The more detailed an artefact description is, the more properties are included in an artefact description.

The difference to Algorithm 4.15 is that a specific depth can be chosen. An example for such a phrase would be “the cat in the bathroom”, where “the cat” and “in the bathroom” can be expressed as two properties. A depth of one would extract the term “the cat”, whereas a depth of two would extract “the cat in the bathroom”. However, it is not possible to print less properties (lower depth) than the entropy value that has been defined for a certain predicate argument structure. If the entropy is higher than a specified threshold once the specified depth has been reached, more properties have to be added or else the output is not unambiguous enough to be understood by the user.

The artefact description can be used as a component in many cloze sentences. Thus, there is no specific cloze sentence provided here.

---

**Algorithm 4.17** Extraction of artefact component statements

---

**Require:**  $a$  is an individual of type Artefact

**Require:**  $depth$  represents the number of arguments that should be extracted

**Require:**  $onto$  is an ontology of type DSRKB

```

1: function RETRIEVEARTEFACTDESCRIPTION( $a, depth, maxEntropy$ )
2:    $depthCounter = 0$ 
3:    $e = getTermEntropy(getPredicateAndFirstArgument(a))$ 
4:   while hasNextPropertyArguments( $a$ ) do
5:      $p = getNextPropertyArgument(a)$ 
6:      $e = getTermEntropy(p) * e$ 
7:     if  $e > maxEntropy$  then
8:       print( $p$ )
9:     else if  $depthCounter < depth$  then
10:      print( $p$ )
11:    else
12:      break while loop
13:    end if
14:     $depthCounter ++$ 
15:  end while
16: end function

```

---

**Artefact Decomposition:** An artefact decomposition describes the components of a specific artefact.

The artefact decomposition also includes ‘is a’ relationships. ‘Is a’ relationships describe instantiations of a specific artefact and are therefore extensions of a specific artefact. Similar to the representation of artefact descriptions, an artefact decomposition can be described up to a certain level of the identified artefact hierarchy. The more levels are used to summarise the artefact decomposition, the more detailed is the summary of the artefact decomposition.

Algorithm 4.18 depicts a recursive algorithm that extracts the artefact hierarchy up to a certain level of detail. Additionally, ‘is a’ relations are extracted for each artefact. A cloze text either presents a combination of artefacts, or an artefact together with ‘is a’ relations that can be identified out of a specific artefact. The following cloze text expresses an artefact combination that does not include ‘is a’ relations. “[Artefact] consists of [Enumeration of Artefact Components].” If ‘is a’ relations can be identified, the cloze sentence is as follows: “[Artefact] consists of [Artefact Component], specifically [is a Artefacts].” This sentence has to be repeated for all other components.

**Algorithm 4.18** Extraction of artefact hierarchy**Require:**  $a$  is an individual of type Artefact**Require:**  $onto$  is an ontology of type DSRKB

---

```

1: function RETRIEVEARTEFACTHIERARCHY( $a$ ,  $depth$ ,  $maxEntropy$ )
2:    $e = 1$ 
3:   while hasNextPropertyArguments( $a$ ) do
4:      $p = getNextPropertyArgument(a)$ 
5:      $e = getTermEntropy(p) * e$ 
6:     if  $e > maxEntropy$  then
7:       print( $p$ )
8:     else
9:       break while loop
10:    end if
11:  end while
12:  while hasIsARelation( $a$ ) do
13:     $isa = getIsARelation(a)$ 
14:    print( $isa$ )
15:  end while
16:  if  $depth \neq 0$  then
17:    for  $child$  in getChildren( $a$ ) do
18:      retrieveArtefactHierarchy( $child$ ,  $depth - 1$ ,  $maxEntropy$ )
19:    end for
20:  end if
21: end function

```

---

**Evaluation:** The evaluation of a specific artefact is expressed in a specific evaluation scenario. An evaluation scenario includes a number of criteria, evaluation methods, evaluands, and evaluation results. The evaluation itself can be described by a set of statements that describes a specific evaluation method together with its evaluation criteria, followed by evaluation results. Algorithm 4.19 depicts the process needed to extract different evaluation components. For each scenario and each component the following cloze sentences can be used to generate summary components.

Cloze text for evaluation techniques: “[Evaluation method] has been used to evaluate the artefact [Artefact].”

Cloze text for evaluand: “The evaluand for the evaluation technique [Evaluation method] was [Evaluand].”

Cloze text for evaluation criterion: “[Evaluation method] has been used to evaluate the following aspect[s]: [Evaluation criterion].”

Cloze text for evaluation result: “[Evaluation criterion] has been determined by [Evaluation result].”

---

**Algorithm 4.19** Extraction of evaluation components

---

**Require:**  $a$  is an individual of type *Artefact*

**Require:**  $onto$  is an ontology of type *DSRKB*

```

1: function RETRIEVEEVALUATIONSCENARIOS( $a$ ,  $maxEntropy$ )
2:    $es = queryEvaluationScenarios(a)$ 
3:   for  $evaluationScenario$  in  $es$  do
4:      $et = queryEvaluationMethods(a, es)$ 
5:      $printEvaluationMethodInformation(a, et, maxEntropy)$ 
6:   end for
7:   for  $evaluationScenario$  in  $es$  do
8:      $ed = queryEvaluands(a, es)$ 
9:      $printEvaluand(ed, maxEntropy)$ 
10:  end for
11:  for  $evaluationScenario$  in  $es$  do
12:     $ea = queryEvaluationCriterion(a, es)$ 
13:     $printEvaluationCriterion(ea, maxEntropy)$ 
14:  end for
15:  for  $evaluationScenario$  in  $es$  do
16:     $er = queryEvaluationResults(a, es)$ 
17:     $printEvaluationResult(er, maxEntropy)$ 
18:  end for
19: end function

```

---

**Similarities and Dissimilarities in Multiple Documents:** Multi-document summaries include a discussion of similarities and dissimilarities of essential components, such as artefacts and requirements. An overview summary should include similarities in artefact designs, as well as dissimilarities between the artefacts in question. Additionally, requirements need to be compared as well as evaluation techniques, evaluation criteria, and evaluation results. The extraction of similarities and dissimilarities include the provision of reference concepts and assertions that relate reference concepts to concepts in DSRDOs.

Such summaries can only depict the state of the ontology repository at a certain point in time. The reason for that is that the ontology will be treated using a closed world assumption at the time of extraction. This also means that such a summary could change over time if the ontology repository is updated. Closed world assumptions enable the identification of dissimilarities. In an open world assumption dissimilarities are hard to extract. By utilising a closed world assumption, dissimilarities can be extracted by calculating all concepts that do not refer to reference concepts that appear in multiple articles. This is possible due to the specification of DSRKB. DSRKB includes reference concepts that either relate to a minimum of two articles and therefore express a similarity between two articles, or they do not relate to any DSRDO. If reference concepts relate to zero or one DSRDO, this reference concept is seen as axiomatic, which means that this concept has been added to DSRKB without the need to identify this concept in a number of DSRDOs that are stored in the ontology repository.

Algorithm 4.20, Algorithm 4.21, Algorithm 4.22, and Algorithm 4.23 utilise narrower and broader transitive relations. Another option is the use of similarity measures as discussed in Section 4.3.4.2. If similarity measures are used, narrower and broader assertions need to be replaced with a probabilistic model that utilises the concept ‘reference concept assertion’.

Algorithm 4.20 and Algorithm 4.21 delineate the algorithms that are used to extract similar artefacts. Algorithm 4.20 firstly identifies reference concepts that are connected to at least two concepts in different DSRDOs. These concepts show a similarity. To further identify similar components between similar artefacts, each component and its sub-components need to be queried (see Algorithm 4.21) to identify further similarities. Algorithm 4.21 is implemented recursively to go through the complete reference concept hierarchy of a specific context. These similarities are then described for each concept. The cloze sentences and tables are as follows.

For each similar concept:

"[All artefacts or Enum of root artefacts] contain[s] [Enumeration of similar artefacts]."

If ‘is a’ concepts are identified:

Heading: Concept [Similar artefact]

"[Artefact] may include the following types of [Similar artefact component]: [Enumeration of ‘is a’ relationships]."

The following table is printed for each similar ‘is a’ relationship:

Artefact	[Artefact component]
[Artefact name]	[Similar ‘is a’ concept]

---

**Algorithm 4.20** Wrapper to extract similar artefact components

---

**Require:** *as* is a set of type Artefact to be included in the comparison

**Require:** *onto* is an ontology of type DSRKB

```

1: function RETRIEVESHAREDREFERENCECONCEPTS(as, onto,
   maxEntropy)
2:   initialise shared reference concept list rcs
3:   for artefact in as do
4:     brrcs = queryBroaderReferenceConcepts(artefact)
5:     insertDistinctReferenceConcepts(rcs,brrcs)
6:   end for
7:   for referenceconcept in rcs do
8:     retrieveSimilarConcepts(referenceconcept, onto, maxEntropy)
9:   end for
10: end function

```

---

---

**Algorithm 4.21** Extraction of similar artefact components

---

**Require:** *rc* reference concepts that is shared between at least two artefacts

**Require:** *onto* is an ontology of type DSRKB

```

1: function RETRIEVESIMILARCONCEPTS(rc, onto, maxEntropy)
2:   context = queryContext(rc)
3:   isarcs = queryIsAReferenceConcepts(referenceConcept)
4:   if size(isarcs) > 0 then
5:     for isareferenceconcept in isarcs do
6:       if refConceptIsIncludedInContext(isareferenceConcept,
7: context) then
8:         nas = queryNarrowerArtefact(isareferenceconcept)
9:         if size(nas) > 1 then
10:          printSimilarIsAArtefacts(referenceConcept,isareferenceconcept,
11: nas, maxEntropy)
12:        end if
13:      end if
14:    end for
15:  else
16:    nas = queryNarrowerArtefact(referenceConcept)
17:    if size(nas) > 1 then
18:      for na in nas do
19:        printSimilarArtefacts(referenceConcept, nas)
20:      end for
21:    end if
22:  ircs = getIncludedReferenceConcepts(referenceConcept)
23:  for increfconcept in ircs do
24:    if refConceptIsIncludedInContext(increfconcept, context) then
25:      retrieveSimilarConcepts(increfconcept,onto, maxEntropy)
26:    end if
27:  end for
28: end function

```

---

Algorithm 4.22 and Algorithm 4.23 depict the identification of dissimilar components. These algorithms extract concepts that do not relate to a reference concept that refers to more than one DSRDOs. These dissimilar concepts are expressed in a table that is comparable to the table above, which expresses similarities between artefacts. Additionally, all concepts that are included in a certain artefact are listed. This supports the reader by providing a full list of artefacts followed by components that are only included in a specific artefact.

---

**Algorithm 4.22** Wrapper to extract dissimilar artefact components

---

**Require:**  $rc$  is a reference concept element of context  $ctx$

**Require:**  $as$  is a set of type Artefact to be included in the comparison

**Require:**  $onto$  is an ontology of type DSRKB

1: **function** RETRIEVEDISSIMILARARTEFACTS( $rc, as, onto, maxEntropy$ )

2:     retrieveDissimilarConcepts( $rc, as, onto, maxEntropy$ )

3: **end function**

---

---

**Algorithm 4.23** Extraction of dissimilar artefact components
 

---

**Require:** *artefact* artefact that is queried for dissimilarities

**Require:** *onto* is an ontology of type DSRKB

```

1: function RETRIEVEDISSIMILARCONCEPTS(rc, as, onto, maxEntropy)
2:   potdisnrls = initPotentialDisimilarityList()
3:   nrls = getNarrowerRelations(rc)
4:   originrls = getNarrowerRelations(rc)
5:   if notEmpty(nrls) then
6:     if includesAllArtefacts(nrls, as) then
7:       rcisas = getIsARelations(rc)
8:       for rcisa in rcisas do
9:         rcisanrls = getNarrowerRelations(rcisa)
10:        if countIncludedArtefacts(rcisanrls, as) > 1 then
11:          incarts = getIncludedArtefacts(cisanrls, as)
12:          for incart in incarts do
13:            if notIncluded(incart, originrls) then
14:              addToList(potdisnrls, incart)
15:            else
16:              removeFromList(incart, nrls)
17:            end if
18:          end for
19:        end if
20:        for potDisnrl in potdisnrls do
21:          if findChildRelatedTo(potDisnrl, originrls) then
22:            printDissimilarity(getSiblings(getChildRelatedTo(potDisnrl,
23:            originrls), maxEntropy))
24:          end if
25:        end for
26:      end for
27:      printDissimilarity(nrls, maxEntropy)
28:    end if
29:    for nr in nrls do
30:      printDissimilarity(getSiblingsNotInNrls(nr), maxEntropy)
31:    end for
32:    end if
33:    children = getChildren(nrls)
34:    for child in children do
35:      retrieveDissimilarConcepts(child, as, onto, maxEntropy)
36:    end for
37:  end function

```

---

**Sentence Generation:** The generation of the final output of a textual summary includes the generation of sentences. Through utilising a predicate argument structure, together with properties and cloze sentences, summaries can be generated with a certain level of detail. A metric entropy can be used and

adjusted to calculate whether a specific term is clear enough. The data property ‘metricEntropy’ was introduced to define a threshold of the level of detail of a specific literal. For instance, ‘the dog’ can refer to any kind of dog, but “the dog that was seen in the vicinity of my house” is more specific and has therefore a lower entropy. Explicit metric entropies can be added manually or by defining a process to calculate the entropy for each concept. Overview summaries usually accept a higher entropy (a less clear representation) to reduce the size of the summary. Algorithm 4.24 depicts the generation of a syntactic representation of a concept that belongs to the semantic layer.

---

**Algorithm 4.24** Extraction of syntactic representations of a concept

---

**Require:**  $o$  is an individual of type Artefact, Claim, or Requirement

**Require:**  $onto$  is an ontology of type DSRKB

```

1: function RETRIEVEWORDCOMPOUND( $o$ ,  $onto$ ,  $maxEntropy$ )
2:    $pas$  = queryPredicateArgumentStructure( $o$ ,  $onto$ )
3:    $p$  = getPredicate( $pas$ )
4:   if exists( $p$ ) then
5:     concatenateWithLeadingWhiteSpaceAndConnectByAnd( $p$ )
6:   end if
7:    $as$  = getArguments( $pas$ ) where  $as$  depend on  $p$  or  $as$  depend on  $null$ 
8:   if exists( $as$ ) then
9:     concatenateWithLeadingWhiteSpaceAndConnectByAnd( $as$ )
10:  end if
11:   $a_{dep}$  = getArguments( $o$ ) where each argument depends on  $a_{n-1}$ 
12:  while getEntropy(next( $a_{dep}$ )) >  $maxEntropy$  do
13:     $a_{next}$  = getNext( $a_{dep}$ )
14:    print( $a_{next}$ )
15:     $child$  = next( $a_{next}$ )
16:    entropy( $child$ ) = entropy( $a_{next}$ ) * termEntropy( $child$ )
17:  end while
18: end function

```

---

## 4.6 Artefact Design - Reflection and Conclusion

Chapter 4 outlined the DSR process that was applied in the research that is presented in this thesis. The artefact design products (DSRCRSA (Section 4.3.1), DSRDCO (Section 4.3.3), and DSRKBO (Section 4.3.4)), and the artefact design processes (the manual indexing process (Section 4.4.3), the information extraction process (Section 4.4.3), and the summary generation process (Section 4.5)) were also described.

The design of the ontologies (DSRDCO, and DSRKBO) followed the ontology engineering methodology that is described in Section 3.4.

All products, as well as the described processes, implemented the principles of utilising semiotic layers in the design and population of the ontology instantiations (DSRDOs for each article, and DSRKB), and the use of axioms that

were restricted to the use of concepts of the lower semiotic layer, as described in Section 4.4.3.

A number of algorithms depicted the summarisation process that utilised the identified semiotic layers, and cloze sentences to extract and display natural language summaries.

The proposed ontologies and processes were implemented in a prototype that is capable of generating automatic single and multi-document summaries of a selection of three papers that were instantiated manually. The prototype can also receive a parameter that reflects an artefact design. This parameter reflects a query of a user of a system that implements the proposed DSRCRSA. The prototype can be forked from the prototype web page <sup>13</sup>.

Chapter 4 provides evidence that the proposed DSRCRSA is capable of generating single and multi-document summaries. Furthermore, the proposed design principles prescribe a novel way of structuring formal ontologies that should enable the presentation of content in multiple semiotic layers. This could potentially be used by any system that utilises ontologies as it provides a more structured access to the content of a formal ontology.

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<sup>13</sup><https://git.et-innovations.org/java/dsrcrsa>

## Chapter 5

# Artefact Evaluation

## 5.1 Evaluation Overview

Section 5.1 provides an overview of the evaluation that has been conducted to identify that the generated single and multiple document summaries fulfil the 5Cs (conciseness, comprehensiveness, coherence, clarity, and correctness) (see Section 2.4.5 for a discussion on the 5Cs).

Section 5.1.1 discusses the evaluands that were used to evaluate the artefact. Section 5.1.2 highlights evaluation criteria (the 5Cs) that were identified in Section 2.4.5 to evaluate single and multi-document overview summaries. Section 5.1.3 describes the evaluation method that was applied to evaluate the criteria in Section 5.1.2. Finally, Section 5.2, Section 5.3, and Section 5.4 discuss the evaluation of salient DSR publication concepts, the evaluation of single document summaries, and the evaluation of multiple document summaries respectively.

To summarise, Chapter 5 is concerned with the summative evaluation of the proposed DSRCRS architecture (see Chapter 4). Specifically, this evaluation assesses whether the ontology repository that is included in DSRCRSA is capable of formalising DSR knowledge with the purpose of generating single document and multi-document overview summaries. Single and multi-document overview summaries were assessed against five criteria - the 5Cs (conciseness, comprehensiveness, coherence, clarity, and correctness).

The summative evaluation that is presented in Chapter 5 refers to the ex-post evaluation in the SDSM research methodology that was chosen in this research (see Chapter 3). A number of formative evaluations were conducted during the design process to refine the artefact, which reflect the ex-ante evaluation stage in the applied SDSM research methodology. These evaluations are not discussed in this chapter. However, a description of the iterations that involved formative evaluations can be found in Section 4.2.4.3.

This research focuses on the domain of DSR. Further, this research is concerned with the summarisation of DSR articles. Resulting DSR summaries are used to provide a general overview for researchers. Additionally, non-experts in DSR do not know the general DSR terminology and theory. Thus, DSR researchers were chosen to evaluate DSR summaries. Three DSR experts evaluated DSR summaries. Each DSR expert was interviewed in three evaluation episodes (see Section 5.1.3.2).

### 5.1.1 Design Realisations / Evaluands

The evaluation of DSRCRSA included three episodes. Each episode was concerned with the evaluation of a different design realisation.

Section 5.1.1.1 describes the evaluand that was involved in the first evaluation episode, which included a set of salient DSR concepts in DSR publications. Section 5.1.1.2 highlights the evaluands that were involved in the second evaluation episode and included a set of single document summaries. Section 5.1.1.3 discusses evaluands of the third evaluation episode, which included multi-document summaries.

### 5.1.1.1 Salient DSR Concepts in DSR Publications

The artefact design process included the design of a formal ontology that utilises DSR concepts that appear in DSR publications (DSRDCO) (see Section 4.3.3). The concepts that were identified in the design phase needed to be evaluated by DSR experts.

A questionnaire was handed out to DSR experts. This questionnaire was chosen to provide DSR experts an opportunity to prepare themselves for the interview. The answers to these questions were used in the interview as a guideline to discuss the provided DSR concepts. The identification of salient DSR concepts in DSR publications is a very subjective topic as can be seen in the analysis of this evaluation. Thus, a qualitative method was chosen that utilised interviews in combination with a questionnaire.

The questionnaire included a list of DSR concepts and a Likert scale from 1 to 5, in addition to a box for comments to identify the importance of a DSR concept in a DSR publication. Each concept included a definition. The questionnaire can be found in the appendix (Section 6.3) of this thesis.

### 5.1.1.2 Single Document Summaries

The second evaluation episode included the evaluation of single document summaries. After the ontologies were developed and instantiated, single document summaries were created manually. Each single document summary reflected the content of a DSRDO that expresses a certain DSR publication.

Evaluators could choose one summary out of a set of three. Two evaluands were chosen by the evaluators. These evaluands summarise the following publications: “Action Design Research” by [Sein et al. \(2011\)](#), and “A Design Science Research Methodology for Information Systems Research” by [Peffer et al. \(2007\)](#). The third summary summarises the publication that is titled “Soft Design Science Methodology” by [Pries-Heje et al. \(2014\)](#).

These three articles were chosen because they are well-known by proponents of DSR. Additionally, all articles are of high quality and qualify as well known DSR research projects that are also known by the majority of DSR experts. Due to the complexity of recruiting DSR experts, articles have been chosen that DSR experts are familiar with. All articles discuss DSR methodologies. This enabled the comparison of these articles to generate multi-document summaries (see Section 5.1.1.3). The summaries can be found in the appendix of this thesis (see Section 6.3 and Section 6.3).

All three articles were manually converted into formal ontologies (DSRDOs) by utilising the process that is described in Section 4.4.2. These DSRDOs were then manually converted into a set of single-document summaries, following the processes that are described in Section 4.5. DSRDOs that were used in this evaluation can be found, together with the source code of the prototype on the GitLab project web page <sup>1</sup>.

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<sup>1</sup><https://git.et-innovations.org/java/dsrcrsa>

Although these summaries were created manually, the summarisation process that is highlighted in Section 4.5 and implemented in the prototype that can be forked from the GitLab project web page<sup>2</sup> produces the exact same result. Thus, the evaluation of the manually created summaries is consistent with the evaluation of the automatically created summaries.

### 5.1.1.3 Multi-Document Summaries

A multi-document summary was used as an evaluand to evaluate a combined summary that discusses three DSR publications. The evaluand can be found in the appendix of this thesis.

Similar to the single document summaries in Section 5.1.1.2, a multi-document summary was firstly generated manually utilising the processes described in Section 4.5. The generation of the multi-document summary utilised DSRKB (see Section 4.3.4), which can be found on <https://git.et-innovations.org/java/dsrcrsa>. DSRKB includes a conceptualisation of different contexts that are represented in DSR publications.

Additionally, a prototype was developed to automatically generate multi-document summaries utilising DSRKB and DSRDOs. This prototype can be reproduced by the process that is described in Section 4.5.

The manually generated summary, as well as the automatically generated summary were evaluated in the evaluation. However, one statement in the manually created summary that was generated incorrectly, which is the name of the artefact that was discussed in the last evaluation result. DSR experts were informed about this matter. Additionally, it was not possible to provide a sorted list of similar and dissimilar concepts in the automated summary, because an ontology usually provides references to concepts in an arbitrary manner. However, this only includes the sort order of concepts within a specific section, and does not affect the general structure of a summary.

## 5.1.2 Evaluation Criteria

It was necessary to evaluate DSRCRSA to identify whether it fulfils the requirement to provide overview summaries of DSR publications that fulfil the 5Cs (see Section 2.4.5). An overview summary of single or multiple DSR publications that fulfils the 5Cs provides evidence for the utility of DSRCRSA. Such an overview summary that is generated by utilising DSRCRSA depends on a correct instantiation of the ontology repository (see Section 4.3.1). If overview summaries that fulfil the 5Cs cannot be generated, or do not reach the quality that is expected by potential readers, the ontology repository cannot fulfil its requirements to provide an accurate representation of a set of DSR publications. Such a summary does not fulfil one or more of the 5Cs. Similarly the ontology repository does not include a comprehensive, coherent, concise, clear, and correct conceptualisation of a DSR publication. Furthermore, it would imply

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<sup>2</sup><https://git.et-innovations.org/java/dsrcrsa>

that an insufficient set of competency questions has been developed to evaluate DSRDCO (see Section 4.3.3.6) and DSRKBO (see Section 4.3.4.5).

Thus, the criteria in this evaluation include (1) the identification of whether a comprehensive representation of salient DSR concepts are included in DSRDCO, and (2) whether the provided single document and multi-document summaries can fulfil the 5Cs (conciseness, coherence, comprehensiveness, clarity, and correctness).

### 5.1.3 Evaluation Method

This research is concerned with the formal conceptualisation of DSR publication content and the automated summarisation of single and multiple DSR publications. A generation of a high number of summaries is not feasible due to the amount of time that is needed to create a manual ontological representation of a DSR publication. Additionally, the DSR expert's opinion has to be identified to develop a clear understanding of why a specific concept should be included in a conceptualisation of a DSR publication, or why a specific component of a summary is correctly represented or not. Quantitative analysis models cannot answer such questions properly. Thus, a qualitative evaluation method was chosen. In a series of interviews, experts evaluated salient DSR concepts, single DSR publication overview summaries, and multiple DSR publication overview summaries.

The design of the summative evaluation that is discussed in this chapter (Chapter 5) included three episodes.

1. Salient DSR concept evaluation episode
2. Single DSR document summary evaluation episode
3. Multiple DSR document summary evaluation episode

The first episode was concerned with the evaluation of whether or not DSRDCO contains the most salient DSR concepts. The concepts that were extracted in the top-down and bottom-up DSRDCO design process needed to be verified. 12 DSR experts were asked to participate in this interview series to validate DSR concepts that are represented in DSRDCO. Section 5.1.3.1 discusses the selection of the DSR experts that were involved in this evaluation. The salient DSR concept evaluation episode should ensure that DSR related concepts that appear in a DSR summary are represented correctly in DSRDCO. This stage should provide evidence that confirms that DSRDCO includes a shared understanding of DSR.

The second evaluation episode was designed to identify whether a single document summary that is automatically extracted out of instantiations of DSRDCO fulfils the 5Cs. If the 5Cs are fulfilled, DSRDCO provides the terminology to correctly express a formal representation of a DSR publication to provide single document summaries. Additionally, this evaluation episode evaluates whether natural language summary representations can be generated out of instantiations of DSRDCO.

The third evaluation episode included a similar evaluation to that in the second evaluation episode. However, the third evaluation episode evaluates a multi-document summary to identify whether it fulfils the 5Cs. The provided multi-document summary is an overview summary that provides a comparison over a set of DSR publications.

### 5.1.3.1 Participants

As mentioned in Section 5.1, DSR experts were chosen to evaluate the outcomes of this research. DSR experts have the experience to identify whether a summary discusses important DSR concepts. All DSR experts that participated in the evaluation are researchers and work in academia. Researchers are able to identify whether the provided overview summaries fulfil 5Cs. One of the most important DSR conferences is the DESRIST conference series. Thus, DSR experts at DESRIST 2016 were asked to participate in these studies.

Participating DSR experts needed to have published at least 10 DSR related scientific publication in peer reviewed journals or conferences. Additionally, DSR experts were required to be cited at least 100 times, which has been verified on Google Scholar.

DSR experts that attended the DESRIST 2016 conference in St. John's, Newfoundland, Canada were asked to participate in this evaluation. The recruitment of experts at DESRIST 2016 was more likely to be successful in person at DESRIST. This enabled the recruitment of an adequate number of participants. In total 12 DSR experts agreed to participate in this study. Two DSR experts were approached via email. Three DSR experts finished all three evaluation episodes. Each DSR expert has published highly cited papers in the field of DSR and is a renowned proponent of DSR. Each DSR expert has accumulated over 1000 citations. Because of the expertise of the candidates, the qualitative nature of this study, and the number of evaluation episodes, these three DSR experts were able to provide important insights in regard to the evaluation of the design artefacts. Further, saturation in the provided answers was identified in the aspects that were evaluated. Thus, three DSR experts were able to sufficiently evaluate the design artefacts.

### 5.1.3.2 Interview Mode

Interviews were chosen as an evaluation method. A Qualitative method in combination with interviews was chosen because the evaluation of natural language summaries is still very subjective, especially in regard to coherence and clarity; moreover, conciseness and comprehensiveness can only ultimately be evaluated by a human. However, DSR experts usually have different points of view in regard to a certain topic. Thus, a qualitative method was selected to identify common denominators amongst statements that were expressed throughout the evaluation.

Three DSR experts finished the complete interview series. Each DSR expert took part in three interviews, which reflects one interview per DSR expert per

evaluation episode. The first evaluation episode evaluated salient DSR concepts in DSR publications. The second evaluation episode was concerned with the evaluation of single document summaries. The third evaluation episode evaluated a multi-document summary.

Each interview took between 30 minutes and one hour.

In preparation for the first interview, DSR experts were asked to fill in a questionnaire. DSR experts were asked (1) to identify the three most important DSR concepts, and (2) to rate DSR concepts that are included in DSRDCO in regard to their importance in a DSR publication on a scale from 1 to 5. Additionally, the first evaluation episode included questions in regard to demographics. These questions included the identification of the expertise of a DSR expert. The expertise of a DSR expert was additionally asserted by the number of publications and the citation index of each DSR expert.

The second evaluation episode included manually generated summaries of DSR publications. Each DSR expert could choose one out of three publication. Once a publication was chosen, a summary of this publication was provided to the DSR expert. This enabled the DSR expert to study the paper in advance. Additionally, DSR experts were asked to read the original paper that was reflected in the summary. The interview consisted of questions that assessed the 5Cs of the single document summary.

The third evaluation episode included a manually generated combined overview summary of three DSR publications. The DSR experts were provided with a reference to the DSR publications that were involved in the multi-document summary, as well as the multi-document summary itself. Each interview included questions that assessed the 5Cs in regard to the multi-document summary.

All interview questions and the transcripts can be found in the Appendix (Section 6.3).

All interviews were conducted via Skype because all DSR experts were spread over the world.

The evaluation reached ethics approval by Curtin University. All interviewees were recruited by utilising recruitment material. All interviewees signed an informed consent form. All forms can be found in the Appendix of this thesis. Additionally, the formatted outputs of the generated summaries are attached to the appendix of this thesis (Section 6.3 and Section 6.3).

Each interview was analysed individually. The answer to each of the 5Cs as well as the DSR expert's opinion on DSR concepts was analysed to identify the meaningfulness and the clarity of each statement. Clear and meaningful statements were then compared with statements from other DSR experts. If a consensus could be reached, this consensus was used as a result of the evaluation. Additionally, individual answers were analysed qualitatively to identify patterns that are important in overview summaries in regard to 5Cs.

## 5.2 Salient DSR Concept Evaluation Episode

The first evaluation episode was concerned with the identification of important DSR concepts and whether there is a shared understanding between DSR experts in regards to the importance of DSR concepts that are included in DSRDCO.

A questionnaire was handed out before the first interview took place. This questionnaire queried the three most important DSR concepts and asked DSR experts to rate the importance of a set of DSR concepts that are included in DSRDCO. The questionnaire was returned before the interview commenced, which included a discussion of each of the concepts, in order to identify each DSR expert's point of view in regards to the choice of the three most important concepts and the proposed DSR concepts.

### 5.2.1 Questionnaire

The questionnaire consisted of two parts. The first part included a question that asked for the three most important concepts in a DSR publication. The second part of the questionnaire listed 16 DSR concepts that are expected to appear in a DSR publication according to the literature review. DSR experts were asked to rate (and to comment on their ratings) each of the proposed DSR concepts.

The questionnaire can be found in the appendix (Section 6.3).

DSR experts were asked to focus on the first part of the questionnaire before answering the second part. This was to ensure that the DSR experts were not influenced by pre-defined DSR concepts whilst answering the first part of the questionnaire.

### 5.2.2 Interview

The interview included (1) questions to identify the demographics of the DSR experts. (2) The three most important DSR concepts identified by each DSR expert were discussed in regard to the importance and the definition of each identified concept. (3) The DSR expert's ratings for each proposed DSR concept were discussed, as well as the DSR expert's opinion in regards to the definition of each concept.

Each of these interviews lasted between 30 minutes and one hour. Transcriptions of these interviews can be found in the Appendix (Section 6.3).

### 5.2.3 Results

This section is divided into a discussion of the most important DSR concepts that were identified by the DSR experts of this study, and a discussion in regards to the importance and definition of the DSR concepts that are represented in DSRDCO.

### 5.2.3.1 Salient DSR Concepts in DSR Publications

All DSR experts identified the artefact design as a main concept in a DSR publication. However, all DSR experts preferred artefact designs that can be applied to a class of problems over lower-level artefact designs that might only solve a specific problem.

Most DSR experts added that an artefact design should not only be described by its structure and processes, but also that the goal (or purpose) has to be described well. In the discussion about the concept ‘purpose’, a question about the difference between the concept ‘purpose’ and the concept ‘requirement’ was raised. The concept ‘purpose’ was defined by most DSR experts as the ultimate aim of a specific artefact design. ‘Requirement’, on the other hand, was interpreted by the majority of DSR experts as a sub-goal; two DSR experts defined it as a smaller goal that is not concerned, but might affect, the ultimate purpose of a specific artefact design.

One DSR expert also stated that a description of the novelty of an artefact needs to be clearly described, otherwise a specific publication is not worth publishing.

The description of design principles that is mentioned in a specific DSR publication is another concept that was identified by two DSR experts. One DSR expert defined the concept ‘design principle’ as important lessons learned that can be applied to a class of artefacts. In the author of this thesis’ opinion such design principles can be expressed as a ‘claim’ that refers to a specific artefact design.

A discussion about the difference between the concept ‘artefact’ and the concept ‘design theory’ revealed that some DSR experts clearly differentiate between artefacts and theories because an artefact should describe something tangible, whereas a theory is not tangible. However, other DSR experts stated that a design theory can be seen as a subclass of the concept ‘artefact’ because a design theory expresses a set of statements that are expressed in a certain document and therefore become tangible. This thesis follows the latter interpretation of the concept ‘design theory’.

Another DSR expert identified the relation between problem and design as an important concept that should appear in a DSR publication. The author of this thesis believes that such a relation could be expressed by the utility relation between the artefact design and its requirements. However, this could not be confirmed by one DSR expert who identified a clear difference between the concept ‘problem’ and the concept ‘requirement’. The DSR expert stated that the problem exists far earlier than the requirement. However, the DSR expert also confirmed that there is a relation between these two concepts. However, many DSR publication focus on the description of a requirement that might include a description of the problem as a justification of the requirement.

Two DSR experts identified the concept ‘evaluation’ as another essential component of a DSR publication.

### 5.2.3.2 DSR Concept Evaluation

The DSR concept evaluation episode (evaluation episode one) revealed that most concepts that were mentioned in the questionnaire were of importance to the DSR experts and should appear in a DSR publication. However, some DSR concepts in the questionnaire were not defined well enough. A more detailed definition that was provided during the interviews was able to resolve most of the misunderstandings.

Concepts such as ‘artefact’, ‘requirement’, and ‘significance’ received a high ranking amongst all DSR experts. However, two DSR experts clearly identified that in a DSR publication, the practical significance is of higher importance than the theoretical significance.

Concept definitions that were a little unclear to some DSR experts were the concepts ‘purpose’, and ‘property’. This was caused by a misleading definition. This thesis utilised the concept ‘purpose’, as well as the concept ‘property’ in DSRDCO to further describe or specify a specific concept, such as the concept ‘artefact’. Thus, the concept ‘purpose’ is not a synonym of the concept ‘purpose’, as discussed in the previous section. However, in the final version of DSRDCO, the concept ‘purpose’ is replaced by the concept ‘property’ so as not to confuse the users of DSRDCO. This is possible because a purpose can be expressed as a certain property, of, for instance, an artefact. However, this does not affect the main output of DSRCRSA, namely the generation of single and multi-document summaries.

Additionally, one DSR expert stated that all concepts should be orthogonal. However, concepts that belong to a generalisation / specialisation relationship cannot be orthogonal and are important parts of DSRDCO. For instance, the concepts ‘artefact’, ‘artefact design’, and ‘design realisation’ are not orthogonal. ‘Artefact design’, and ‘design realisation’ are subclasses of the concept artefact. This hierarchy was chosen to be able to reflect any kind of artefact in a specific DSRDO. For instance, if an artefact cannot be identified as a ‘design realisation’ or an ‘artefact design’, it can still be assigned to the concept ‘artefact’.

Finally, most concepts that are concerned with the evaluation of a specific artefact received high ratings by the DSR experts. However, the concept ‘evaluation aspect’ has received lower ratings. This concept was also understood differently by the DSR experts. Most DSR experts understood that the concept ‘evaluation aspect’ expresses a certain evaluand in an evaluation. However, the concept ‘evaluand’ can be expressed by the concept ‘design realisation’, and in this thesis, the concept ‘evaluation aspect’ describes a certain aspect in regard to the criterion of an evaluand. Nevertheless, the concept ‘evaluation aspect’ can be fully replaced by the concept ‘evaluation criterion’. Thus, the final version of DSRDCO does not include the concept ‘evaluation aspect’. However, this does not have an effect on the generated single and multi-document summaries.

### 5.2.4 DSR Concept Evaluation - Conclusion

Salient concepts in DSR publications that emerged out of the interviews in evaluation episode one are the concepts ‘artefact design’, ‘design theory’, ‘design principle’, ‘requirement’, a strong relation between problem and requirement and the concept ‘evaluation’.

Additionally, structural relations, as well as relations between the problem and the artefact design need to be expressed in a DSR publication. Also, the generalisability of a specific artefact design has to be expressed in the conceptualisation of a DSR publication.

The proposed DSRDCO is capable of representing all concepts that were identified by the experts. However, some concepts, such as the concept ‘design principle’, have to be expressed by its surrogates in DSRDCO. For instance, the concept ‘design principle’ can be expressed by the concept ‘claim’. The next sections depicts that this conceptualisation (DSRDCO) enables the generation of natural language single and multi-document summaries. Thus, the concept surrogates fulfil the purpose that the DSR experts expected.

The DSR concept evaluation phase showed that most concepts that appeared in the questionnaire were awarded with a high rating. This outcome provides evidence that DSRDCO consists of DSR concepts that DSR experts expect to appear in a DSR publication. Additionally, the following sections will show that these concepts are also of importance in DSR summaries.

Although some of the provided concepts were misunderstood by some DSR experts, most of these misunderstandings were resolved by providing a more detailed definition.

## 5.3 Single DSR Document Summary Evaluation Episode

This section presents the outcome of the second evaluation episode. The second evaluation episode was concerned with the identification of whether a provided summary fulfils a DSR expert’s opinion of an overview summary of a single DSR document. Each interview included a discussion of whether the 5Cs (conciseness, coherence, comprehensiveness, clarity, and correctness) are met in the presented summary.

All DSR experts confirmed that the 5Cs are generally met. However, some aspects were identified for further research on this topic as described in the following sections.

If there is evidence that all 5Cs are met in a single document summary, there is evidence that all important DSR concepts are represented that an expert would expect in an overview summary. Additionally, a successful evaluation infers that the proposed ontology repository is capable of producing such a summary. This further infers, in concert with the identification of the consistency of the proposed ontologies with a reasoner, that the provided ontology

fulfils the requirement of generating natural language summaries of single DSR documents.

The provided ontologies were instantiated manually. Due to the extensiveness of such a formal conceptualisation, only three articles were converted into a DSRDO (design science research document ontology)..

Each DSR expert could choose one DSR article out of three DSR articles. A discussion of why these three articles were chosen can be found in Section 5.1.1.

The DSR experts chose to evaluate summaries of the following publications: “Action Design Research” by [Sein et al. \(2011\)](#), and “A Design Science Research Methodology for Information Systems Research” by [Peffer et al. \(2007\)](#).

### 5.3.1 Conciseness

A summary is concise if it does not contain irrelevant concepts and knowledge. The following questions were asked in the interview:

- Does the summary meet the criterion ‘conciseness’?
- Is there any unimportant information expressed in the summary?

In addition to these two questions, each DSR expert was asked to further outline his or her decision.

All DSR experts agreed that the provided summary is concise as no irrelevant concepts are mentioned. One DSR expert also outlined that that all key information is mentioned, and that all DSR concepts that are mentioned in the provided single document summary are relevant. This means that, at least one person mentioned the fact that the right level of conciseness had been chosen for an overview summary.

Nevertheless, one DSR expert stated that although the summary is concise, the purpose of a specific artefact should be presented more prominently. Currently, the generated summaries do not mention the general purpose of a specific artefact. The reason for this design decision is that in DSR publications there is a higher interest in the requirements of a specific artefact than the purpose. Additionally, extracting the main purpose of an artefact is sometimes not possible as this information might not be presented in a specific publication. For instance, the purpose of an aeroplane, which can be expressed in the fact that an aeroplane flies, might not be mentioned in an article about how the interior of a modern aeroplane should be designed. Nevertheless, further research could be conducted to verify this claim.

### 5.3.2 Coherence

A summary is coherent if all the concepts and knowledge are well organised and related to each other. The following questions were asked in the interview:

- Does the summary meet the criterion ‘coherence’?

- Does any information contradict other information in the summary? If yes, please name these contradictions.

In addition to that, each answer was further discussed to retrieve more detailed information.

All DSR experts agreed that the provided summaries are coherent. All summaries are readable, although each concept that is expressed in this summary has a code attached to it. These codes were implemented to identify whether all concepts are correctly mentioned in the summary. However, this was not clear enough for the DSR experts and therefore it seemed to be too complex for one DSR expert to read. A system that generates such a summary would provide a summary that does not include these tags.

One DSR expert also mentioned that the summary is well organised, which is an important feature of a coherent summary. However, to this reader, it was not quite clear why specific artefacts are described in more detail, whereas other artefacts are described in such a detail. This fact relates to the underlying ontology and how much detail was formalised in regards to a specific artefact. However, the formal ontologies and the summarisation process in DSRCRSA support customised specifications of the level of detail that should be represented in a summary.

### 5.3.3 Comprehensiveness

A summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in an article that should appear in a single document overview summary. The following questions were asked in the interview:

- Does the summary meet the criterion ‘comprehensiveness’?
- Is there any information or topic missing in the summary?

In addition to these questions, DSR experts were asked to provide further information to their answers.

Most DSR experts expressed explicitly that the provided summaries are comprehensive enough for an overview summary. However, one DSR expert did not express this fact explicitly. This DSR expert mentioned two shortcomings of the summary in terms of comprehensiveness. (1) Figures are missing in the summary because figures can convey important information in a DSR publication. (2) One statement in the summary is too generic. However, the DSR expert also stated that this is dependent on the reader of the summary.

This research is concerned with textual components of a DSR publication. Thus, figures were been incorporated into the summary because they are beyond the scope of this research. However, the incorporation of figures into a summary might be of value to the reader. Thus, further research on the integration of figures could be conducted.

The verdict of one DSR expert that one statement in the summary is too generic could not be confirmed by other DSR experts. However, more detailed

information results in more extensive summaries. Thus, there needs to be a balance between the level of detail of a specific fact and the size of an overview summary. However, the proposed ontology repository and summariser implement a feature that enables a reader to choose the level of detail of a specific summary by lowering the expected maximum entropy.

Another DSR expert mentioned that although the summary is comprehensive, it was difficult to confirm whether all important concepts that appear in the article are included in the summary due to the size of the original article. However, due to the fact that an overview summary was presented and all DSR experts agreed that the summary is comprehensive to their knowledge, the summaries can be seen as comprehensive enough to provide an overview.

One DSR expert also mentioned that design principles are missing by also stating that there are many different interpretations of what a design principle is. However, such statements can already be expressed in the proposed ontology, and they are stated in some summaries where this information could be extracted from the article.

#### 5.3.4 Clarity

A summary is clear if all concepts and relations can be clearly understood. The following questions were asked in the interview:

- Does the summary meet the criterion ‘clarity’?
- Does the summary contain information that is unclear?
- Does the summary contain ambiguous information?

Most DSR experts stated that they could properly understand the provided summary. However, one DSR expert pointed out that due to the integrated codes, the summary is somewhat harder to read. Nevertheless, once these codes were ignored, the sentences themselves could be clearly understood by this DSR expert.

One DSR expert stated that the sentence “A search process draws from existing theory and knowledge to come up with a solution” is not clear enough because the sentence is too generic. However, this is exactly what was expressed in this specific publication.

Some definitions might be missing, such as the definition of action research in the summary of the publication by [Sein et al. \(2011\)](#). Whether this definition is important to the reader to properly understand a summary certainly depends on the reader’s expertise in the topic of research methodologies. However, if an ontology repository includes a publication about action research, a link could be provided to a summary of this specific article to provide a definition of this specific concept.

### 5.3.5 Correctness

A summary is correct if it does not draw any incorrect conclusions, including inconsistencies. The following questions were asked in the interview:

- Does the summary meet the criterion ‘correctness’?
- Can you name incorrect parts in this summary?

Again, the provided answers were further discussed to achieve more detailed responses.

All DSR experts agreed that no incorrect conclusions can be drawn by the provided summaries. However, some DSR experts stated the fact that an incorrect conclusion could be drawn by overly generic statements. Nevertheless, it was not possible to identify the statements in the provided summaries that the majority of DSR experts found overly generic.

One DSR expert stated that some instantiated concepts might be more related to the concept ‘purpose’ than to the concept ‘requirement’. However, after the provision of an explanation about the difference between purpose and requirement in this research, the DSR expert agreed with this interpretation. In this research, the concept ‘purpose’ does not have to describe the general purpose of a specific artefact; rather it describes the purpose of a specific noun. However, in the final version of DSRDCO the concept ‘purpose’ was exchanged with the concept ‘property’ to reduce any confusions.

Another discussion with a DSR expert involved the difference between a property and a boundary condition. However, even the DSR expert was not sure whether the use of the concept ‘property’ is incorrect. In this research, a boundary condition can also be expressed by the concept ‘property’ as a boundary condition expresses a property of an artefact.

### 5.3.6 Single-Document Evaluation - Conclusion

The single-document summarisation evaluation evaluated single document summaries in regards to the 5Cs. All DSR experts acknowledged that the 5Cs are fulfilled in regards to the provided overview summaries.

The results of the interviews provide evidence that DSRCRSA, as well as the ontology repository that is included in DSRCRSA, are capable of providing the structure to represent a conceptualisation that includes the most important concepts of a DSR publication.

This single document evaluation episode also provides evidence for the feasibility of creating a natural language single document overview summary.

However, the formatting of the single document summary could not be fully verified. One DSR expert stated that the concept ‘purpose’ should be highlighted in a DSR summary. This might not be always possible, because the purpose is sometimes not mentioned in a DSR publication. However, the concept ‘requirement’ has to appear in a DSR publication, as well as in a single-document summary, because requirements have to be evaluated in the evaluation of a specific artefact.

Additionally, this evaluation included single document summaries that incorporated a code of the concept expressed in the summary attached to a specific statement. The aim of this strategy was to evaluate whether the concepts were correctly instantiated. However, this reduced the readability of the summaries. All DSR experts identified that without these codes the summaries are coherent and clear. This can also be seen in the multi-document summarisation evaluation episode because in this phase these codes were eliminated.

One DSR expert could only confirm the comprehensiveness of the single document summary to the DSR expert's best knowledge. The DSR expert stated that there might be other components of the original DSR publication that should be mentioned in the summary. However, the intent of this evaluation was to identify whether a DSR expert would evaluate the provided summary as being comprehensive to their best knowledge, which could be verified.

Some statements were too abstract for two DSR experts. However, each DSR expert identified a different statement in the summary. Thus, these results could not be used in the evaluation. Additionally, the mentioned statements clearly expressed what was written in the article.

## 5.4 Multiple DSR Document Summary Evaluation Episode

The single-document summary evaluation provided evidence for the ability to store and to summarise a formalised representation of a DSR publication. The evaluated single document summaries fulfil the 5Cs. The evaluation of the 5Cs infers that all important DSR concepts are represented in the ontology repository, and in the resulting single-document summaries.

The evaluation of a multi-document summary will now show that the 5Cs can also be met in regard to a multi-document summary that discusses a certain concept (the concept 'DSR methodology'). Thus, the concept 'DSR methodology' can be seen as the search query that is used to extract a multi-document summary. This evaluation provides evidence that the ontology repository is capable of representing similarities between multiple DSR publications. The ontology repository also enables the generation of a natural language summary that discusses the similarities and dissimilarities of DSR publications. The generated multi-document summary represents the state of a specific ontology repository at a specific point in time. Due to the open world assumption, the generation of a multi-document summary only represents the state of an ontology repository at a certain point in time.

Single-document summaries as well as multi-document summaries were evaluated utilising the 5Cs as evaluation criteria. The evaluation of single-document summaries and multi-document summaries utilises the same criteria because the 5Cs have been identified as general evaluation criteria for the generation of summaries (see Section 2.4.5) regardless of whether a summary is of single or multiple documents.

All DSR experts were provided with a multi-document summary. The next sections discuss the results for each of the 5Cs and the implications to the outcome of this thesis.

### 5.4.1 Conciseness

A summary is concise if it does not contain irrelevant concepts and knowledge. The following questions were asked in the interview:

- Does the summary meet the criterion ‘conciseness’?
- Is there any unimportant information expressed in the summary?

All answers to the questions above were further discussed to provide a comprehensive analysis of each DSR expert’s opinion.

All DSR experts agreed that the summary is concise and that nothing irrelevant is mentioned in the summary. However, DSR experts could not agree on the amount that has to be covered in a multi-document overview summary to generate a concise, but meaningful overview summary. All DSR experts had a different view about the depth that should be provided in regard to a specific DSR concept. For instance, two DSR experts found the evaluation section of the provided multi-document summary to be detailed enough, whereas one DSR expert expected a more extensive representation of the evaluation section.

The ontology repository and the summarisation process enables the selection of a certain depth for the presentation of a specific DSR concept. However, this evaluation aimed to identify if an overview summary of multiple documents is concise. This conciseness was confirmed in this evaluation. Nevertheless, research in regard to the optimal level of detail in a multi-document summary might be necessary to further identify patterns to produce personalised preferences on the level of detail.

Even though all DSR experts confirmed that the provided multi-document summary is concise, there were still different interpretations of conciseness. In addition to that, DSR experts also agreed that the audience and the scenario that a specific summary is used in are important aspects to define the expected level of conciseness.

### 5.4.2 Coherence

A summary is coherent if all the concepts and knowledge are well organised and related to each other. The following questions were asked in the interview:

- Does the summary meet the criterion ‘coherence’?
- Does any information contradict other information in the summary? If yes, please name these contradictions.

Reasons for each provided answer were subsequently discussed with all DSR experts.

All DSR experts agreed that the summary is written coherently. However two DSR experts were not able to find an explanation of the term ‘BIE cycle’. However, the term ‘BIE’, as well as a spelled-out version, is mentioned in the multi-document summary. Once these DSR experts were reminded where to find the spelled-out version of BIE, the DSR experts also identified the coherence of this part of the summary.

One DSR expert explicitly mentioned that the tables that identify similarities between different interpretations of a certain artefact are very useful in providing a coherent summary of multiple documents. This DSR expert also stated that the evaluation paragraphs could be separated into tables. In contrast, another DSR expert would have preferred to receive a natural language overview, rather than concepts that are presented in a table.

Although all DSR experts agreed on the overall coherence of the provided summary, there was still a personal preference in regard to the representation of such information.

No DSR experts could identify any contradictions in the summary.

However, the audience of a multi-document summary has to be taken into account. For instance, a layman might need more information to connect certain components in the summary due to a lack of knowledge about certain concepts. Nevertheless, the DSR experts generally expressed that the provided multi-document summary is coherent..

### 5.4.3 Comprehensiveness

A summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in an article as well as in a multi-document summary. The following questions were asked in the interview:

- Does the summary meet the criterion ‘comprehensiveness’?
- Is there any information or topic missing in the summary?

A further discussion, in addition to the questions above, identified further aspects in respect to the comprehensiveness of the provided multi-document summary.

Generally, all DSR experts agreed that the provided summary is comprehensive to their knowledge.

Most DSR experts did not have a complete representation of all three articles discussed in the multi-document summary in their mind. However, all DSR experts had read all three articles at some point. The interview took that fact into account by focusing on the identification of topic-related concepts that refer to the articles that remained vivid in the DSR experts’ memory. DSR experts were also asked to provide their opinion on the comprehensiveness of the summary in regard to the discussed DSR concepts that are expressed in the summary. No DSR expert could identify missing components in regard to the articles that the DSR experts were familiar with, and in regard to DSR concepts that should generally appear in a comparison of multiple articles.

Interestingly, two DSR experts assumed that there are missing components in regard to articles that the DSR experts had not read for a while. For example, some DSR experts were not sure of whether the creation of higher-level knowledge is covered in these articles. These are concepts that a DSR expert would be interested to see in a summary. However, the DSR experts were not sure whether these concepts appear in the corresponding article.

Similar to the single document summary evaluation, one DSR expert expressed to be interested in figures, or content in these figures, that are mentioned in a specific article. However, the interpretation of figures is considered to be beyond the scope of this research. One DSR expert expressed that the arrows that are included in the figure of the DSR methodology in Peffers et al. (2007) are missing in the summary. However, these arrows are only mentioned in one sentence in the publication and this sentence does not reflect the whole idea that is expressed in the figure. Nevertheless, such information could be expressed in the provided ontology repository, and opens up new research opportunities in regards to the identification of information in figures.

Finally, it was identified that the audience that reads such an article is an important factor in defining the correct level of comprehensiveness of a summary. For instance, one DSR expert highlighted that ex-ante and ex-post should be defined in more detail in regards to the article by Pries-Heje et al. (2014). However, another DSR expert, who was not completely familiar with this article, was able to describe the meaning of these two concepts without additional information. Nevertheless, a summary has to be adapted to the audience that a summary is intended for. In general, the DSR experts were content with the comprehensiveness of the summary, regarding the summary as an overview summary that compares important concepts on a rather higher level. The comparison of concepts on a higher-level is necessary to avoid generating summaries that are a too extensive for an overview summary.

#### 5.4.4 Clarity

A summary is clear if all concepts and relations can be clearly understood. The following questions were asked in the interview:

- Does the summary meet the criterion ‘clarity’?
- Does the summary contain information that is unclear?
- Does the summary contain ambiguous information?

DSR experts’ answers to these questions were further discussed to gain a more complete answer in regards to the clarity of the provided summary.

In general, the provided multi-document summary could be clearly understood by all DSR experts. However, there are minor points that some DSR experts found somewhat difficult to understand.

One DSR expert expressed that the concept ‘entry point’ needs to be defined a little more clearly. Again, this very much depends on the personal expectation

of a specific DSR expert. However, all other DSR experts did not expect further information in regard to this concept.

Another DSR expert did not entirely like the formatting. This DSR expert stated that there are too many headings and tables in the summary. Another DSR expert expressed that tables improve the readability and clarity. However, in general, the provided summary was clear enough to all DSR experts.

All DSR experts agreed that there is no ambiguous information. Nevertheless, most DSR experts also highlighted the fact that some information could be described in more detail and that a high-level description of a concept might lead to ambiguity; however, this again depends on the type of reader. In particular, one DSR expert expressed that the terms ‘evaluation’ and ‘search process’ could be described in more detail. However, most DSR experts mentioned that too much detail might destroy the purpose of an overview summary.

#### 5.4.5 Correctness

A summary is correct if it does not draw any incorrect conclusions, including inconsistencies. The following questions were asked in the interview:

- Does the summary meet the criterion ‘correctness’?
- Can you name incorrect parts in this summary?

All of the DSR experts agreed that the summary is correct to their knowledge. However, all DSR experts also stated that they could only provide an insightful answer about the correctness of the representations of publications that they had recently studied. Nevertheless, this limitation was already taken into account in the design of the study.

One DSR expert also stated that it would be easier to identify the correctness of the summary if more detail was provided. However, overview summaries need to limit the level of detail for the sake of the length of a multi-document overview summary.

#### 5.4.6 Multi-Document Summary Evaluation - Conclusion

The multi-document summary evaluation provided evidence that the proposed multi-document summary fulfils the 5Cs for an overview summary. Because the main intent of this evaluation was concerned with the provision of overview summaries, the 5Cs were verified.

The verification of the 5Cs further infers that the comparison of multiple DSR documents can be captured in the provided ontology repository. Additionally, multi-document natural language summaries can be generated utilising the ontology repository and the information extraction process and summarisation process that is included in DSRCSA.

However, this evaluation could not decisively evaluate the format of the multi-document summary as all DSR experts had different expectations as to how the summary should be formatted. Whereas two DSR experts preferred

tables in the summary, one DSR expert preferred natural language descriptions of the summaries.

One DSR expert stated that figures should be included in a multi-document summary. However, this is beyond the scope of this research as only textual components are taken into account.

Finally, another DSR expert would have liked to see definitions of certain concepts in the summary. However, such definitions would result in extensive summaries and multi-document overview summaries are designed to provide a comparison of high-level concepts.

## 5.5 Artefact Evaluation - Conclusion

The 5Cs were confirmed by the DSR experts in regard to the scope of producing readable, correct, and comprehensive single and multi-document overview summaries, if the proposed DSRCRSA is instantiated properly and the ontology repository includes assertional boxes (a DSRDO per DSR publication and a DSRKB) that instantiate the terminology boxes in DSRDCO and DSRKBO.

However, there are some aspects that could not be evaluated and are beyond the scope of this research. The level of detail that a specific DSR expert expected, other than the minimum that is necessary to provide a comprehensive overview summary, could not be evaluated in this evaluation. A qualitative analysis cannot provide an answer to this question. A quantitative analysis might provide an answer, but is beyond the scope of this thesis. The correct formatting / representation that is needed to provide a personalised experience of a natural language summary could not be reliably confirmed.

Apart from these aspects, the ontology repository is capable of retrieving a formal ontology of a single or multiple DSR publications and can provide natural language summaries that fulfil the 5Cs.

## Chapter 6

# Discussion and Conclusion

## 6.1 Discussion

**Summaries:** Researchers, as well as lecturers and practitioners, consume an increasing number of scientific publications to gain knowledge in a specific field.

Even though researchers seek to retrieve a comprehensive picture of a topic of interest and current search engines try to include relevant work, there are still challenges a searcher has to overcome. For instance, publications might be included in search results that do not correctly relate to stated query terms. This reduces precision and searchers have to review a much higher number of publications to identify publications of interest. Because it is nearly impossible to browse through all documents of a search result set, searchers need to trust ranking algorithms. This can result in an incomplete search result set.

Although this thesis cannot provide a cure that solves the issue of precisely and comprehensively identifying publications that cover a specific query, the proposed architecture and its design principles provide a way to summarise a set of documents to provide a concise, but still comprehensive search result presentation.

Additionally, this thesis depicts a novel ontology engineering approach that utilises semiotic layers, which results in a set of axioms that describe concepts on each of the identified semiotic layers to enable the generation of summaries. This representation can also potentially support many other systems that utilise formal ontologies by providing a more structured ontological representation of a specific concept.

Semiotic layers were adapted from [Stamper \(1996\)](#) and integrated in DSRCRSA. Semiotic layers enable the representation and separation of empiric, syntactic, semantic, pragmatic layer. This separation supports the search process within the ontology as well as the summary generation process.

**Ontology Repository and Formal Ontologies of DSR Articles:** Many summarisation approaches in the literature return extractive summaries. Other summarisation approaches generate abstractive summaries. Abstractive summarisation techniques can include semantic technologies to create document models. Such document models are used to generate summaries. Abstractive techniques need to include a step to generate natural language texts. However, none of these techniques (see [Section 2.4.4](#)) generate an ontology that consists of individuals that are specific to the topic in question, or that include a concept hierarchy that represents semiotic layers.

An ontology repository that includes individuals of important DSR concepts that appear in a specific DSR publication can support the generation of single and multi-document summaries, as was shown in this thesis (see [2.4.6](#)), instead of returning extracts.

The proposed ontology repository consists of two terminology-boxes named DSRDCO and DSRKBO. These terminology boxes utilise the semiotic framework and semiotic triangles to reason over a hierarchy of different representations of high-level DSR concepts. The utilisation of the semiotic framework and the

semiotic triangle supports the development of ontologies that incorporate different semiotic layers (the syntactic layer, the semantic layer, and the pragmatic layer). Formal ontologies that implement semiotic layers can be compared to other formal ontologies at different semiotic layers. Such a differentiation enables the comparison of high-level concept expressions, as well as a comparison on the lower, syntactic layer.

**Design Principles:** Many DSR projects propose a set of design principles that are applicable to systems that solve a specific class of problems. Design principles describe knowledge that emerges out of DSR projects.

Design principles that guide the realisation of DSRCSA include (1) the use of a semiotic framework to depict DSR publications in natural language, and (2) the definition of statements utilising complex classes by adhering the semiotic triangle.

These design principles are named (1) the use of semiotic layers in formal ontologies, and (2) the use of complex classes at each semiotic layer.

Both design principles emerged as a reflection on the design and include prescriptive statements that a general solution is based on.

**The use of semiotic layers in formal ontologies (Semiotic Framework):** The semiotic framework enables the description of concepts on three different layers. These layers represent syntactic, semantic, and pragmatic interpretations of a DSR concept. These layers enable the introduction of axioms that support the deduction of higher-level concepts out of lower-level concepts.

The integration of a semiotic framework further enables a regulated process of defining concepts. This enables the comparison of DSR concepts on each layer of the semiotic framework. Additionally, the introduction of semiotic layers provides a more structured access to components in a formal ontology. Many formal ontologies express a concept by a description that can include a number of paragraphs. However, such information is not helpful if it has to be used by a computer.

Additionally, high-level representations enable the combination of DSR concepts. Concepts on the pragmatic layer express the reader's expectations of a summary in a certain context, whereas the syntactic layer includes a fairly low-level presentation that, for instance, can be used to generate summaries.

**The use of complex classes at each semiotic layer (Semiotic Triangle):** This work delineates that semiotic triangles facilitate the design of ontologies that follow a semiotic layer approach. With the help of semiotic triangles, the transition between different semiotic layers can be expressed. Such a transition includes the definition of a concept by a set of axioms. Such an axiomatic description enables the identification of higher-level concepts. Further, a set of axioms can be replaced by instantiations that fulfil these axioms. These instantiations become the object of the semiotic triangle in the next higher-level, whereas another set of axioms describe the concept of the next higher layer.

**What are Semiotic Layers and Semiotic Triangles for?** Firstly, these design principles support a unified process in instantiating formal ontologies. This process results in syntactic layers that are comparable with other ontologies that might describe a completely different topic, but use the same syntactic representation as a basis.

Secondly, such design principles enable the integration of a process that is capable of generating natural language overview summaries. Natural language summaries can be generated because a high-level (pragmatic) representation of DSR provides a structure that should appear in a summary, and a low-level (syntactic) representation enables the generation of natural language summaries.

**DSR vs. Applied Science:** This thesis briefly discusses the difference between DSR and other research approaches in the applied sciences. In this thesis, a DSR publication describes artefact designs that serve a specific purpose. Thus, an artefact design is considered a purposeful artefact (see [Venable \(2010a\)](#)). Further, a purposeful artefact needs to be evaluated to provide evidence that depicts whether the requirements have been fulfilled.

This definition of a DSR publication deliberately leaves out ‘information systems’ and DSR as a research paradigm. DSR publications do not have to be tailored to problems in information systems. Any research that evaluates and invents a purposeful artefact can be described in a DSR publication.

The research that is presented in this thesis is not limited to DSR in information systems or publications that apply the DSR paradigm. However, there is no general agreement that DSR can be applied to other research in the applied field. Thus, further evidence is needed that supports this position.

To summarise, this thesis follows an adapted interpretation of DSR. This thesis uses the following definition of DSR. DSR is concerned with the invention and evaluation of purposeful artefacts. The output of a DSR project is concerned with artefacts that solve a class of problems and their evaluation. A DSR output includes artefact designs, design theories, and design principles.

**Artefact Evaluation:** Renowned DSR experts were available for three lengthy interview sessions. These experts have many followers, as can be seen in the high number of citations, which means that their opinions are highly credible. These opinions also represent a shared understanding of important DSR aspects.

Although automated evaluations produce results that can be easily compared, natural language summaries include aspects that are hard to evaluate automatically.

Due to the nature of this research, which deliberately excludes natural language processing tasks, it was not possible to prepare a large set of summaries, which would have been necessary if automated evaluation approaches were to be applied.

The evaluations presented in this thesis provide evidence that shows that DSRCRSA is capable of providing overview summaries of single and multiple documents that fulfil the 5Cs.

**Limitations:** This research focussed on the domain of DSR and whether DSR experts can make use of DSR summaries that were extracted utilising DSRCRSA. Thus, DSR experts were asked to evaluate DSRCRSA. Another potential application of DSRCRSA is the utility of DSR summaries for practitioners. Future research on this topic is needed to identify the needs of practitioners in regard to the use of scientific articles.

This research was able to confirm that summaries have to be adjustable to fit the right audience, but more importantly, to fit the scenario for which a specific type of summary is designed. However, this research is unable to show how a specific summary can be personalised by identifying the personal requirements of a certain user. Nevertheless, this research provides evidence that shows that the generated summaries can be used as overview summaries that fulfil the 5Cs.

Additionally, an agreement on one preferred format of a single and multi-document summary could not be obtained. Although participants could agree on the components that should appear in a summary, and the clarity and coherence of the provided overview summaries, the modes of representations could not be clearly identified. This is because all participants had different expectations about the formatting of a summary.

## 6.2 Conclusion

This thesis is concerned with the formal representation of DSR publications by utilising formal ontologies. This thesis provides evidence for the utility of such representations by providing summaries of single documents, as well as multiple documents that were further evaluated by DSR experts.

The generation of natural language overview summaries by utilising DSRCRSA was demonstrated to be feasible. Additionally, the evaluated natural language overview summaries were evaluated to satisfactorily fulfil the 5Cs (conciseness, comprehensiveness, correctness, coherence, and clarity).

**Novel Presentation of Search Results (main RQ):** Research question 1 tries to identify whether cloze text sentences can be used to create concise, comprehensive, clear, coherent, and correct single document summary representations of DSR publications. Research question 1 identifies whether a general solution (the use of cloze text sentences) can solve the general problem, which is expressed in the main research question and described in the following paragraph. The general problem emerged as a result of a literature review, and own and other researchers' experiences in regard to a researcher's literature review process.

The literature review chapter discussed the importance of novel presentations of search results (see Section 2.3.7). Current search result presentations are limited to a list of documents that include additional information per document. However, search engine providers, such as Google with the Google Knowledge Graph, have started to build in functionalities that try to provide answers to certain topics. Nevertheless, overview summaries that include salient concepts

of a number of important search results, especially in academic search engines, are not available yet. The research in this thesis provides a possible solution to this issue.

**Formal Ontologies and Summarisation (RQ 1, RQ 2):** The general problem has been described in the previous paragraph ‘Novel Presentation of Search Results’. A general solution would be the use of cloze text sentences to provide standardised summaries that fulfil the 5Cs. This could be identified in iteration 3 to 5 of the research process (Section 4.2.4.3). Additionally, it could be identified that formal ontologies can support the generation of filled in cloze text sentences.

Iteration 2 identified structures to create cloze text sentences. These structures are simplified ontological representations of DSR content. The feasibility of cloze text sentences in combination with a structured representation could be identified.

Research question 2 was concerned with the question of whether formal ontologies can sufficiently describe DSR and support the summarisation process. Formal ontologies can and are used in many summarisation approaches in the literature (see Section 2.4.4). However, the formal ontologies that are used in such summarisation approaches are reasonably shallow. Often, only subsumption relationships are expressed in formal ontologies that are used in a summarisation process. Additionally, axioms and reasoners are rarely integrated in state-of-the-art summarisation approaches.

However, the research that is reported in this thesis has demonstrated that more expressive ontologies can support the search process, as well as the summarisation process. Formal ontologies that consist of a rich set of axioms to describe a specific concept, are capable of inferring higher-level concepts if reasoners are implemented. Additionally, reasoners validate formal ontologies in regard to their consistency and satisfiability.

**Semiotic Layers:** In addition to the use of more expressive ontologies in the summarisation process, the identification of axioms for the syntactic layer, the semantic layer, and the pragmatic layer, which are expressed in the semiotic framework (see Stamper (1996)), provides a novel approach to interact with formal ontologies. The identification of axioms for each layer provides a more structured description of the concept in question.

The separation into semiotic layers enables the representation of concepts on different levels of the semiotic ladder. Each of these layers serves a different purpose. For instance, the syntactic layer supports the summarisation process as well as the ontology population process. The semantic layer supports the identification of important relations in the document by analysing the meaning of a specific statement. The pragmatic layer supports the identification and composition of concepts that are expected by the reader of the summary.

In this thesis, the utility of these layers was confirmed in the evaluation of single and multi-document summaries. Without these layers, syntactically

correct sentences could not be easily produced.

**Natural Language Overview Summary Generation (RQ 1, RQ 2.a):**

The main research question and research question 1 was determined with a summative evaluation of summaries that have been manually created and then automatically generated by a prototype. The summative evaluation also reflects on research question 2.a. Only if the produced summaries fulfil the 5Cs, the ontology includes all concepts necessary to create such a summary. This was also identified with a set of competency questions that were involved in answering research question 2.b.

The evaluations that are presented in this thesis provide evidence for the effectiveness of design science research document ontologies, in concert with a DSR knowledge-base, to process and to create natural language overview summaries of single and multiple DSR publications.

If DSRDOs make proper use of DSRDCO that is presented in this thesis, and the DSR knowledge-base properly instantiates DSRKBO, DSR concepts can (1) be inferred utilising axioms in DSRDCO and DSRKBO, and (2) overview summaries can be automatically generated utilising the proposed semiotic layer approach.

The evaluations further provide evidence that the generated summaries fulfil essential criteria (the 5Cs) of overview summaries for single and multiple DSR publications.

**Formal Ontology Evaluation (RQ 2.b):** Research question 2.b was concerned with the identification of competency questions. These competency questions enable the summarisation process of single-document and multi-document summaries.

The formal ontologies that are included in the ontology repository of DSRCRSA were evaluated by applying a set of competency questions. The proposed competency questions include the identification of components that are included in single and multi-document summaries. Answers to these competency questions resulted in information that was used by the proposed summariser software to produce single and multi-document summaries. The summaries were successfully generated, which provided evidence in regard to the correctness of the formal ontologies that are proposed in this work.

**The 5Cs (main RQ, RQ 1):** Research question 1 directly reflects on the main research question. The resolution of research question 1 provided a solution that answers the main research question, which is the provision of summaries that can be used as overview summaries.

In this thesis, the 5Cs were identified as important criteria to evaluate single and multi-document summaries.

The single and multi-document summaries that are presented in this thesis fulfil the 5Cs. The fulfilment of these 5Cs provides evidence that the proposed

automatic summariser is able to generate summaries that are readable and concise and that the summaries include all the concepts that are of importance to DSR experts.

**DSR and the Applied Sciences (general applicability):** Many publications in the applied sciences include the concepts that are represented in DSRDCO. Such publications describe the invention and evaluation of purposeful artefacts. However, even though the most important DSR concepts that were confirmed by DSR experts appear in such publications, the work in these publications is not usually described as DSR. This is because DSR is not recognised in many other disciplines. Nevertheless, in this thesis, the term DSR publication is fulfilled if a scientific publication invents and evaluates a purposeful artefact, even if DSR terminology is not used in the publication.

**Limitations:** Most research outcomes include certain limitations. The research in this thesis failed to provide evidence for the following aspects.

This thesis (1) could not identify one correct level of conciseness of a specific summary for all people. However, it was able to identify that the provided summaries are concise enough for an overview summary. Nevertheless, it might be of interest to research the factors that enable the identification of the right level of detail that a specific person expects in a summary.

(2) A single, unanimously agreed upon way of formatting of a summary and how a summary is presented could not be identified in the research of this thesis. Even though all participants agreed on the coherence and clarity of the provided summaries, it was not possible to agree upon the modes of representation. Some participants agreed that tables are a perfect representation to compare certain aspects, whereas others were more interested in a more detailed natural language comparison. Thus, research that identifies the best representation of content in a summary might produce important insights into how summaries should be represented in search engine results.

A third limitation (3) of this research is that the evaluation episodes did not include practitioners as evaluators, which is a matter of future research.

### 6.3 Suggestions for Future Research

**Extraction of Novel Information:** Future research on this topic could include the identification of whether the ontology repository of DSRCRSA that is presented in this thesis could potentially support the identification of novel artefacts that fulfil a specific set of requirements. This could be achieved by combining artefacts in the knowledge base.

Another potential application of the ontology repository could be the identification of evaluation methods that could be used to evaluate a specific artefact. This could enable the comparison of artefacts that could not be compared beforehand, because a common set of criteria was missing.

**Automatic Identification of Axioms:** Currently, natural language processing techniques are still struggling to generate highly accurate results. The identification of semantics in articles that could enable the comparison of a number of relations or concepts, or the identification of salient sentences, could be improved further. For instance, the identification of whether a specific relation or concept that is expressed in an article is related to another relation or concept cannot be answered with 100% accuracy. The identification of salient sentences that consist of instantiations of concepts that should appear in a summary faces similar problems. However, once these issues can be resolved and accurate low-level presentations of salient sentences can be produced, it could be possible to automatically generate formal ontologies that could, with the help of axioms, infer high-level concepts, such as DSR concepts. This identification of high-level concepts could be achieved by automatically identifying axioms that express semantics through the use of syntactic information. Current state-of-the-art dependency parsers, as well as state-of-the-art POS taggers, can provide a structure that is capable of instantiating the syntactic layer of the proposed formal ontologies.

**Format of Textual Summaries:** This thesis could not obtain personal preferences in regard to the correct format of a textual summary. Future research on this topic could include the identification of personal preferences in regard to the format of textual summaries. Additionally, an artefact could be developed that is capable of providing formatted summaries that match the preferences of a specific user.

**Factors of Right Level of Detail of a Summary:** The evaluations could not identify one correct level of conciseness of a specific summary for all people. However, it could be identified that the provided summaries are concise enough for an overview summary. Future research could include the identification of factors that enable the identification of personal preferences in regard to the right level of detail that a specific person expects in a summary for a specific topic and a specific scenario.

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# Appendices

## **Evaluation Artefacts**

**Salient DSR Concepts in DSR Publications Questionnaire**

# DSR Publication Conceptualisation Survey

This survey wants to assess important concepts in regards to publications that follow the Design Science Research (DSR) paradigm. We would like you to participate in this little survey to identify the most important concepts of DSR and after that we would like to ask you to rank a set of pre-identified concepts.

Please name and briefly describe the 3 most important concepts that have to be covered in publications that follow a DSR approach:



Please tick the importance of each concept in regards to publications that discuss research publications that follow a DSR approach.

Concept Name	Description	Importance to DSR Publications					
Artefact	An artefact describes a tangible concept of something that is artificial / human made. "An artefact is <i>"something created by humans usually for a practical purpose"</i> (Merriam-Webster 2016)	1 not important	2	3	4	5 very important	Comments:
Artefact Design	The concept "artefact design" is a subclass of the concept "artefact". An artefact design is an abstract artefact that expresses the design of a product or a method and should show utility for a specific purpose or set of requirements.	1 not important	2	3	4	5 very important	Comments:
Design Realisation	A design realisation expresses an instantiation of a specific artefact design. This realisation is usually used as an evaluand to prove the utility of a specific artefact design.	1 not important	2	3	4	5 very important	Comments:

Requirement	A requirement expresses certain aspects an artefact design should inherit. It can be a requirement, which describes a class of goals to be met (Walls et al. 1992) a theory applies to, or a specific goal an artefact should fulfil.	1 not important	2	3	4	5 very important	Comments:
Theoretical Significance Claim	A theoretical significance claim states a proposition that expresses a piece of research which improves the body of knowledge by a novel application of an artefact, by creating a novel artefact, or by extending existing artefacts using novel concepts.	1 not important	2	3	4	5 very important	Comments:
Practical Significance Claim	A practical significance claim states a proposition that a certain artefact design benefits a certain group significantly to justify a certain piece of research.	1 not important	2	3	4	5 very important	Comments:
Support	<i>"An argument is a set of assumptions, together with a conclusion that can be obtained by one or more reasoning steps. The assumptions used are called the support of the argument."</i> (Besnard and Hunter, 2008)	1 not important	2	3	4	5 very important	Comments:

<p>Base Reference</p>	<p>A base reference addresses a scientific article that contains a certain concept or artefact utilised in research expressed in a certain article.</p>	<p>1 not important</p>	<p>2</p>	<p>3</p>	<p>4</p>	<p>5 very important</p>	<p>Comments:</p>
<p>Main Concept</p>	<p>A main concept expresses an important term / concept used. This term is often related to the artefact or evaluation in question and is often further defined in the document.</p>	<p>1 not important</p>	<p>2</p>	<p>3</p>	<p>4</p>	<p>5 very important</p>	<p>Comments:</p>
<p>Evaluation Technique</p>	<p>An evaluation technique or method can be used to do systematic acquisition and assessment of information about an artefact. (Trochim, 2006)</p>	<p>1 not important</p>	<p>2</p>	<p>3</p>	<p>4</p>	<p>5 very important</p>	<p>Comments:</p>
<p>Evaluation Aspect</p>	<p>An evaluation aspect expresses a feature of a specific artefact or artefact instantiation that further will be evaluated against a number of identified requirements.</p>	<p>1 not important</p>	<p>2</p>	<p>3</p>	<p>4</p>	<p>5 very important</p>	<p>Comments:</p>

Evaluation Criterion	An evaluation criterion is used to describe the utility of an artefact towards a specific requirement.	1 not important	2	3	4	5 very important	Comments:
Evaluation Metric	An evaluation metric can be used to identify how well a certain criterion can be met. In qualitatively assessed criteria this can be a set of levels and in quantitatively assessed criteria there are often certain thresholds identified.	1 not important	2	3	4	5 very important	Comments:
Evaluation Result	An evaluation result is a proposition that expresses the interpretation of a metric that has been analysed towards a certain criterion. This criterion further reflects on the identified requirements.	1 not important	2	3	4	5 very important	Comments:
Purpose	To further define any of the concepts above a specific purpose can be expressed. A purpose identifies what a specific artefact, requirement, evaluation technique, etc. can be used for, which expresses the scope of a certain concept instantiation but also its limitations. This concept is used to further qualify a concept instantiation in a summary.	1 not important	2	3	4	5 very important	Comments:

Property	A property is also used to further define an instantiation of the above mentioned concepts. It expresses inherent features of a certain instantiation. This concept is used to further qualify a concept instantiation in a summary.	1 not important	2	3	4	5 very important	Comments:
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**Thank you very much for your contribution**

## **Single Document Summaries**

**A Design Science Research Methodology For Information Systems  
Research**

## Summary of the article “A design science research methodology for information systems research” (Peppers et al. 2007)

Peppers, Ken, et al. "A design science research methodology for information systems research." *Journal of management information systems* 24.3 (2007): 45-77.

### Thesis statement

This article describes an artefact named <Design science Research (DSR) methodology for Information Systems (IS),[1]>. The proposed artefact fulfills the requirements to <be consistent with prior literature,[2]>, to <provide a nominal process model for doing IS research,[2]> and to <provide a mental model for presenting and evaluating DS research in IS,[2]>.

### Significance

This <DSR methodology for IS,[1]> offers the possibility to <help aid DSR research in the IS discipline,[3]> and to <present research with reference to a commonly understood framework,[3]>.

<This <DSR methodology for IS,[1]> adds a <procedure, [1]> to the body of knowledge, [3]>. This <procedure, [1]> is used to <provide a generally accepted process [10]> to <carry out <DSR research for IS,[9]>, [10]>

### Artefact description

This <DSR methodology for IS,[1]> consists of <principles,[1]>, <practice rules <for DSR research, [11]>,[1]>, <procedures,[1]> and <entrypoints,[1]>.

<Practice rules for DSR research,[1]> consist of <the creation of an artefact to address a problem, [1]>, <the relevance to the solution of an unresolved and important business problem, [1]>, <a rigorous evaluation of the artefact's utility, quality and efficacy, [1]>, <a search process to design an artefact, [1]>, and <the effective communication <to appropriate audiences, [11]>, [1]>.

The <search process, [1]> <draws from existing theories and knowledge, [11]> to <come up with a solution <to a defined problem, [11]>, [10]>. <(Hevner et al.), [12]>

<Procedures, [1]> consist of <problem identification and motivation,[1]>, <definition of the objectives for a solution, [1]>, <design and development, [1]>, <demonstration, [1]>, <evaluation, [1]>, and <communication,[1]>.

<Entrypoints, [1]> consist of <a problem centered initiation, [1]>, <an objective centered solution initiation, [1]>, <a design and development centered initiation, [1]>, and <a client/context initiation, [1]>.

### Evaluation

#### Setting

<Retrospective application, [4]>, and <logical reasoning, [4]> have been used to evaluate the artefact.

The evaluands in the <retrospective application, [4]> were <four already published IS research projects , [7]>.

The <four already published IS research projects , [7]> have <different <entrypoints, [1]>, 11>.

The evaluands in the <logical reasoning, [4]> were <7 DSR publications, [7]> and <the created procedures, [1,7]>.

<Logical reasoning, [4]> has been used to evaluate the following aspects: <compliance to consistency of the artefact with prior literature, [5]>, and <existence of a mental model for the presentation of research outcomes,[5]>.

<Retrospective application, [4]> has been used to evaluate the following aspect: <compliance of the developed model to a nominal process, [5]>.

## Results

The <compliance to consistency of the artefact with prior literature, [5]> has been determined by inferring <the created procedures, [1,7]> out of the <7 DSR publications, [7]>.

The <compliance of the developed model to a nominal process, [5]> has been determined by successfully mapping the <DSR methodology,[1]> to <four already published IS research projects , [7]>.

The <existence of a mental model for the presentation of research outcomes,[5]> has been determined by inferring the <mental model, [9]> out of the <four already published IS research projects , [7]>.

<DSRM, [1]> can be <used as a structure to present action research, [10]>. The <search for a designed artefact, [1]> can be <presented as action research, [10]>.

## Key

- [1] Artefact Design
- [2] Requirement
- [3] Theoretical Significance Claim
- [4] Evaluation Technique
- [5] Evaluation Criterion
- [6] Evaluation Aspect
- [7] Design Realisation
- [8] Evaluation Result
- [9] Main Concept
- [10] Purpose
- [11] Property
- [12] Base Reference
- [13] Artefact
- [14] Support
- [15] Practical Significance Claim
- [16] Evaluation Metric

## Action Design Research

## Action Design Research (Sein et. al)

Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research.

### Thesis statement

This article describes an artefact named <action design research (ADR), [1]>. The proposed artefact fulfils the requirements to <generate prescriptive design knowledge, [2]>, to <build IT artefacts in an organizational context, [2]>, to <learn from the intervention while addressing a problematic solution, [2]>, and to <focus on ensemble artefacts emerging from design, use and ongoing refinement in context, [2]>.

### Definitions

<Ensemble artefacts, [9]> consist of <material features, [9]>, and <organizational features, [9]> that are <socially recognized as bundles of hardware and/or software, [11]>.

### Significance

<ADR, [1]> offers the possibility to <provide explicit guidance for combining building, intervention, and evaluation in a concerted research effort [3]>.

<<ADR, [1]> adds a <procedure, [1]> to the body of knowledge, [3]>. This <procedure, [1]> is used to <support the influence of the relevance cycle <(Hevner 2007), [12]>, [10]>.

<<<ADR, [1]> shapes the artefact design over multiple artefact versions, [3]> <through intervention and iteration, [11]> whereas <<classic DSR models, [1]> produce only an initial prototype, [3]>, [3]>.

### Artefact design description

<ADR, [1]> consists of <building and evaluating <ensemble IT artefacts, [9]>, [1]> <in an organizational setting, [11]>.

<ADR, [1]> <can be used for open ended IS research problems, [10]> that <require repeated interventions in organisations, [11]>.

<ADR, [1]> consists of 4 <stages, [1]>, specifically <problem formulation, [1]>, <building of the IT artefact, intervention in the organisation and evaluation (BIE), [1]>, <reflection and learning, [1]> and <formalization of learning, [1]>.

All <Stages, [1]> consist of <principles, [1]> and <tasks, [1]>.

<Problem formulation, [1]> consists of 2 <principles, [1]>, specifically <practice inspired research, [1]> and <theory-ingrained artefacts, [1]>.

<Problem formulation, [1]> consists of 6 <tasks, [1]>, specifically <identification and conceptualisation of the research opportunity, [1]>, <formulation of initial research questions, [1]>, <casting of the problem as an instance of a class of problems, [1]>, <identification of contributing theoretical bases and prior technology advances, [1]>, <securing long-term organizational commitment, [1]>, and <the set-up of roles and responsibilities, [1]>.

<BIE, [1]> consists of 3 <principles, [1]>, specifically <reciprocal shaping, [1]>, <mutually influential roles, [1]>, <authentic and concurrent evaluation, [1]>.

<BIE, [1]> consists of 4 <tasks, [1]>, specifically <discovery of initial knowledge-creation target, [1]>, <selection or customisation of building of BIE form, [1]>, <execution of BIE cycle(s), [1]> and <assessment need for additional cycles, [1]>.

<Reflection and learning, [1]> consists of 1 <principle, [1]>, specifically <guided emergence, [1]>.

<Reflection and learning, [1]> consists of 3 <tasks, [1]>, specifically <reflection on the design and redesign during the project, [1]>, <evaluation adherence to principles, [1]> and <analysis of intervention results according to stated goals, [1]>.

<Formalization of learning, [1]> consists of 1 <principle, [1]>, specifically <generalized outcomes, [1]>.

<Formalization of learning, [1]> consists of 5 <tasks, [1]>, specifically <abstraction of the learning into concepts for a class of field problems, [1]>, <sharing of outcomes and assessment with practitioners, [1]>, <articulation of outcomes as design principles, [1]>, <articulation of learning in light of theories selected, [1]> and <formalisation of results for dissemination, [1]>.

## Evaluation

### Evaluation Setting

<Retrospective application, [4]> has been used to evaluate the artefact.

The evaluand in the <retrospective application, [4]> was <a previously published research project at Volvo IT called VIP, [7]>.

### Evaluation Result

The <emergence of the artefact from the interplay between design ideas contributed by the researchers and the organizational environment, [5]>, the <ensemble nature of the artefact, [5]>, the <instantiation of the artefact as a member of a class of Competency Management System (CMS) artefacts, [5]>, and the <importance of the BIE cycle in developing the artefact, [5]> have been determined by <retrospective application, [4]> of <ADR, [1]> to the <VIP research project, [7]>.

## Key

- [1] Artefact Design
- [2] Requirement
- [3] Theoretical Significance Claim
- [4] Evaluation Technique
- [5] Evaluation Criterion
- [6] Evaluation Aspect
- [7] Design Realisation
- [8] Evaluation Result
- [9] Main Concept
- [10] Purpose
- [11] Property
- [12] Base Reference
- [13] Artefact
- [14] Support
- [15] Practical Significance Claim
- [16] Evaluation Metric

## Multi-Document Summary

## Description and Example of a Combined Summary of <<DSR Methodology>> artefacts

### Introduction

The summary below depicts a combined, context related summary of the DSR knowledge contained in the articles “Soft Design Science Methodology” (Pries-Heje, Venable, Baskerville 2014), “A design science research methodology for information systems research” (Peffer, Tuunanen, Rothenberger, Chatterjee 2008) and “Action Design Research” (Sein, Henfridsson, Purao, Rossi, Lindgren 2011).

### Context

The context of this summary is to display and compare artefacts that describe the reference concept <<DSR methodology>> in response to a query from a user. This summary contrasts the identified artefacts relevant to the reference concepts <<artefact requirement>>, <<artefact decomposition>>, and <<evaluation technique>>, the last of which is used to evaluate the identified artefacts.

What follows is the example summary as it would appear to the user, except that the text delimits parts extracted or derived from the ontological representation, using single, double or triple brackets as shown in the key to the right. For the user, these brackets would not be included to improve readability.

### Summary of <<DSR Methodology>> artefacts

This summary answers the query to compare <<DSR methodology>> artefacts in terms of their <<requirements>>, their <<artefact decomposition>> and their <<evaluation technique>>, the last of which is used to evaluate the identified artefacts.

The query returned <3> <<DSR methodology>> artefacts: <Action Design Research (ADR)> <(Sein et al. 2011)>, <Soft Design Science Methodology (SDSM)> <(Pries-Heje et al. 2014)>, and <Design science research methodology (DSRM)> <(Peffer et al. 2007)>.

### 1. Requirements

### Key:

<<Reference Concept>>	These double brackets (quillemots) contain reference concepts. “Reference Concepts are selected for their use as concrete, subject-related or commonly used notions for describing tangible ideas and referents in human experience and language.” (UMBEL webpage 2016) Here, reference concepts are used to identify common concepts represented in scientific articles.
<Specific concept identified in an article>	These single brackets contain instances of reference concepts or concepts only expressed in one specific article. These instances are often more detailed than the reference concept itself and can include further clarifications in terms of properties.
<<<Derived concept / complex class>>>	A triple bracket contains combined single bracket components to improve readability.

### 1.1. Similarities between all artefacts

All artefacts fulfil the requirement to <<<provide a process for doing DSR research>>>.

### 1.2. Differences

In addition to the requirement mentioned above, the identified artefacts also fulfil the requirements below.

<ADR> fulfils the requirements to <<<learn from intervention>>>, and to <<<build an IT artefact in an organisational setting>>>.

<SDSM> fulfils the requirement to <<<develop new ways to improve human organizations>>>, and to <better support design creativity>.

<DSRM> fulfils the requirement to <<<be consistent with prior literature>>>, and to <<<provide a mental model for presenting and evaluating DSR research>>>.

### 1.3. Requirements about <<Artefact output>>

<ADR> outputs <ensemble artefacts>, and <SDSM> <sociotechnical artefacts>.

## 2. Artefact Decomposition

### 2.1. Similarities

All artefacts contain a <<process>>.

#### 1.2.1. Concept <<Stages>>

A <<process>> consists of <<stages>>.

A <<DSR methodology>> may include the following types of <<stages>>: <<problem formulation>>, <<building an IT artefact>> and <<evaluating an artefact>>.

#### 1.2.1. Concept <<Problem formulation>>

The following table displays <<stages>> that instantiate the concept <<problem formulation>>.

<<Artefact>>	<<Stage>>
<ADR>	<problem formulation>
<SDSM>	<inspire and create the general problem and general requirements>
<DSRM>	<problem identification and motivation>

### 1.2.2. Concept <<Building an IT artefact>>

The following table displays <<stages>> that instantiate the concept <<building an IT artefact>>.

<<Artefact>>	<<Stage>>
<ADR>	<building an IT artefact> included in the <BIE cycle>
<SDSM>	<intuit and abduce the general solution>
<DSRM>	<design and development>

### 1.2.3. Concept <<Evaluating an artefact>>

The following table displays <<stages>> that instantiate the concept <<evaluating an artefact>>.

<<Artefact>>	<<Stage>>
<ADR>	<evaluating an artefact> included in the <BIE cycle>
<SDSM>	<ex ante evaluation> and <ex post evaluation>
<DSRM>	<evaluation>

### 1.2.4. Concept <<Communication of the artefact>>

The following table displays <<stages>> that instantiate the concept <<communication of the artefact>>.

<<Artefact>>	<<Stage>>
<ADR>	<formalisation of learning>
<DSRM>	<communication>

### 1.2.5. Concept <<Iterative process>>

<ADR> and <SDSM> include an <<iterative process>>.

In <ADR> the <<iterative process>> is expressed in the property that it <<shapes the artefact over multiple versions>>.

The following table displays <<stages>> that instantiate the concept <<iterative process>>.

<<Artefact>>	<<Stage>>
<ADR>	<BIE cycle>

<SDSM>	between <intuit and abduce the general solution> and <design specific solution for specific problem>, between <design specific solution for specific problem> and <construct specific solution>, and between <construct specific solution> and <learn about specific problem>.
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## 2.2. Differences

### 2.2.1. Concept <<Stages>>

<ADR> consists of <4> <<stages>>, specifically <problem formulation>, <BIE cycle>, <reflection and learning> and <formalisation of learning>.

<BIE cycle> consists of <building an IT artefact>, <intervention in the organisation> and <evaluating an artefact>.

<SDSM> consists of <8> <<stages>>, specifically <learn about specific problem>, <inspire and create the general problem and general requirements>, <intuit and abduce the general solution>, <ex ante evaluation>, <design specific solution for specific problem>, <specific ex ante evaluation>, <construct specific solution>, and <ex post evaluation>.

<DSRM> consists of <6> <<stages>>, specifically <problem identification and motivation>, <definition of the objectives for a solution>, <design and development>, <demonstration>, <evaluation> and <communication>.

The following table depicts <<stages>> that do not show similarities to other artefacts mentioned in this summary.

<ADR>	<SDSM>	<DSRM>
<intervention in the organisation> included in the <BIE cycle>	<learn about specific problem>	<definition of the objectives for a solution>
<reflection and learning>	<design specific solution for specific problem>	<demonstration>
	<construct specific solution>	

### 2.3. Concept <<Setting>>

<ADR> is used in an <organisational setting>.

## 2.4. Concept <<Entry Point>>

<DSRM> contains <<<entrypoints of research initiations>>>.

## 3. <<Evaluation techniques>>

This section discusses <<evaluation techniques>> that were used to evaluate these artefacts.

### 3.1. Similarities

The utility of all artefacts has been evaluated using <<retrospective application>>. All artefacts have been evaluated for <<<compliance of the developed model>>> with <<published literature>>.

### 3.2. Differences

<ADR> has been evaluated using a <<<published IS research project at Volvo>>>. <ADR> used <<retrospective application>> to confirm the <<<emergence of the artefact from the interplay between design ideas contributed by the researchers and the organisational environment>>>. <ADR> also used <<retrospective application>> to confirm the <<<ensemble nature of the artefact>>> and <<<the importance of the BIE cycle>>>.

<SDSM> has been evaluated using a <<<published research project at Danske Bank>>>. <SDSM> used <<retrospective application>> to confirm <similarities> and <differences> to <action research>. <SDSM> used <<retrospective application>> to confirm the likelihood of <<<applicability of solution artefacts>>>. <SDSM> used <<retrospective application>> to confirm the likelihood of <<<more structure>>> in the <search process>. <SDSM> used <<retrospective application>> to confirm the likelihood of an <improvement> in <action research projects>. <SDSM> used <<retrospective application>> to confirm the likelihood of <gaining clearer insight> into <<<generality of solution>>>. <SDSM> might be limited to <<information systems>>.

<DSRM> has been evaluated using <4> <published IS research projects>. <DSRM> using <<logical reasoning>> between <7 DSR publications> and the <<process>> artefact.

<SDSM> used <<logical reasoning>> to confirm the <<<compliance to consistency of the artefact>>> with <<published literature>>.

## Transcripts

### Participant 1

# Transcript Interview 1

E: Thank you so much. Thanks. Ok. As I have said, so, this is the first stage. There was this one questionnaire to fill in. Thanks a lot for doing that.

P1: You're welcome.

E: And the second one after that would be that I will send you a summary of one of the 4 papers I have proposed and after that I would only like to discuss with you briefly concerning the 5 Cs.

P1: OK

E: But that. Yeah.

P1: Yeah.

E: OK. And, so the questions I have is just of general nature, you know, so what are your fields of expertise you would say?

P1: Knowledge Systems, Philosophy of Technology, Human computer interaction

E: OK.

P1: They are the main ones.

E: OK. As well as design science research in general.

P1: Yeah, Yeah that one. Yeah

E: Yeah. OK, So, thanks a lot. The second question would be. What's your level of expertise in DSR on a scale from 1 to 5. What do you think.

P1: That's probably pretty high. It's probably 5.

E: Yeah. I would say so too but I have to ask that so.

P1: Yeah. Alright.

E: Do you have an idea of the years of experience in design science research.

P1: Yes I can. It goes back to - in actual design science research I date it back to 1999. I wrote a paper with [NAME OF AUTHOR] but we called it [NAME OF PAPER] but it was really design science.

E: Oh. Great. OK. Thank you very much for this information. Ahm. OK. So that's more or less it and now I have some follow up questions concerning what you've already filled in. So it's about, you know, the most important concepts in your opinion when it comes to design science research or let's say scientific publications that follow the design science research paradigm and I really like what you've put in as the 3 main concepts which I just want to clarify whether I got that right or not. So it's actually - requirements and goals, the artefact itself, design principles, and what's new and novel.

P1: Yeah, yeah. What was the first one you said that wasn't requ - did you say requirements for the first one.

E: Actually what you've written here is the description of the artefact with what it does and how it does it.

P1: Yeah.

E: So goals on one side. What it does? Correct?

P1: Yeah.

E: And how it does is actually the description of the artefact itself in terms of components and processes.

P1: Yeah.

E: So, you would say it's only - what it does means the goals and not so much the requirements?

P1: Well, that gets to be a very tricky thing and I'm working with [NAME OR RESEARCHERS] on that a bit because requirements are - I mean you can say the goal, what are things supposed to do but do requirements mean that you are just specifying the goal in more detail? Or does it mean, if you ones - if you start specifying exactly how something should be doing, then you not - it could be constraints. I would be very careful whether you into - you must gonna do something about that. Logical - anyway - just the wording can get quite tricky.

E: Oh yes. And I found it very interesting. I'll come to that shortly actually because you pointed that out quite clearly that there is a difference between requirements and goals and if you see it that way I would actually agree with that but I'll come to that shortly. One question I have - because design principles is missing in the conceptualisation I proposed and the reason for that is that I always thought that the artefact design, the actual output of design science research, can be treated as design principles. Would you agree with that?

P1: I definitely not, no.

E: OK.

P1: You can have the artefact. So this is this debate we had, you know, theory vs. artefact. And I reckon if you just do the - the artefact often is not enough. Got abstraction about it. An example [PERSONAL INFORMATION] was the sponge cake - a cake. I can show you a sponge cake. There is absolutely no way you want to recreate the sponge cake from looking at it. I know, probably, because you are a male and it is very unlikely that you mother taught you how to make sponge cakes.

E: Well, I'm not very good in baking, that's right, but I can do a bit

P1: Yes, but sponge cakes are very special if you haven't learned when you were younger about the creaming of butter and sugar you won't know how to do it. So anyway, the general thing there is that the artefact itself is sometimes is just not enough. You can't do the reengineering.

E: Yeah. I agree with that. The differentiation we actually have come up with is the artefact design, which actually could be a method to tell you how to create a sponge cake for example, and the design realisation, which is actually the instantiation, like the sponge cake itself, the actual product.

P1: Yeah. There is quite a good paper by, I think it is partly by - "Yair" is one of the authors about what is design. And what you just called design, they call the specification.

E: Do you know the paper? The authors maybe.

P1: Yair is one of them. Jeje - Y - A - I - R. If you send me an email I could try. I know it's in a folder.

E: OK. Thanks a lot. I don't wanna steel too much of your time so we just move forward. The idea is that the artefact design could consist of design principles whereas the design realisation is the sponge cake but I won't go any further now, else we can't finish that in time. So we just move forward. Is that OK?

P1: Yeah.

E: OK. Then you had these requirements vs. goals, which I found very interesting and what you just said beforehand actually I found interesting too that, you know, is that true that even for you you currently try to analyse a research topic. How far are they related. Or do you think.

P1: It's part of something else we are doing but again there is a problem. We found that ourself when we tried to extract design principles in a project we are working in. The requirements is something, more like subsidiary goals. Or subgoal

E: Yeah. That sounds good. Because I actually - I thought about that and tried to come up with an example. So, one example I've come up with is like a requirement could be - maybe digital libraries retrieve articles

with a higher precision and the goal could be return relevant articles. I guess this would fit that the requirement is actually the subgoal.

P1: Yeah.

E: OK. Thank you. So, theoretical significance: You wrote don't be precious about theory. Do you think about the outcome or about the input then.

P1: What I meant there. You know, because I wrote the paper about theory everybody thinks that I think that design science should produce theory. I think, if you could produce a few principles that's OK. Doesn't have to produce theory. It should make a contribution to knowledge. I think, some design principles or a novel artefact as long as you give the actual specifications for it is enough.

E: Thanks for that. What the concept theoretical significance, which is in there, is actually the justification of let's say why it's different to other work in this area, so, it could actually also be that these principles are described in here which didn't appear in any other paper. Just a form of identifying the significance of an article.

P1: That's right. The significance. You know what the journal editors always want, the contribution to knowledge.

E: Right. OK. Practical significance: You said that you think that the definition is incorrect, and I actually like the definition, like utility for practical real world problem. Do you think that's related to actually providing a benefit to a certain group of people?

P1: Yes. That's similar.

E: But I like. Well, you know. I'll do the study first and then I will adapt the definitions but I actually like your definition. OK. Support. What did we have there? Ah, yeah, you like the Toulmin's arguments better, you have written, when it comes to the concept of support. It's, I like the Toulmin structure as well. What we have thought in here is to simplify it as good as possible so just saying that an argument consists of a support and a claim. And that's what we think is a bit easier to handle. Especially when it comes to instantiating this ontology because Toulmin's concepts.

P1: It's just that I used Toulmin in my own papers so, I quite understand that to other people it might not be that meaningful. That's find.

E: No, I also like Toulmin and the problem is that we have to find a way that the ontology is still abstract enough and easy to instantiate but on the other hand it should be meaningful enough to, you know, so it's a kind of, you know, we have to find a balance here.

P1: And that's fine. I understand that. That's OK.

E: Evaluation aspect: You didn't understand what I meant here, or we. It's actually the aspect of the artefact, or let's say the design realisation you want to evaluate, to actually identify whether the requirements have been met or not. So that's the idea behind that. Because it's not - you never can't evaluate the whole artefact. You should - in my opinion - but it might not be possible.

P1: Yes that's good. That's a good idea. Yes. OK.

E: OK. Then purpose and scope: It's, I guess it's similar to requirement and goal. Isn't it? So, it's the purpose itself restricts the scope. Do you think that's. Or is that what you think about the differentiations.

P1: Oh, I don't know. Again these words are getting used in all sorts of ways, don't they. So, scope. So I want a design. I always go back to those examples of Heidegger. So, a silver chalice, the scope, it's being used in religious rituals. Giving a bit more background / context.

E: So the scope gives more context? Is that?

P1: Yeah. To be applied for. Or I wanna design a coat. The coat has to be warm in winter. So the scope is a coat for winter. For some. Yeah. Boundaries is probably the best word. Scope, boundary.

E: Mhm. Boundary. Thank you very much. So,

P1: You've got birds singing in the background.

E: That's right. There are many birds here. But

P1: Are you Austrian. I've forgotten.

E: I'm Austrian. Yeah. Yes.

P1: So which town are you in?

E: I'm in Graz. That's 2 hours south of Vienna and ...

P1: Alright. Any more questions?

E: Sorry. Ah. OK. There is one last question. You said - pointed out that support as well as evaluation has only got 3 points on the Likert scale I provided. So, what's your opinion on that. Do you think that evaluation is not so important or?

P1: Ahm. Evaluation?

E: And argumentation?

P1: They are 2 different things, so evaluations is when you are at work - I should have made that pretty important - that should be important. But the support. I think sometimes with a novel artefact you need not necessarily know why it worked or there may not be any reason for it working. It is something that you kept. You know, if I would say I designed something like a Bubble sort. What's the support. It just works.

E: Yeah, that's right Mhm. Hm. OK. But evaluation is still important for you, you think.

P1: Yeah, it should be important. Yeah I don't know why I didn't give it top - it should be top or second top.

E: Maybe it's the level of evaluation or how valid *the evaluated* ??? 17:13 because there are many different levels - I would say, when you read all these articles.

P1: Sure.

E: OK and four points for design realisation. Do you think design realisation, like the actual instantiation of the artefact might not be important in an article.

P1: Sometimes you could have a design science paper without an instantiation. Yes.

E: OK

P1: You could just have a pure theory paper. So for example there is one paper by - it's called visual notations by Daniel Moody. It's a design theory. He doesn't have an instantiation, so.

E: OK. Thank you so much. That's more or less it. I hope that is OK - there is one last question. Do you know what summary you want to read?

P1: What was the first one.

E: It was action design research. The Sein et al. paper. Then there would be

P1: Oh the summary paper. Yes I happily review that because I use that.

E: OK. OK great. So, I just want to give you a summary you are familiar enough with the article as well because then you don't need to spend so much time on it, you know.

P1: Alright that's good and it's a good useful paper.

E: OK great. I'll send it to you in the next couple of days. You know. It might be Monday because I have some family business to do and then we can arrange another meeting. Would that be OK?

P1: I'm so far behind it's you know. But the tasks haven't taken very long so far so I try hard. OK.

E: OK thank you very much. It's actually the summary is not very long anyway so it shouldn't take too long.

So thanks a lot.

P1: Thank you. Have a nice ...

E: Thank you for your help. Have a good day. Bye.

# Transcript Interview 2

E: OK Great. I don't know. Oh is it OK again that I record this call. Only audio recording.

P1: Yeah that's OK.

E: I need to transcribe it afterwards that always takes a while to. This interview is actually only about this one summary / abstract which actually has been created manually but should be able / possible to be created automatically. I'm actually currently finishing that up but the important things here is to identify whether in your opinion as a researcher these 5 Cs hold if you wanna see it that way. Well firstly I hope I could answer all questions you had.

P1: I got one further question. I asked you about 3 thinks that I thought are a bit similar. Your artefact design to me is basically a specification, the abstract specification.

E: Yeah right, that's correct.

P1: And the design realisation is the physical thing.

E: Yes.

P1: What's the other one?

E: Artefact you mean?

P1: Yes.

E: Artefact is just. In my conceptualisation, artefact is the supertype of it, which actually means artefact design, as well as design realisations, they are both artefacts, and artefact itself is the supertype, which means that if it's not possible to identify right away whether it's an artefact design or design realisation I can still assign it to be an artefact and specialise it later, once I find it out.

P1: That's fair enough because sometimes with us too you get software - the software specification becomes the artefact, doesn't it.

E: Yeah.

P1: At a level you could write pseudo code that expresses basically the artefact.

E: Right.

P1: OK

E: It also depends on the publication and so on. A design realisation might also become - well, that's usually not the case. Well it can become an artefact design to some extend as well but important thing is that I just don't know right away when you read or you parse such an article whether it's the artefact design or it's the design realisation you evaluate further but it's a very important concept in DSR because the artefact, the design realisation is usually used to identify the utility of the artefact design or to evaluate the utility of the artefact design, so

P1: Another one I've had problems with the work I'm doing, mostly with [NAME OF RESEARCHER], is distinguishing between purpose and requirements.

E: Ohm

P1: It's someone the sorts of different level. The purpose is. I suppose you could have lot's - you could have a purpose. I want to shift a rock with the minimum amount of. I want to shift a rock - then the requirement says with the minimum amount of effort.

E: Yes, that's exactly the idea I had to there.

P1: Alright, so that's OK.

E: It's the - what I actually - the idea behind the use of 2 different concepts is that the requirement is usually something you wanna evaluate at a certain point. So you have a certain set of criteria or a metrics to evaluate whether this requirement is fulfilled by the artefact or the artefact design.

P1: You have that for the purpose as well.

E: Yeah. That's right. No no, I agree but I had to distinguish between these 2 things because I want to describe the artefact, and being able to describe the artefact I want to describe properties of the artefact but as well as the purpose and the purpose – because these 2 things can further define a specific artefact. The requirement is also, as you have already said, also a kind of purpose but this requirement is actually the requirement in this study, so this – the thing that has to be evaluated.

P1: OK, towards more specific.

E: Yeah

P1: OK, alright so you go ahead with what you wanted to ask me.

E: It's actually – I only wanna go through these 5 Cs. So firstly, what do you think about, you know, conciseness. Do you think the summary is concise, or is there too much information in it, or too little?

P1: Seems OK to me.

E: OK. So there is - because you know there is always - obviously it's the point of view of the reader and you as a researcher might be interested in other thing than other people / practitioners are. So I only ask you as a researcher. So the conciseness is OK? Or should there be more information or less information?

P1: If it was me. If I would right an abstract I would put the purpose at a higher level.

E: OK. So, you mean – because there is actually - I have to write that down. I'm sorry. There is am - so the thesis statement itself is usually the artefact together with the requirements that have to be evaluated then.

P1: OK. That's alright. Fair enough.

E: So that could be the purpose then and further down I have the artefact description where you actually - in this specific case - there - it's the components of the artefact I described here. There is not so much further about the purpose and so. As far as I can remember. Yeah. OK. Ahm. Great, so you thing it's concise enough and it maybe the purpose is more important but because it's in the thesis statement I hope that's OK. Ahm.

P1: Not actually you got fulfil the requirements.

E: Yeah, right, right. These are the requirements. So you think the purpose itself should also be more on top of - in the beginning of the actual Ahm summary of abstract. OK, the next question would be coherence. So do you think that, you know, the abstract or summary is coherent? So, are this concept or the knowledge within well organised?

P1: Yes, once I've been able to know what the actual key things meant.

E: *laughter*

P1: The only other things is perhaps to give a definition and example of the key.

E: Yeah, Yeah, Yeah - I'm very sorry. I should have done that. I did that in the questionnaire I have sent you for the first interview where I put in the definition but I forgot to put them in here too so I'll actually change that.

P1: No, no that's alright and we all have slightly different views on this but anyway OK.

E: Yeah, Yeah well that's right - that's right. Ohm. Ok and the structure itself, you know, with thesis

statement and some definitions that are necessary, significant, artefact description, evaluation. You think that's alright?

P1: Yeah apart from purpose being a bit highlighted.

E: OK, so it would be good to add section - a purpose section.

P1: Yeah you could put in the actual name of the artefact. What it's called.

E: Yeah, it's in the first sentence. The article describes an artefact named Action Design Research.

P1: OK, alright - sorry I missed that. OK good ??? (11.14)

E: Ahhm - Soo. The next question would be comprehensiveness.

P1: Yeah just hang on a second. So name you get the same as (1) artefact design. You said it's named such and such.

E: Mhm.

P1: Well, I don't think it's quite the same thing as the design to me.

E: Ah, Ah OK so you do.. - So the name is. You wouldn't say that the name is the artefact design, because there has to be a name for the artefact design. I have to choose a name for the artefact design then the artefact design has to be described so.

P1: The artefact design. I mean just if I took an example. Ahm. I can say a name to you: "Bubble Sort". That's a name.

E: Mhm. Ja.

P1: The name of an artefact. And then the design of that is the specification - how it works. I'd start talking about how it bubbles up and bubbles down. That's the design. I mean the implementation is the actual physical running bubble sort.

E: Mhm. Mhm. Mhm. So you have - you mean - there is the name, then you have the specification, which describes the design, and then you have the realisation, which is the actual code.

P1: Just - to tell you the truth a lot of time when I reviewed articles - design science papers - they get into a lot of trouble because they just don't give this thing a name.

E: Yeah. That's right.

P1: And they are talking about, you know, such and such artefact. If I say to you bubble sort and you understand what a bubble sort is and then it (A) it should represent the main concept.

E: Mhm. Mhm. Yeah. Right. Well, actually I found that out too, you know. If I can't find a name for the actual artefact then I use the author's name like Sein et al.'s artefact, for example but you are right, that's often a problem.

P1: I mean it's probably to late to change your actual list of concepts - the list of things you've gotten on the 16 things but that would just be my suggestion that you would put in a name somewhere, the name of the artefact.

E: Hmm. The name of the artefact.

P1: I would call it the main concept as well, the main concept / name

E: OK. OK. Thank you. I've written that down.

P1: If I say to you "cup", that envisages the concept of a cup, doesn't it? or desk, or I mean you could actually define what the specification of desk is.

E: That's right. Yeah.

P1: The desk is to support things.

E: And the property is that it has four legs, or something like that.

P1: Yeah. Alright. Like a flat surface and that sort of thing.

E: Right. Yeah.

P1: Off you go again then. OK.

E: OK. Hmm. The next thing is comprehensiveness. Do you miss some information?

P1: Yeah - names. - *laughter*

E: *laughter*

P1: Yes. Yeah. OK

E: So, when. In. Well, in relations or in regards to the actual article. Do you think that maybe some information should be a bit more complete or a bit more detailed?

P1: I think that we might come to the amount of correctness.

E: Yeah. Yeah. OK. *laughter* OK. I'll ask that again then because that's actually a very important point to and then - in my opinion, well it depends on a person and it depends on the field of expertise as well. So, if you, if you very - if you are an expert in this field then you might not need that much information but if you are not an expert then you might need a bit more detailed information. But on the other hand it's a summary, you know, so, you can't, you can't write a 20 page summary about a 30 page paper. You know.

P1: Yeah. That's right. You got one there.

E: Yeah.

P1: OK.

E: OK. Great. So the next one would be clarity. So, is the summary clear enough and the relations in here are clearly understood. The relations mean that the sentences actually make sense?

P1: They do. I mean the one, there is some that maybe. Again, I'm not sure whether to address this under, under clari - correctness. So can we just go through and maybe look at the - some of the things I had problems with?

E: Mhm.

P1: OK. Well, the definition of ensemble artefacts. Yeah that's OK. Ah. Maybe are there more definitions that you needed there or that's the main definition isn't.

E: That's the main definition mentioned in the article. I can only take what's in the article.

P1: Is that the only definition that you really? I mean I would like the definition probably in action design research.

E: Mhm. Mhm

P1: And maybe action research.

E: Oh yeah, yeah. That makes sense. Ahm. Mhm. Yeah action research. That would be very important for this article. That's right. Actually that's not outlined. Yeah. OK. Yeah. Thanks that makes a lot of sense.

P1: Well, I just going through because some of my, my other, things are look I didn't understand the terms properly. From the first thing I can.

E: Mhm

P1: Yeah. Alright.

E: So, so the idea is you have to figure well the main concept you are talking about is kind of, you know, action research in general and then you have to clearly outline, you know, all the different components in this term like action design, obviously, is missing. So that should be defined and ensemble artefact has been defined because it's actually used later on in the artefact description and therefore I had to outline it. But action design is actually missing. Yeah, very important part, thanks.

P1: Well, actually, yes.

E: Action research - not action design. Yeah

P1: Action research. Yeah. And probably design science. It's This is a combination. Isn't it. OK. But you not got them from the description if you are doing this automatically.

E: Yeah.

P1: The authors haven't explicitly said this is a combination AR and DSR.

E: By the way thank you very much for pointing out the [SOFTWARE TOOL]. I now got the licence. I have it on my computer.

P1: Really.

E: Yeah. Haha.

P1: That's good. Isn't it.

E: Yeah, no, it's a good tool. It's actually great. I wanted to use it for a while and then I just couldn't get a license for it and then I thought, well, doesn't matter, just try the evaluation - the the the - come on - the trial version and then I sent them an email and then they wrote back. Well, Curtin University actually has a license for that. *laughter*. So I called the IT service here, so CITS and they actually gave me, oh well, installed it on my computer and now I have it yeah. So, it's very good. I used a couple of other tools because I did that in my Master's already - concept extraction and these things but leximancer is obviously much much easier to use than all the other tools there are out that.

P1: It comes from my home university - [NAME OF UNIVERSITY], so.

E: Ah. Great. No, thanks a lot for pointing that out and I now have it here and helps me a lot actually in my work.

P1: OK. So that's alright, so.

E: Mhm.

P1: It's pretty good. Ahm. Keep going down.

E: OK. So, the last thing would be correctness and I guess that's where you have a lot of things to say.

P1: I had a little bit of problem.

E: Mhm.

P1: Ahm. The - Some of those 4 paragraphs at the end of the first page.

E: Mhm. — So you mean the principles and the tasks for each of these stages?

P1: Exact. There you take the fourth last one.

E: Mhm.

P1: There you saying problem formulation, which is 1,

E: Mhm.

P1: Which is ??? 20:33, that we would already said that the design ??? ???(20:41) of that 1,2,3,4, the 6th, the 6th last paragraph is the one I think is the most important.

E: Yeah. So the 4, the 4 stages.

P1: Yeah.

E: Yeah.

P1: It's a. Get down in the next one row, I'm not sure if that the - then this next one consist of 2 - one consists of practice inspired research and theory-ingrained artefacts. Well, that if you are going back to conciseness I wonder why you needed that one.

E: Mhm. Mhm.

P1: Doesn't mean this much to me.

E: OK.

P1: You have to got problem formulation that's that that is not. Problem formulation is part of one isn't it. OK. So you are going down into another level.

E: Mhm.

P1: Yeah and the next one problem formulation. Yeah that 4th last one seems quite strange to me so just we just note that.

E: Mhm, Mhm, Mhm

P1: And then the next one you got problem formulation which is indeed part of one, part of the artefact design. So that's OK. Then the 2 last ones. What does BIE mean?

E: Oh yeah, it's ah actually I abbreviated it, ahm, and I mentioned it in the third paragraph of artefact design description. So, actually, ahm, building of the IT artefact, intervention in an organisation, and evaluation. And then I put in brackets BIE. Ahm, well, actually usually that wouldn't be abbreviated anyways but in this case I abbreviated it in the last 2 sections.

P1: So what you are doing here with all these sentences is really doing a, a breakdown,

E: Yes

P1: Another level ??? ??? 22:31

E: That's right. So I drill down, ahm, in the actual artefact design, you know, so ahm going through all the principles and the task that I have identified for each of these stages.

P1: OK. That's alright, that's good.

E: The only question here is always that, ah, is that enough, you know, should I actually, ahm, give more information. Sometimes you know, someone reads, ah, I don't know practice inspired research, maybe, you know, that's not good enough and you have to define that further.

P1: Yeah sure, So I noted that I have had a paper published that used this method and one of the reviewers was an absolute pest because, according to them we were not properly defining what we did as an ensemble artefact.

E: Yeah

P1: And that was thing that stuck with them and I thought, well, so what we said it is an ensemble artefact. We didn't see it as the main

E: contribution

P1: No, somewhere you got the main concept, too. I got a question mark there. So the main concept number 9. Where can I find that?

E: Well, Yeah, Well, actually, that's interesting. Ahm, yeah, so it's actually ensemble artefacts is the main concept in here. But actually I have to admit that main concept might have misused a bit sometimes you know. So it's just an important concept in the article that can't be really assigned to an artefact or you know it's just not an artefact we are talking about it's just a concept that's used often in the article. So.

P1: Yeah. Again, I'm thinking of this because of that paper I had with, Ach, with abstraction theorising or something, abstraction reflection so that must have been [NAME OF RESEARCHERS] and we went sort of tried to work this out but the main concept to me like the concept / the concept "main concept" is action design research. Cause that's it, so that's what I sort of call it the name, you know like, and the main concept in a cup is being a cup.

E: Yeah, Yeah

P1: And a leaver, is being, you know, being a leaver and you could say that and you don't. Like if you say leaver, you don't have to really describe it because people have learned what that concept means.

E: Mhm. I completely, That's a very good point actually, so what. Do you have an idea of how to name concepts that are important in an article?

P1: I always thought once the author can actually say what his concept is and give it a name then often the - that's the article is just so much better.

E: Yeah. Right. But this is actually the artefact design usually they are talking about isn't it. That's the main contribution of the paper. Well, it could be principles in the end but.

P1: We've always got little of - We've been trying to do this talking about a leaver.

E: Mhm, Mhm.

P1: OK, a leaver. You know what I'm talking about a leaver.

E: Yeah.

P1: Alright. So I say that to you and I go like this and you got the concept you can remember in your head.

E: Hm. Hm.

P1: Do anything about the design, you know being - I've / we've tried to describe this. You go their name and you've got it on a fork prong. You need a view more sentences and you can describe, you can describe the main concept but you haven't. See you almost got to the design stage but you haven't got down to the real design of stating to say the fork prong needs to be here and you need to have such and such a plate.

E: Mhm.

P1: So if you could get something about the concept being identified by the name.

E: Mhm

P1: The name of the thing.

E: Mhm. Yeah

P1: We. In other papers that we do, that I'm working on at the moment we've had, we've been round and round about trying to find what we are actually talking about and what we are going to call it.

E: Yeah. Yeah no that's a really hard thing to do and actually we had the same problems in, in my research actually. But what I actually want to get to is, you know, ensemble artefacts, I know that you don't think that it's very important but it had to be identified and defined here because it's used in the article. That's the only reason why it's here and, Ah, and and main concept maybe is not a good idea. So do you have an idea - how you would name such a concept? The concept of ensemble artefacts in this article?

P1: Yes, that's not the main point of the article.

E: Yeah, no, it's not the main point but it's something that has to be outlined in the article here and so I need a name for it, you know, for these concepts.

P1: Put it under definitions

E: Mhm. Mhm. So just name this concept definition.

P1: Yeah. So what we've done, what we've done in another paper, so this is a paper with you know [NAME OF RESEARCHERS]. Course you know him.

E: Yeah, yeah. *laughter*

P1: *laughter* At George Street. You know [NAME OF RESEARCHER] from George Street.

E: That's right, That's right. *Laughter*

P1: We are doing one, which we are now calling - at DESRIST we called it [NAME OF ARTEFACT] - now we are calling it [NEW NAME OF ARTEFACT].

E: Mhm

P1: And can you get the concept there what that is? Just by me saying that name?

E: Ah. Intelligent what again?

P1: [NEW NAME OF ARTEFACT].

E: Ok, yeah well, it's about interfaces, obviously of intelligent system. I would say a systems that work with certain set of information and would like to provide an insight to this information somehow.

P1: OK. So it communicates with the user. But look we've had to put a whole ??? ??? 29:07 page in the paper to say this.

E: Yeah. Yeah.

P1: Frame the concept and we said it's not this and it's not that.

E: Yeah.

P1: So we did define the concept, we did talk about the type of artefact that we concerned with. So ours is actually a class of artefacts.

E: Yeah. Mhm. And it's ah. So you defined the boundary and identified what is not and what's within so to be pretty clear.

P1: Yeah. In order to get. And so there is a paper you could look up. I think it's spelled OSIGWEH.

E: OSIGW.

P1: EH.

E: EH.

P1: And it's about concepts in management. So lot of our students use it. And the use it for - sometimes concepts get stretched so much that they don't mean anything anymore

E: Mhm.

P1: And sometimes they anyway. And he took so he couldn't spell concept stretching, concept travelling and he says different - and he's got the very good idea saying that when you define a concept you have to say what it is not.

E: Yeah, right, yeah. That's actually a very good point. It's - when it comes to concepts and how abstract a concept should be to be a concept - that's a very good question too, because in my work we actually have, ah, this, ah, this ontology instantiation of scientific articles. Yeah. So this one would be an ontology instantiation and then, ah, and then we have, ah, a knowledge base, ah, which then stores certain contexts, yeah, ah, which actually means when it's possible to find a certain context in one article and in another article as well, so they talk about the same thing - then it's being extracted into the knowledge base. But.

P1: We had, we are having exactly the same problem because we are trying to summarise a great deal of research

E: Mhm.

P1: into this, like it is a review paper that we've had to go through, same as you, search all the literature

E: Mhm.

P1: And they where in what we called user interaction some other paper called user experience

E: Mhm.

P1: and we had to work out they were the same thing.

E: Mhm.

P1: So, yeah, anyway, look I really, that that would be, anyway, so I've said it, just, already said it but I really thing that's a really important thing to try and get - like for clarity, that Ahm really could like communicability

that you need to say the main concept, which is probably the highest level of abstraction you can use for the ??? 32:01 up leaver, bubble sort. I suspect you would be really well off to do some an example all the way through through a well known artefact.

E: Mhm.

P1: Relational Database. I say relational database to you.

E: Yeah.

P1: And you don't have to think anymore, do you?

E: No.

P1: You see some. Because you are in my field you understand the meanings and that's enough. If someone else does not understand you gotta go a bit further down.

E: Mhm. So when it comes - so - so action design research would be such a concept too, wouldn't it?

P1: Yeah, it should. I think that's the main concept.

E: No, no, it certainly is there is no question about that and I think I named, I named it incorrectly, the, the, you know, number 9 - the main concept. Because main concept, I only used it to express that it's a concept that is necessary to understand the article. You know. Ahm, ahm - because it's used often in the article.

P1: Yeah.

E: Yeah but ah, yeah. I have to find a better name for that and I completely agree with you that the actual main concept is action design research, which is also the artefact.

P1: Under name you could put main concept / name. *laughter*

E: *laughter*

P1: You are very agreeable how unstable these things. You don't confirm. You are very easy going with me being critical.

E: *laughter* Why?

P1: Being constructive critical.

E: Yeah. No, no. That's actually good. I appreciate that a lot, you know. So, it's, well, you know, we have these interviews to, to, to get the opinions of experts, so, you know, so. I appreciate your opinion a lot and I'll incorporate it as well, as far as possible, so. Obviously there is the thesis part and there is the future research part. You know so.

P1: Yeah, and I know you are talking to other people and of course we all, we all think differently, which is good.

E: Mhm. Yeah. Well, I can tell you, I have 4 supervisors and they all have 4 different opinions.

P1: *laughter* Terrible.

E: Yeah, it's terrible. *laughter* Some of them are actually don't even acknowledge design science research to be a research paradigm *laughter*.

P1: Well, that's really terrible.

E: It is but it's, well, you know it made my life pretty hard sometimes but ahm, in the end, he in the end accepts that this research is valid research, ja, but he actually things that there there is no need for a name, ah, because that's just, you know, applied science.

P1: Is he a computer scientist?

E: Yes, yes, he's coming from that field.

P1: It's just what they do.

E: Yeah. Right. Right

P1: They have very few books on methods

E: Hm.

P1: to learn it. There is one book on methods for them. Ahm. Some - He's got some ??? 35:21 a Z named. Justin Zobel. Z - O - B - E - L He has written a book on methods for computer science. He is from Melbourne uni.

E: That's interesting. I'll look that up actually.

P1: Yeah. Yes because they - he does, he does. It is an interesting book. For a while we had a network group, we had computer science and information systems people together and it was very valuable. His name is Zobel. I think is - I can't remember. I'll look it up. It's Zobel or - with a Z. But when we are started talking they had very similar concerns and some of these concerns where about evaluation.

E: Yeah.

P1: Now, they really had been arguing about how to do evaluation so for example for just simulation - how to get a simulation - sort of how a range it need to be and these sorts of things, so they do think of these things - some of them.

E: Yeah.

P1: One thing is really good with "Chen Fing Fao" 36.26 (*Don't know if spelling is correct*) from University of Queensland and he would also be concerned about the significance and he said in computer science they are slicing the onion too far he meant. Each one is doing this much contribution.

E: Yeah, Yeah, Yeah.

P1: Some of them don't though. They make a contribution and it's something that's already out in industry.

E: Yeah, yeah.

P1: So, they would all. Tell your supervisor they would all have been better on if they looked at this.

E: Yeah. *laughter* That's right. That's right. Well actually that's also, that's also why I'm actually doing this research because as I pointed it out at the DESRIST conference it is actually the idea is to be able to apply these concepts, ah, to the applied science field in general.

P1: Yeah. And the fact - "Chen Fao" I said to him. Ok if you want to specify - if you got an example in computer science that's really well written and really presents things properly - and he gave me that one, the very first database mining paper. It's 1989 or something, something, so it's the very first one that presented. This is a good example to use.

E: That would be great. If you - If you could find that out and that would be great because I really would like to to conceptualise this one to, to show that this ontology works for that.

P1: Yeah, because he did it really, really well, he based it out and they introduced, so they had several concepts they introduced. So one of them was just the idea of database - database mining and they had another couple of their confidence interval used. I don't even get through because I don't know. Can't really remember. It's a concept like what percentage of items this relationships should have to hold. And there is a another one. There is 2 or 3 concepts. Agriwal. That's. It's A - G - R - I - W - A - L.

E: A - G - R, ah sorry

P1: A - G - R - I - W - A - L.

E: W - A - L. Yeah.

P1: And it's called something - It's calling something like Mining Association Rules.

E: Association Rules - OK. Great.

P1: Being cited 10,000 times.

E: Yeah. So. I guess I should find it then. *laughter*

P1: But look that up association rules. That is their concept.

E: That's great.

P1: In association rules you sort of know vaguely what that means, don't you?

E: Hm. Yeah. Of course, of course. When it comes to entity relationship diagrams or any UML class diagrams it's important.

P1: No, no, sorry, that's in big data.

E: Yeah.

P1: And if I've got a huge database - if I go and buy coffee, I also buy milk.

E: Yeah.

P1: Trying these association in the database. This is about the first big data paper.

E: Oh, that's a very important paper for my research anyways. So it's not only interesting to conceptualise but it's also important to put into my thesis so thanks a lot for pointing that out. I'll actually look that up. And I don't know, I don't know if that's OK with you but, ahm, once I found time to do that, which be only in about one months time or so because there are so many things I have to do till then. Ah, ah, I would actually send it to you. I don't know whether you are interested or not but I'll just let you know about the outcomes anyways. Ahm. And also if this study here.

P1: Yeah, I'm really interested in this because as you can see it sort of fits in with other things that I'm working on with different people. It's a good fit.

E: Mhm.

P1: I've always been interested in ontologies and things.

E: Yeah, yeah I know, I know. Well you know one of ahm your, well, ahm, papers is about the anatomy of design science research, which is in my opinion a very important paper for me. Well it is a very important paper for me and that goes into that direction anyways, you know, so.

P1: ?????? 40:45

E: Sorry that I took so much of your time, so.

P1: This has been the fun part of the day.

E: *laughter* Yeah I have to prepare exam papers now actually so I have to finish that. So, that's also not fun.

P1: OK then.

E: Thank you so much thanks thanks. Have a good day.

P1: OK.

# Transcript Interview 3

E: Thank you so much to, you know, participate one more time in this study. So, it's about the combined summary this time, which means that I've presented you with a summary that summarises 3 articles about DSR methodologies and is it OK to start with the questions?

P1: Yes that's fine.

E: OK, so, again it's about the 5 Cs but this time about multi-document summaries. So, I'll just start with the first C, which is conciseness. So a summary is concise if it doesn't contain irrelevant concepts and knowledge. Do you think ...

P1: And I think it's concise, yes.

E: Yes, why is it concise in your opinion?

P1: Well, it's - it actually got the very bare minimum that you need. In some places I felt there is a little bit more needed.

E: OK. I have check whether the audio recording really records everything so just one second.

## **Continued with the second recording**

P1: I can probably put the volume up.

E: Yeah, but I think - no, no that should be alright. It's - no - it should be alright - it's all good - so, I could hear it and that's the most important thing. I have to transcribe it anyways. OK. OK so, it's the bare minimum - I guess when it comes to completeness. Well, we'll get to that point anyways. OK. Thanks a lot. So the second one would be coherence. A summary is coherent if all the concepts and knowledge are well organised and related to each other. So do you think it's coherent and if yes, why?

P1: OK. So, you got - section 2 - artefact decomposition and then you got process - that's OK - and then stages, which is OK to put it in stages - that's alright and then you went into differences. It's OK too. When I got to section 2.2.1 I wasn't sure that BIE had been defined. Actually BIE, what does it stand for?

E: BIE? BIE is build, intervention and evaluation - building an artefact ... It's actually mentioned in the second sentence in 2.2.1 but I had the same problem with another participant.

P1: Yes, OK then, alright. So, I think it's coherent.

E: OK, So, you could follow the information that is being conveyed in there and yeah. OK.

P1: Wait, wait, wait. So when you, when you looked at the similarities I have to believe you that that's the, that's the main similarity that they all contained a process. So I have to believe you that there is not any other similarities.

E: Yeah.

P1: Hm. Alright.

E: So there is also, well one of the other similarities in there is in 1.2.5 and that's actually the iterative process.

P1: Yeah. I did put a question mark about that because I thought probably DSRM did actually have an iterative process to from memory.

E: Mhm. OK.

P1: (???) so much but I think the arrow is on the top so you can go backwards and forwards. Doesn't it?

E: Mhm yeah but only in the diagram. Wait a second. I just want to double check. Yeah, yeah, right, actually you are right. It's not in the ... OK. Great. Thanks a lot for this input. Ahm. OK. So, is there anything else to say about coherence, because else I'll move forward to comprehensiveness?

P1: No.

E: OK. So. Sorry?

P1: I'd suppose if I'm reading this, I want to know how you got to this. Because that question I just asked you.

E: Yeah, yeah. It's actually - this summary has being created out of these document summaries. So all the information that's in the single document summaries has then being compared to find the differences in regards to a reference ontology that has also being created, you know. So this reference ontology references to single document summaries and therefore points out the similarities and as you can see here... With this iterative process - this hasn't been mentioned in the single document summary and that's why it doesn't show up here.

P1: Remind me how you created the single document summaries?

E: The single document summary is actually. The first thing is - there was a creation of an ontology about this document itself, but this has been done manually and this ontology then can generate the single document summary.

P1: OK, I mean at some point you - I mean of course you'll mention that method but, you know, you probably need to compare that method with other methods that would do the same thing. For example, it's pretty much a grounded theory method. Isn't it?

E: Yeah. It's. I wouldn't say it's grounded theory. You mean in the method - the research method, or the method of creating the summary itself.

P1: Creating the summary. So when you do. The coding - it's a little bit like open coding in the grounded theory method.

E: Yeah. It's. I had. There was another discussion a couple of weeks ago where lot's of people were very much against saying it's grounded theory when you take something out of literature. It should also be - always be coded in a specific setting where you get to this information. So.

P1: I don't think you should say it is grounded theory but when you construct an artefact you normally have to compare it with prior artefacts - to see an improvement.

E: Yeah that might makes sense. It's a good point.

P1: It's not actually in the stages. Isn't it? It's not in the stages, isn't it?

E: What's in the stages? Sorry?

P1: Well building an artefact. It doesn't say anything about difference to prior knowledge and prior artefacts.

E: The - it's actually - so the thing is that, once similarities are found in a couple of summaries, these similarities are then combined and being put into this reference ontology because that means that a certain context is covered in the paper.

P1: OK. So, I'm jumping around now. So my comment was to do with your own method in creating summaries. Now I'm back on - and you realise, Emanuel, you have asked us to criticise, so we are criticising.

E: Yeah, yeah. That's fine. No, no perfectly fine.

P1: We are trying to be a bit picky. So now I'm back onto the comprehensiveness of this. So in the process, I know because I've just been looking at the one Richard drew up for a different version of DSR. The one

that is done by Chatterjee. You know, they quote - say they use prior knowledge in the building stage.

E: Yeah, ahm. The thing is this summary only contains information out of 3 documents and this is actually only Action Design Science, sorry Action Design Research, then the paper about soft design science methodology, and design science research methodology by Peffers.

P1: Well, OK. That's just a comment that you might look more carefully into each of those 3. Just yet I do mention using prior knowledge bases.

E: OK, so that's an information that would be interesting to put in there. OK. OK, so where have we been. OK, so, is comprehensiveness - did we cover that? I'll just - no I don't think so. Can I?

P1: Emanuel, just going back a bit. In my view if you don't have that, if you don't have a step where you relate what you found to other knowledge, knowledge base - you are not doing science you are just doing building. And even then - even in ordinary building you do it as well. Even in software engineering.

E: Yeah. I'm ...

P1: You base what you are doing against, you know, the knowledge in the world. For myself, I mean, that's really important. But anyway. I just make the comment.

E: No it's actually, it's - I'm not. OK, so these are 2 things. So one thing is my research and this is a research output of being able to combine a number of documents and it doesn't really reflect to what I've done in terms of design science research interpretation. This is just a summarisation.

P1: Because I'm interested in that bit. I would go and search those 3 methods and I would probably find it somewhere.

E: Of course. Well I hope so.

P1: So anyway, this just can't be an answer of your method again anyway. Interesting - very interesting.

E: OK. So comprehensiveness. So a summary is comprehensive if includes all the relevant concepts and knowledge conveyed in an article or in the 3 articles actually. So, I only wanna, you know - I'm only talking about these 3 articles that I summarised in this.

P1: Alright. So section 1.2. The last sentence in that - that wasn't - I didn't think that that was particularly meaningful.

E: That DSRM fulfils the requirement to be consistent with prior literature.

P1: Yeah. I didn't really understood or understand what that meant.

E: Ah. OK. Well, yeah, good point. It's actually a requirement mentioned in the paper that they - this methodology they have come up with should be consistent with prior literature in this field.

P1: Prior literature on what?

E: On DSR.

P1: OK. So if you add that in that it would probably make it meaningful.

E: OK. So anything else that's missing in your opinion - only reflecting on these 3 papers? And if you haven't read all of them that's fine too. It's just, you know, what would you think should be in a combined summary in general?

P1: Just the only other thing which might come under - so that last point is probably under clarity rather than comprehensiveness. Section 2.4 in terms of clarity. That sentence is a little bit hard to understand too. I mean - contains different entry points for research - contain different points for research initiation.

E: OK. So. It should be a bit more detailed. So, there should be a bit more information about entry points or.

P1: Yeah. just clarify things. Yeah.

E: OK. Then yeah. Next point would be clarity: So a summary is clear if all concepts and relations can be

clearly understood. So...

P1: That's the 2 points I just made.

E: So anything else?

P1: No.

E: So the last thing is correctness. So a summary is correct if it doesn't draw any incorrect conclusions including inconsistencies.

P1: Alright. Well, I'm OK with that except that for correctness again - it looks OK but I need to know what your process was. What your research method is. I mean that usually lends - you know we look at any article - any research we can see the results. We think - Oh that's good but we want to see the method (???), which they got to it so we can look at the method.

E: OK, so method is missing here. Again it's

P1: Yeah, somewhere else ...

E: That's not an output of how I've done my research. It's just an output of the artefact design I've designed to create the summaries. It's I guess so that - that's a bit clearer.

P1: Alright. Under the knowledge I can't see any incorrectnesses except for that leaving out the connection with the prior knowledge base.

E: OK, so. Yeah. Thank you very much. That's actually all the questions I had. It's very interesting. I think one of the most important points here from your side is that it doesn't cover all DSR methodologies in this combined summary.

P1: Well, every research has got limitations. That's OK.

E: The think is - to be able to provide the summary I can discuss with many people I had to limit it to a number of publications and that's why only the 3 are in there.

P1: I could understand this, yeah.

E: Another very important point is this iterative process, which is missing from the DSRM because it's mentioned in there too, which is interesting because it didn't come up in the single document summary and that's why it didn't transfer or translate into the multi-document summary so that's a very interesting point.

P1: No, yeah that's good. You are doing a good job.

E: Thank you.

**Participant 2**

# Transcript Interview 1

E: So I have to ask again. I hope it's OK to record this interview?

P2: Yes.

E: OK. Thank you.

P2: It is OK. I need to. I'm trying in the background to get access to the documents you wanna me to have a look at but for some reasons I can't get a secure connection here. I have to go upstairs and have to get my portable, my laptop.

E: OK.

P2: If I need to have a look at the documents you sent.

E: Well, it depends, so the first thing is the survey where I have a couple of follow up questions and the other thing - did you have time to read one of the summaries I provided?

P2: Yeah that's.

E: Yeah that would be great if you could get that. That would be helpful.

P2: I'll go and get it, so we have it.

E: OK, no worries.

## **Pause**

P2: OK.

E: Hello, OK, great. So, I would say I would start with the interview right away if that's OK with you, so, it's divided into some general questions first. I'll have some follow-up questions on the questionnaire you've filled in and as a last point I would like to talk about the 5Cs concerning the summary I've provided you with.

P2: OK.

E: OK. General questions: Please list your fields of expertise.

P2: Well, recently it was systems development, software engineering and but I have my degree from a business school so it was very easy to look at systems development in the context of business and business alignment, IT strategies, so very fast I moved into that - those kind of areas. Then, ten years ago I attended a conference in Los Angeles or outside Los Angeles - the first DESRIST conference and I realised that what people started calling design science research was actually what I've been studying. I've been specially interested in the design process within systems development.

E: OK. Thank you.

P2: I could reuse all the data from my PC and I could re-aim it as design science research - so that became my co-area, and then I also picked up with this organisation point of view, I picked up process improvement, so at an organisational model - you know, there is a lot of maturity models and I became part of a project that later was made into an ISO standard for software process improvement. So that's probably the piece of research I'm most proud of. So design science research, systems development and business alignment and process improvement.

E: Hm. OK. Thank you very much for this information. Just one follow-up question. It's not in here - in my list of questions but I'm just curious. What do you think there was a research methodology you used - Or was there a research methodology you used before you thought that that's a proper research methodology

and then you switched to the DSR paradigm or was that just standard research for you. Because you could map all the research you've done to DSR.

P2: A lot of what I was doing was. I was doing mainly two things: action research and case studies and I used other theory to analyse these case studies because fields of systems development at that point was not very well developed - conceptually. So my most cited paper by the way is reporting from my PhD and it's called grounded theory for action research.

E: Well, right, yeah. I have - and I read that as well - of course.

P2: That's - and then when you do action research - in my PhD I actually designed a tool called before [NAME OF TOOL] that was meant to be used before you use the [NAME OF TOOL] tool - [NAME OF TOOL] tool is computer aided software engineering. It was for the feasibility analysis to get an overview and it was heavily inspired by design rational thinking that took place in Austin and other places - Compton?? and Gibis?? and those guys 25 years ago. So I actually designed the tool in my systems - in my PC. So the step to design science research was not big at all.

E: Hm, great. Thank you very much. OK. So I continue to the next question. I don't really have to ask this question but I have to ask it anyway. What is your level of expertise in the topic of DSR on a scale from 1 to 5 where 5 is very experienced?

P2: I probably have to say 5.

E: Yeah. I thought so to. OK. Thank you. So, how many years of experience do you have in the field of DSR. You already said you went to this conference. So was that your first experience?

P2: No if I count the years while I was doing my PhD I would say 25 years. But it wasn't called design science research at the time. But it was more or less the same thing I was doing. Of course we had over the last 10 years to write a number of principles and ways of doing things. You have sent me 2 papers. Action design research and the Peffers one. They are both steps forward that I didn't have 20 something years ago.

E: OK. Thank you. OK that's it concerning general questions so I would now move on to - I'm having some follow up questions on the conceptualisation survey I provided you with. So you came up with the 3 most important concepts for you. The first one is a good relationship between a need or a problem and the design and there I would have one question. How would you express a problem using the set of concepts provided in the survey. Do you have the survey somewhere?

P2: Possibly, possibly. I don't have my answers I think.

E: I don't need the answers here in this specific case. It's only - because - you know. Would you actually say that one of the concepts mentioned here can relate to the concept you understand as problem?

P2: So now I have the conceptualisation survey in front of me. So, the 3 most important concept and I have said something about addressing a problem or need. - And what was your question.

E: The question was - from page number 3 to page number 7 there are all the concepts listed where I asked you to identify how important they are and do you think you can assign the concept problem to one of the concepts that I've mentioned in this survey? Or where would it fit the best, if at all?

P2: I'm looking and I don't find it. When I teach design science - and I do that for first year students - and I kind of say that a problem is something that puzzles you - it's a paradox, anomaly, or something that you cannot do and would like to do - and I couldn't find any of these things in here in the left of your conceptualisation survey.

E: You know. Turn around problem and think about requirement as an expression of a solution of a specific

problem. Could you accept that?

P2: No it's two different things. So problem and solution are distinctly different. So, you cannot ask to come up with. I know that a requirement is an expression but if you go way back to systems development - where I started - and before you do an analysis you typically have a feasibility study. And in the feasibility study it is where you identify the problems and the needs and for different stakeholders and then you facilitate a discussion of them, and way later, namely at the end of the analysis phase you have requirements. So the requirements is the outcome of a long discussion, called the analysis phase that typically takes up about 20 to 25% of the whole process when developing something or designing something. So problem to me is right at the beginning or the initiation and it's often the initiation of a design process and requirements is a milestone 1/3 down the way but of course, at that point it is an expression of the problem. So but it's not the same.

E: OK, cool, thank you very much for the input. So the next one was a meta or generalised level, each expressed in the form of design principles or design theory. So, as another important concept you mentioned. Can you use one of the concepts in the list to be used to describe principles and design theories?

P2: Not really.

E: OK.

P2: So what I think about is. You always have this instance of a problem. So typically, a person, or an organisation have a problem and then to make that interesting you have to consider it, can we generalise this problem to a class of problems. So that's the meta level or the generalised level and none of the concepts I see here to the left in the conceptualisation survey. The concept names you want me to look at are artefacts and artefact design, design realisation and so on.

E: Yes.

P2: None of them are really talking about the generic level or the meta-level of design.

E: OK. Thank you. So one follow up question on this is. Do you think design principle as well as a design theory can be named an artefact?

P2: To me an artefact is something tangible. So that you can grasp and a design principle is not tangible. An artefact is tangible. A design principle and a design theory is definitely not. I know it's in the word artefact and there is the problem that artefact translates into (ginstan???) and (there's along a scotch???) in Danish and that means something you can take in your hands and carry around. I know there's a long discussion about whether a design artefact can be a process or workflow and I agree to that, of course it can be but still that's different from the meta-level.

E: OK, Ok. I understand. That means if you have a certain process or a model that you can - it's tangible to you - but if you further abstract it it can - it becomes intangible then.

P2: Yes.

E: OK, great - thank you very much. So the last point was a good evaluation of the design. So what components are necessary for a good evaluation.

P2: Well I can repeat the whole paper I wrote with [NAME OR AUTHORS] - so - What's the essence out of it. The essence is that you have - first of all you should decide

P2: on a strategy and how will you evaluate this thing - and then you typically go from the artificial to the naturalistic and you go from the ex co? (Note: I guess he meant ex post) to the ex ante - that's called formative to summative in the latest version of the paper. So that's the strategy part. Then, for the specific

instance - we don't call it that, we call it episode. For the specific evaluation episode you have to. For the purpose of that episode you have to decide on some criteria, you have to decide on how to organise the evaluation, what subjects you involved and then what criteria should you use to evaluate. So, and then carry out the evaluation and do the analysis and see if you lived up to your purpose and then you've got an evaluation of what you want.

E: Thank you very much. Follow-up question on that, sorry - purpose.

P2: Evaluation aspect and evaluation technique are clearly related to that. Maybe even main concept. Evaluation criteria, evaluation metric, evaluation result and purpose. All 6 of there are clearly related, so. Finally there was something that I could use.

E: Well, I can - in the end I'll actually tell you - there is a specific purpose for that. But that's another. OK Great. Thank you very much for that. So, you now said you evaluate a specific purpose. What's the difference in your opinion between a purpose and a requirement. Or is there no difference?

P2: A requirement is, as we talk about, a late in the process, late in the analysis phase statement of the problem whereas a purpose is a purpose of the evaluation. The way I just used it here. So, let me go back - way back to my design in my PhD. I developed using an Apple Hypercall Stack I developed this tool called before [NAME OF TOOL]. And the purpose of that tool was to capture the design rational while the software developers were developing their software. So an design rational consists of the alternatives that you considered and the criteria and objectives and then the discussion and the choice of the design. So we tried that in a real project with 2, only 2 participants and they used it to deliver me - and they captured the design rational. And the purpose of the evaluation in that iteration was to see whether they could understand the concept of design rational and whether they were able to capture their own design rational while discussing how they should design this tool.

E: Hm.

P2: So they were designing the tool for a total different purpose - an interface between man and machine. A new way of organising that and, so that was the tool they were building and in doing that they considered a number of design alternatives. They captures these design alternatives and the discussions in my tool. Kind of a double layer. But the purpose of the evaluation was clearly different. That was "can they understand it, can they do it while they develop their own or will it hinder or harm their own design process that they have to stop and capture" and we found was that it was not a hinderance that it gave structure to their design discussion so they so it as a benefit and not as a hinderance. So that was a good evaluation outcome. But the purpose of the evaluation was clearly different from the requirements to the tool.

E: Hm.

P2: Return to your original question.

E: Cool. Thanks you very much. That was very interesting input.

P2: And let me - just - the problem I was trying to solve was that a lot of software is developed and then 10 years later some people have to maintain it and they can not see from the code what did the original designers think. So they have lot of difficulties maintaining software developed by others. So that was the whole idea. So that's the problem. It's really hard to maintain software that other people developed years ago. So that's the problem we were trying to solve. And the solution - so there were some requirements

E: the requirements for your tool.

P2: The alternatives that you capture. Sorry: that were the requirements for my tool. The before [NAME OF TOOL] tool. So those where the requirements for that tool and you can actually find that if you go to that -

my most cited paper - grounded theory action research - (I just discovered??) the tool and it comes up at the top - then you can see the concept there. Those are the requirements and they are quite different from - so there was a problem statement that was different from the requirements because the requirements came out in the analysis process and was more related to a solution, namely this before [NAME OF TOOL] tool then to the original problem, which was that often designers have difficulties maintaining other peoples software later down. So that was the difference between problem and requirements and the purpose of evaluation was more related to can they use this tool and will it be help or hinderance - that was - so the purpose of my evaluation was only marginally linked to the problem I recently - in which my PhD was trying to cope with and looking at all the tools and techniques that were around and that could help you maintain your software better because we had banks and finance companies with millions and millions of lines of code that were so old that people was retiring. It's still a problem today.

E: Oh it is absolutely, absolutely it's an extreme / big problem. I'm actually working in software development as well besides from my PhD but at the moment I'm only focusing on my PhD because I need to get it finished but I actually, we are working on such a system, which is a system for a medical information system for general practitioners in Austria and there we have exactly this problem, you know, but you usually you thinking - but maybe not too many people thought about it that way that you have all these diagrams that should explain the design and the ideas behind that but these things are often getting lost over a longer period. The other thing what also happens is that this information is getting superseded by the actual implementation and this documentation is not getting updated because it's just too much work or it's a quick fix you put into the system and so on and then you have these issues actually that you have to reengineer the actual design the people that initially developed the system have thought about.

So, it's a very important problem. It's very interesting. OK but I need to go on.

P2: And it solved one thing. So, that Reiterer is an Austrian name.

E: That's right. I'm from Austria, yeah. That's correct. OK. So I continue with my survey because I have to transcribe it as well and that will take a while the longer we talk about these things the longer it takes, so.

P2: The longer it takes.

E: OK, so that's the 3 most important concepts you mentioned and now I have some follow-up questions on the actual concepts you - you have rated and I just follow up with the not ranked ones. So one of them is artefact design. What do you think - because it's written that "I've never used the expression artefact design" - so what do you understand about artefact design if you read this definition or description I put next to it?

P2: It was the description that confused me. But to me artefact design is a - you say: "artefact design is a subclass of the concept artefact" and to me that's bullshit - Oh sorry.

E: No that's fine.

P2: So the artefact is an end-product - either of a design process - you can call that design process - artefact design - feel free. So artefact design is to me a process and it ends up with an artefact. And that's because the word design can both be a verb and a noun in English.

E: That's right. It can.

P2: And I would - the way you used it here is only one side of it and I would typically never use that kind - use that word artefact design in that context. I would use it in the other meaning.

E: Hm - OK - I understand. Well. OK. Thank you very much. It's actually the noun that's meant here. Ahm. The next thing is practical significance. So DSR is not aimed at basic research but at solving some problem.

So, do you think that theoretical significance has to be expressed in an article when it comes to design science research?

P2: Yeah. I think so. I think there is a log of designers and they do design all the time. When you get into university and you are talking about design science research you have to have more than just the practical contribution or practical significance because this is what all designers do. So being at a university I think you need to be able to explain the theoretical significance and that's actually where meta-level or the generalised level comes into play because that - that's where the scientific importance lies.

E: Yeah. Makes sense. OK. You rated theoretical significance 4 and practical significance 5. So it just means - or what did you think about this rating.

P2: There are both very important but I would hate to have a paper that was only theoretical with no practical implication. Then I would think they have chosen the wrong research methods. They should not chosen design science research because design science research to me is prototyping make scientific where you design something and then you learn from it. And of course you can learn at your own desk but the real learning is when you present it to practice in some way. So that's why having a practical contribution and showing that there is a link to some problem or need in practice is more important than a theoretical contribution. If they have a very strong practical contribution I'm OK with a weaker set of principles, a weaker theory - so to say.

E: OK Thank you. Actually I would like to talk but I'm not allowed to. I completely agree with what you say but maybe later - OK. So - OK - evaluation technique - Ah OK we already answered this question, or you already answered this question - OK. Ahm, yeah. OK how important is the design realisation in scientific articles that follows the design science research paradigm? So you rated it with 4.

P2: I'm not sure what is meant by that. Where do we have that?

E: OK. It's on the first page number 3 the bottom one.

P2: OK. "A design realisation expresses an instantiation of a specific artefact design". OK so it's the instance.

E: Hm, Hm.

P2: Usually used as the evaluand to prove the utility of a specific artefact design. Yeah of course that's important. 3 - what did I give it?

E: 4, 4, 4.

P2: Let's stick with a 4.

E: Yeah you already pointed out that it was actually hard for you to actually come up ...

P2: The reason is - I see it as an iterative process. So you develop a prototype or an instance, you try it out, maybe at your best, then you learn from that, then you develop a new, a new one and after 5, 6 iterations you have something that you can show and argue (actually?) that's the solution to the problem. But were is the design realisation. Is that the first, the second, the third, the fourth, the fifth. I was just not clear about that.

E: Yeah, I understand.

P2: And if it's any of that. Of course that's important. That's why probably why I said 4.

E: OK.

P2: But it's more important that you have this iterative process and I didn't see that in your concepts.

E: Mhm. Right.

P2: The iteration.

E: Yeah, yeah. OK thank you. So, let's go on. Oh yeah. OK, we already have that. OK. Well, is it theoretically possible that an article is not based on other work at all?

P2: I don't think so. Of course you can imagine it. I just never met anything coming close to it. There are so many researchers in the world. There will always be related work. Somehow. And in arguing about related work and presenting related work is very possible that you identify a whole in the existing literature. So people have done this and they have done that and they have done this and they have done that but right here in the middle we have a hole and that we try to fill but just writing about or designing something to fill that hole without arguing that it's missing in the existing literature. I would never accept that. So, no is my answer.

E: So that's the arguing part and when you say OK, well you know, I need to use or I'm using several techniques that are already out there and I'm building up on them. So that's.

P2: Yeah. Something like that.

E: That's also important. OK. OK. Thank you. So the next thing is - You had a bit of a problem in answering some of the concepts on a scale from 1 to 5 and I think that's why you actually rated them 3 - most of them.

P2: Yeah. That's always the way when you say a scale with a middle point that's the safe retreat when you are not really sure you understand this.

E: Yeah. It is. Well, we had actually a couple of discussions about this scale as well and usually, often you don't put a middle point in there to avoid these things.

P2: Ja

E: but there were different opinions here about that. Anyways, so I'll just continue - so support was hard to answer - main concept but also evaluation aspect, criteria and purpose and property. Is that correct?

P2: Yeah, the support - the language you use there and you have a definition from Besnard and Hunter 2008 and now I talk about design rational, I'm simply more used to the vocabulary of design rational - so - and let me see if I can get to Wikipedia on that and see the explanation there is a good one. It's hardly working. Maybe Skype uses all my bandwidth. I'm using my portables. No, I can't get a connection up when I'm using Skype so I have to do it on my laptop. That's funny. Skype swallows my connection.

E: Yeah it looks like that. I just opened it.

P2: Yeah. Design rational is an explicit documentation of the reasons behind decisions made when design, a system, or artefact. It was initially developed by Kuntz and Riedl design rational seems to provide argumentation based structure to the political collaborative process by addressing wicked problems.

E: Hm.

P2: So that's the kind of vocabulary what I would be using. Going back to my PhD on design rational and developing a tool for dealing with that and that was why I didn't really.

E: You couldn't assign or you couldn't rank it. Oops.

### **Skype broke up. Tried to reconnect**

E: OK. Does it work again. There seems to be a problem. OK.

P2: Hello.

E: Yeah. Hello. OK. So you are back again. OK.

P2: I don't know what happened.

E: I don't know either. It's just

P2: And I had a funny thing. I had my iPad calling here. I thought I stop Skype on that but obviously I haven't. So maybe that's what's confusing...

E: I had the same problem. It also rang on my phone actually. So, yeah Skype is interesting sometimes. OK I think now the video is not working on my side. OK. Oh now it's working again. OK great. So that's support. Main concept you also wrote possibly. So what would you understand under main concept here.

P2: Yeah. I still don't understand that. A main concept expresses an important term or concept used... In the problem definition in the requirement specification in the architectural design, in the detail design - where is the main concept?

E: OK. I understand. OK, well, now I can say where. It's in the article actually but OK that's not clear enough obviously. So it would be a main concept in the article. That would be the idea.

P2: OK and that's probably more meaningful to talk about making an ontology. So that makes sense. Ja.

E: So, evaluation aspect.

E: Yeah, so, what do you understand under evaluation aspect?

P2: I don't use that word. That's why I'm confused. And I don't think we talk about an aspect in the evaluation paper. I'm a little unclear. I don't think we do that, so. So an evaluation aspect expresses a feature of a specific artefact or artefact instantiation that further will be evaluated against a number of identified requirements. I would call a feature a part of the solution or a part of the design or component is typically what I would call things. But an aspect. An aspect to me if I would use it without an evaluation is something that a stakeholder brings to discussion process. So it's another aspect of a discussion and I would have to discuss these aspects before I can make my design and divide it into design components that I then evaluate.

E: So these aspects are ..

P2: You know, I'm not a native English speaker. So, here I may have a false friend because we have the word "aspect" in Danish and it doesn't have the meaning that you use here.

E: OK Thank you very much. So the next would be evaluation criterion. Was also hard to rate? What's your understanding?

P2: Yeah that's because - typically I use evaluation criteria - those are criteria that you evaluate. So, for example, my before [NAME OF TOOL] example that I used before in this interview. Some of the criteria was. Is it a utility is it a hinderance, does it add structure. So those are criteria for evaluation and then you say "it's used to describe the utility of an artefact towards a specific requirement" and I agree to the first part of the sentence - that it is used to describe utility of an artefact - but I don't agree to the second part - towards a specific requirement - and that's because I think it can be across a number of requirements and that's back to old requirements specification that you talk about functional requirements and non-functional requirements and very often what you evaluate are non-functional requirements and those are not related specifically to one requirement because they are across, so user friendliness, portability, reliability, those kind of things will be across the artefact and not related to one specific requirement unless you express them as a non-functional requirement. So this system or this design has to be user friendly. Meaning easy to learn, easy to remember, easy to use, easy to - no catastrophes and pleasant when using or something like that and then you can measure against these non-functional requirements and then they, I guess, they turn into criteria, so maybe it makes sense.

E: OK. Thank you very much. Evaluation result you wrote yes and... - and also rated 3.

P2: Yeah.

E: So, what do you understand under evaluation result by reading this and ja - what's your comments on that?

P2: Yeah. What I - what puzzled me here is your use of metric and the word proposition. Both of these words are very quantitative oriented and a lot of the evaluations that I do is more like you are doing now. So you are not using any metrics or you try that in your. Right now you are trying to get a lot of words and opinions and so your evaluation result of this soon to be one hour.

E: Sorry.

P2: Expressing the interpretation of a metric that has been analysed towards a certain criteria. So evaluation results can be a number of other things than proposition relate to metric.

E: OK Thank you very much.

P2: So I think your definition of the evaluation result is too narrow. And that's why I declared that in between...

E: Ah. Yeah. I understand because the metric is in there. Yeah.

P2: And also the word proposition. Proposition is very much related to when you are developing quantitative models and I'm from a tradition where we very often turn to qualitative research methods and we would never ever use the word proposition in doing that.

E: OK. OK. Thank you very much. So the last thing concerning the survey would be purpose and property. You already described what you understand under purpose and property?

P2: So property expresses inherent features. So, it's the same thing as components, features, or - what did I answer to this?

E: Your answer was yes and... and rated 3.

P2: Yeah. It's important that you describe the properties. Of course you cannot get away with a paper without describing the properties of your design. So it's probably a 4. Let me move it to a four.

E: OK Great. OK. Thank you very much so that was the survey - ahm follow-up questions to the survey and now to make it as short as possible to not steal to much of your time - thank you very much to take the time and I know it always takes a bit longer than expected. I'm sorry for that. So, you chose one paper to read - or did you choose one paper to read? One summary - sorry.

P2: I looked at both. The Peffers one and the action design research method. The design science research method for information system, that's the Peffers one and I also opened the action design research one. I probably be more, most familiar with the Peffers one.

E: OK then lets just take the Peffers one. Or you can actually - you can comment on both. It's a - in another email I also send you a summary about the DT Nexus one you wrote together with Richard Baskerville. But that's in a different email. But you've had a look at these to so let's just take these 2 so we'll just have a look at these 2 I would say. And I just go briefly through the 5 Cs we have identified to evaluate these summaries. These 5 Cs are conciseness, coherence, comprehensiveness, clarity and correctness. And I'll just start - I'll start with conciseness. So conciseness: A summary is concise if it does not contain irrelevant concepts and knowledge. So does the summary meet the criterion conciseness?

P2: Let me - take one step back. I very much like the idea of automating the process of creating an ontology. And instead of people's abstract and because that what you have today. You're searching the abstract and you can do word search. So, I think it's a great idea to improve on that and I compared the Peffers one with the abstract in the Peffers paper and asked myself the question, would I like one or the other.

E: Yeah. Good question.

P2: And because of all the parentheses and square and point arrow this way and point arrow that way it's

very hard to read. So I would prefer the abstract.

E: OK

P2: So and that leads me to - I would suggest that you look for papers that was published with a very bad abstract. Where the abstract does not cover the content of the paper but only part of the content of the paper. Because then you can - will your ontology show that it's better and the Peffers abstract - the Peffers paper abstract is not bad at all. So you are up against something that is quite good. On your scale 1 to 5 you have chosen an abstract that is probably at 4. So it's hard to get up there and above. You have to be very, very good at it. So - and right now it's very hard to read this PDF. So, I tried to put myself into the shoes of the user and say would I prefer getting this and as a description of what it is in this paper or would I prefer the abstract. And unfortunately I would prefer the abstract.

E: Hm. OK

P2: I think it requires a bit more work and maybe carefully choosing some papers that are really bad at writing an abstract, because - so you would clearly show that you add value for the user. And I would be willing to read it and comment on it when you have tried to do that but right now I. That's my comment. I hope - it can be a little discouraging but I think it's a great idea and you just need to - to work on 2 things would be my recommendation. One is - find some papers with a bad abstract so you can really show some difference and (2) make the PDF that you send people easier to read because you stop - maybe if you could switch off all these squares and brackets and numbers because I really, really tried to read without having them and it's just nearly impossible.

E: OK I understand. OK I would have, I'm not sure if that's OK with you but I'm - so - I understand what you mean and these brackets and so on these were in there to actually identify, you know, how the concepts are used in the summary but I understand it's much harder to read that way. So there.

P2: In a very old version of Word Perfect which was a text editing system before Word came to market standard. There was a button, I think it was F7 or something where you could switch off and switch on all the quotes. So, and you could always get back to the quotes. So that would be an idea that you can - in an easy way to switch on and switch off and the way you can implement that is generate 2 PDF documents, one without quotes and one with quotes and then you can see both and that's just an idea, so.

E: Would there, I'm not sure, I know that that's a lot to ask from you but would it be possible if I would provide you firstly one without these brackets at all, just the standard text, then also a combined version of 3 DSR Methodology papers. Could you have a look at that. Would that be OK for you?

P2: Yeah that's OK.

E: I would also try to make this interview much, much shorter then and because that would be really, really important for me because, you know I need that in my evaluation part for my PhD. Is that OK. Can we do it that way.

P2: Ja. I think we should go with. I don't know why 3. Let's try it with one and if that works well we can take another one.

E: No, no, it's only the combined one. It's not - It's one summary that combines 3 papers.

P2: OK. OK so then you are adding value to the - because you can't do that easily with an abstract, so that, ja OK.

E: So actually that's the ultimate aim of my research anyways you know. So the first thing is summarising single documents and then combining it into a multi-document summary. I would actually provide you one of the single ones still because I need that in my evaluation and the combined one which is a combination of 3

papers. Can we do that?

P2: Let's do that. Ja. 2 weeks or when do you imagine ...

E: 2 yeah 2 weeks would be fine. I would send it to you end of the week or so and then you would have a week to read. Is that fine?

P2: OK. Let's set a time for a follow-up interview then.

E: OK great, thanks. I appreciate that a lot thanks. So just.

P2: 2 weeks from now. What time is it in Perth. Are you in Perth?

E: Yeah. I'm in Perth. It's 4 PM at the moment.

P2: OK. So you could do it a little earlier.

E: Oh yes. Any time.

P2: OK. How about the 26th at 8 o' Clock. An hour earlier than today.

E: That's perfectly fine. That's 2PM here.

P2: OK.

E: Great. I'll send you the combined one as well as one summary without out any clutter or without any of this unreadable text and then we'll discuss the 5 Cs again. As I said it's conciseness, coherence, comprehensiveness, and clarity and correctness.

P2: Yeah write that in the email you send

E: I will I will. I'll write that in the email and I'll also put in the definition of the 5Cs - the definition we use.

P2: OK fine.

E: Great.

P2: OK bye.

E: Great. Thank you so much. Thanks, bye.

## Transcript Interview 2 and Interview 3

NOTE: The recording started late. The participant mentioned that he liked the tables used and that he is a visionary type of person.

E: OK. So now it should work. Great. OK. Yeah I'm happy. Well, you know, now I removed all the brackets of the first summary and the combined summary also has other elements in there now, like these tables and so on. So, I hope it makes it a bit clearer. Should I start right away or do you wanna have a further look at it?

P2: I, so, we can start right away. I looked at the document called DSR methodology version 6.1 cleaned where you compare 3 methods and the Peffers one, the Sein et al. and our own soft design science methodology.

E: That's right.

P2: A general comment: So they give a good overview in a textual way but a lot of information is in - are buried in the figures. So when I for example explain people how to use a soft design science methodology I immediately start drawing a line and say you have the instance level and you have the meta-level and then you have this activity and that leads to that activity so I think there is some meaning lost in not having any figure - and I know that's probably difficult with the - It's just an overall comment that I think meaning that was in the paper and that covers especially the soft design science methodology also to some extent the Sein et al. but Peffers also has this stage model with arrows and so.

E: Entrypoints.

P2: Soft design science method and the Peffers one you lose something by not having the figures there and I don't know how that could be done but that's an overall comment.

E: Yeah. I don't know either at the moment but that's a good point. That's for sure. Thanks. Is it OK that I go through the 5 Cs with you or do you wanna just give some general comments first and then ...

P2: What 5?

E: It's the - they are actually in - these 5Cs, which would be conciseness, coherence, comprehensiveness, clarity, and correctness.

P2: OK

E: And I'd like to go through all of these.

P2: Yeah.

E: OK. Did you also get the chance to have a look at the single-document summary as well so I can ask you for both summaries - about both summaries?

P2: I looked at them both but I can't have them both up here on my little - for some reason my computer show my email and Skype at the same time.

E: Oh.

P2: I get an error message from every time I try to log in. So, I have to log in on my little iPad.

E: OK.

P2: And that's - so I cannot have a look at 2 papers at the same time but I have this one pager on Peffers.

E: OK.

P2: And I have these 3 - it just takes me a while to swap.

E: Yeah we can do one after the other. Is it OK to start with this one pager first? Is that fine?

P2: OK. Let's start with the one pager.

E: OK. Great. Thanks.

P2: I have that up now.

E: OK. So, the first one would be conciseness. So, a summary is concise if it does not contain irrelevant concepts and knowledge. So, does the summary meet the criterion conciseness? Or does it contain irrelevant concepts in your opinion?

P2: I don't think it contains irrelevant concepts. So in that sense with that definition it is concise.

E: OK. Great. Coherence: So a summary is coherent if all the concepts and knowledge are well organised and related to each other. So, is it readable - coherent?

P2: It's much more readable than before. Some parts are clearly readable, some other parts are, when you read it you stumble a little. Let me see if I can find a good example. So on the artefact description there is a practice rules for DSR research consists of creation of an artefact to address a problem, relevance to the solution of an unresolved and important business problem, a rigorous evaluation of the ... so that flows nice. So that's a good. So then under evaluation and setting it says the evaluands is a logical reasoning where 7 DSR publications and the created procedures - OK. I didn't get the meaning of that. So I think there are examples (that) are good flow meaningful text that I immediately get and then there are other examples maybe that was not the best where I'm puzzled.

E: OK, so the evaluation part especially and the mentioning of the techniques in there.

P2: Then there is another sentence on the artefact description. The search process draws from existing theories and knowledge - come up with a solution to a defined problem. That's very generic. So, isn't any search process doing that. So, so what's special here. So I think that it's too generic for me to capture what Peffers et al. is really doing. So, I think there are examples where it flows very well - just above here - and examples where I don't really get the meaning and I think utility here would be that I don't have to read the paper but I can get the most important meanings from reading your coding of it or summary of it.

E: That's it. OK. Yeah, that makes a lot of sense that there is some too generic information about that. It's - Do you think that it also depends on the reader in the end?

P2: I'm pretty sure it does. When we look at the other document I had the advantage of being one of the authors of the [NAME OF PAPER]. So I knew all the time what you were talking about. So that gave me another - so I read that in a different way. I've also - I recently used the ADR paper as - to organise a paper I wrote - so that was also fresh in my memory whereas the Peffers et al. It's a long time since I've read that. I have a slide with a figure I always show and - but the details are way back in my memory - if at all there.

E: That makes a lot of sense.

P2: And that maybe the - now the detailed one you gave me was especially on the Peffers et al. And that's a long - it's probably 5 years - 4 years since I've read that in detail. So I forgot all the details. So I don't remember what a search process that they recommend. That's why I say it's too generic here. If it had been a detailed summary from my own paper I probably have said "Oh yeah that's right - we did that"

E: Yeah. Well, that would have been a good idea but the problem is then you are - you can't really say whether you understand what's in there because you relate it right away to what you have read - ah to what you have written, I mean. So, then it's quite easy for you to say "Oh yeah, I understand everything because you can make the connection to the actual paper."

P2: And in that sense it's a good thing that you sent me the Peffers one because that was a long time since I read that.

E: It's always very hard to choose what papers you are actually offer. What summaries you offer to the actual evaluator.

P2: It could be fun to see one that I've never read. Could you do it for one of the papers that was in the last year's DESRIST I didn't participate in. I would not have had a chance to have a look at any of these, except my own one of course. It would be fun to see whether I would get the meaning out of one of these.

E: That's a very good point. Yeah maybe. You know the thing is that I need to finish this study now, write it down and then I would have some interesting follow ups. For example there is another methodology presented at the last DESRIST, which was this PADRE paper, which also builds up on a number of other methodologies. It would also be interesting to include that. But yeah - one thing after the other. I tend to do too many things as John already told me many times.

P2: Ja. And now he's back.

E: Yeah, yeah. He just arrived. Well actually he's still - it's the second day he's here so has some things to do at home. Tomorrow he'll come in shortly and on Thursday I'll have a meeting with him.

P2: OK.

E: But he arrived. That's right. OK. I just continue. Is there any information that contradicts another information in the summary you think.

P2: Nothing that I so. No I don't think so.

E: The next thing would be comprehensiveness.

E: A summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in an article. That's always hard to say but you know from the experience you had when you read it a couple of years ago, do you think it meets the criterion comprehensiveness or are there any concepts or topics missing.

P2: I think my comment on the figures belongs here.

E: Yes it does.

P2: So there is information in the figures that is lost or left out in the summary. And for the Peffers one it's especially this with the phases and the arrows.

E: And the entry points.

P2: I think that's the main figure of the paper - of the Peffers one.

E: OK Great. So then clarity: A summary is clear if all concepts and relations can be clearly understood. So does the summary meet the criterion clarity in your opinion?

P2: Mainly. There was this comment on meta-level but is that a lack of clarity. Probably not a lack of clarity.

E: But maybe what you just said beforehand about the search process.

P2: Yeah that was the one I talked about and that's to - Well it's clear what it is. A search process draws from existing theory and knowledge to come up with a solution. Yeah. OK. It's saw generic. You draw on existing literature and you come up with a solution. Tara - It's like a wizard. I don't know what they actually do - but it's clear. It's clear enough.

E: I understand.

P2: But it's not detailed enough.

E: It could be ambiguous in the end. So that would be one question here too. So, does the summary contain ambiguous information?

P2: Yeah, yeah that is ambiguous.

E: OK. Great. The last one would be correctness. A summary is correct if it doesn't draw any incorrect conclusions including inconsistencies. So, do you think you can draw incorrect conclusions out of this summary?

P2: Not really. Nothing that I know so. Of course there is always a danger when something is generic that you then imagine things that are not in the paper because the brain wants to add detail where no details are found but it's not a problem of your summary it's a problem of the thought process and the cognitive process in the brain and the reader. You cannot give every detail. Then you can repeat the paper and that would be valueless.

E: That's it.

P2: So, but it's - I think your challenge is to find the right level or the most you've done that in a few places it is a little bit too generic. So, that's my comment.

E: OK. Great. Thank you so much. So that would be the questions I had for the individual paper and for the multiple document summary it's actually the same questions. So, I would go through each of these questions again in regards to the multi-document summary. If that's OK?.

P2: Yeah.

E: OK. Or do you have some general comments on the single document summary first?

P2: No.

E: OK. Great. Then let's do the multi - or work on the multi-document summaries. So again conciseness: A summary is concise if it doesn't contain irrelevant concepts and knowledge. So, does the summary meet the criterion conciseness?

P2: Is there any irrelevant - I don't think.

E: OK. So all the information here is important for a reader of a combined summary.

P2: Are there 3 too. I was - There are some very long repetitive sentences at the very bottom of the document. SDSM used this and that. DSRM uses this and that and it's hard to get an overview of that. Section 3.2. Even after having read it now a second time I'm not sure I'm having an overview of the differences.

E: So you mean that should have been presented in a different way.

P2: Maybe. I don't have a solution for it. But if you have a look at the first sentence for all 3. You could say ADR and SDSM has been evaluated using a case from one company whereas DSRM was evaluated using 4 published IS literature. When you come up with differences it's - typically you want to say. B does this and C does something different. Now you have to jump around and make that linkage yourself as a reader. So, I think there - then you said - the second line says ADR used retrospective application. SDSM used retrospective application and DSRM used logical reasoning. So ADR and SDSM used retrospective application and DSRM used logical reasoning. That would be one sentence that kind of said what are the equalities and what are the differences between the 3. So, as this is written now it is not really doing the job. 3.2.

E: So in 3.1 there are actually the similarities mentioned where it's written that all used retrospective application - oh evaluation actually.

P2: Ja.

E: Any other comment. Else we move on.

P2: There is no one.

E: So, is there any unimportant information expressed in the summary?

P2: Any unimportant. Well you compare 5 things. 1.2.1., 1.2.2, 1.2.3, 1.2.4, 1.2.5 and I was puzzled why these 5. So they were problem formulation, building an IT artefact, evaluating, communicating and the iterative process. The 3 first ones I clearly understand. So that's the problem the solution and the evaluation. Those are 3 core things in any design science research.

E: Yeah.

P2: But the last 2 ones. Communicating the artefact - hm - I could mention a number of other things that could be compared. So, I don't see that as - the use of kernel theories could be - if you use Walls et al. Do they distinguish between product and process if you use Hevner. I don't think it's odd to compare communication as one out of 5 and the same with the iterative process - why that? I would - do they have a meta-level or I would say is more important. But that's my interpretation of design science. So, so the last 2 puzzles me. Why these 2. And I would not have missed them if they hadn't been there.

E: OK. Great. I'll give an explanation about that after I'm finished. OK? Just to let you know how these things have been created so you have an understanding about that but I need to finish this interview first. OK. So coherence: A summary is coherent if all the concepts and knowledge are well organised and related to each other. So, does the summary meet the criterion coherence?

P2: I think the tables in 1, 1.2.1, 1.2.2, 1.2.3 are nice. When I read a paper I'm probably more visual oriented than most. So, my eyes are always drawn to pictures and tables and so. Immediately when I - I remember when I opened it first I went to page 2 and I started reading one of the tables. I think it was the first one and I didn't find anything that shouldn't be there. So, the answer is pretty well. I was confused in the differences but we talked about that already in 3.2.

E: OK. Thank you. So, does any information contradict any other information in the summary? Do you think there are contradictions in here?

P2: Maybe in 2.2.1 you talk about stages and you say they have respectively 4, 8, and 6 stages. And by how that related to the iterative process right above and for example on the iterative process you say that ADR has a BIE cycle.

E: Yeah.

P2: Ups where was that defined. I don't think it was defined. So I have to go to read the paper to understand the BIE cycle. That's the only thing I found.

E: Thank you. That was clear. OK. Comprehensiveness: A summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in an article. So, do you think it's comprehensive or are you missing some information?

P2: When you compare the evaluation it's 1, 2, 3 how (simply??) evaluated the artefact. The DSRM is again too generic. Just says evaluation. For SDSM it says ex ante and ex post evaluation and I would have been puzzled if I had known that beforehand. Now I know what it is meant by ex ante and ex post but there is something. So, a reader that didn't have the same insight into this paper would probably have been puzzled and it builds on the - that you distinguish between design and construction and the idea that a design can be something in the head of someone and construction is when you start building something physical and then ex post and ex ante is related to this distinction between when you have design and when you have construction. So, where ex ante is before construction and ex post is after construction but you don't get that from reading your summary. Again it's - I think there is a figure in the paper - I'm not sure. I know we have a figure on a slide that we always used to explain it. Now we have changed - we talk about formative

and summative evaluation. So, ja I'm not sure you are getting the full idea and for DSRM where it just says evaluation that's - what's the concept of evaluation - that's the evaluation. OK? So something is missing there.

E: OK. I understand. A follow-up question on that. How far would you go?

P2: At least for DSRM I would go a little further. And for SDSM I would probably say (that it) states ex ante evaluation before construction and ex post evaluation after construction of an artefact. So it's just adding 6 words or something like that. I don't wanna be (??) a novel or anything like that. I just want a little more.

E: So one sentence in the end that explains each of these concepts.

P2: Ja.

E: OK. So, is there - Do you think there is a topic missing in here.

P2: Yeah the meta. Do they distinguish between an instance and a meta level or a generic level and do they talk about generalisation and the generalisation process. You know, some authors like myself believe that the real scientific value lies in - at the generalised level. Scientific value is not that you could help one company. Is whether this problem is interesting to more companies - to a class of companies and - so I'm missing that.

E: OK. Thank you. So, clarity: A summary is clear if all concepts and relations can be clearly understood. So, can all the concepts and relations be clearly understood.

P2: Yeah. Except for the one we talked about. I think you need to explain a little more what is meant by ex post and ex ante and it's - the 3.2 section is also - it's just too. It's not really a good comparison to list one and then list the other and then list a third. So, the way you compare them above with your tables is much better. And maybe after each table you could come up with the similarities and the differences. Just a summing up. Instead of doing it at the bottom. I don't know whether that would work but. I always hesitate to when you are redoing something - you shouldn't come up with a solution because I looked at it for an hour at the most and you looked at it for a year or more. So, I'm not in a position to come up with a better solution.

E: No problem. OK thanks a lot.

P2: OK

E: No, not - there are 2 more questions. Sorry. So, is there an ambiguous information in here. I guess I already know the answer.

P2: Not beyond what we talked about.

E: Sorry.

P2: Not beyond what we have talked about in 3.2 - so I will not add anything to that.

E: OK. So, in the end evaluation can be anything. That was what I got out of it.

P2: And evaluation is not a good explanation of evaluation. So, just repeating the word.

E: Yeah that's not good.

P2: As far as I remember if we head back to section 1.2.3 where it says DSRM evaluation. They have an explanation in their figure of what is meant by evaluation. So you could have taken, lifted one sentence out of the paper there but I don't know to what extend you code the figures.

E: Yeah no - the figures we couldn't include at all you know. So that's the problem. It's when you do textual representations you can only concentrate on the text and that's it.

P2: Yeah.

E: OK. Great. So correctness is the last one. So is the summary correct if it doesn't draw any incorrect

conclusion - Oh sorry: A summary is correct if it doesn't draw any incorrect conclusions, including inconsistencies.

P2: I especially checked it for [PERSONAL INFORMATION] - soft design science methodology. I don't think you say anything that is not correct.

E: Great.

P2: And I'm not sure - I'm not to the same extent certain about the 2 others because I don't know - I didn't stumble over anything. so. As far as I know they seem to be correct.

E: Great. Cool. Thank you very much. I'm really pleased that you could actually take part in this study and your input is very, very important to my research here. Thanks a lot for taking the time.

P2: All the best to your research Emanuel and I look forward to see some results of it.

E: I will.

P2: If you want me to approve the minutes or anything like that I'll be happy to do that.

E: OK Great. Thank you very much.

P2: OK. Bye.

E: Thank you very much. It was a pleasure. Bye.

P2: OK. Bye.

**Participant 3**

# Transcript Interview 1

P3: OK. Here it is. DSR publication conceptualisation survey. Please name and briefly describe the 3 most important concepts or name 3 concepts and then you are asking for what should definitely be in each DSR publication.

E: Right. That's correct.

P3: I see. OK. So it's in front of me. I'm looking at it now.

E: Great. So, first things first. Is it OK that I record this interview?

P3: Yes.

E: OK. Great. Thank you very much. You already signed it in the consent form but I still would like to ask it beforehand. OK so there are actually - I'll start with 4 very general questions where I just wanna identify - well, your fields of expertise and your expertise in design science. We all know that but I still need to put that into my study - into the results. OK, the first question would be. Please list your fields of expertise.

P3: In the field of information systems research?

E: Mhm (Yes). Well, any research you are interested in.

P3: OK. So I'm mainly interested in IT change, green information systems, and digital innovation. And from a methodological point of view I'm doing DSR and I have a background in grounded theory development.

E: OK. Great.

P3: Mostly. That's just what I'm focusing on.

E: OK. Great. Thank you very much. The next question would be - on a scale from one to 5 where 5 would be, you know, very high level of expertise. What do you think is your expertise concerning the topic of DSR?

P3: That's a tough one. Perhaps 4.

E: Yeah. I thought so too. I would actually give you a 5. I actually - yeah. OK great. So, the next question would be. How many years of experience do you have in this field - DSR.

P3: DSR - I would say. That's again a tough one. So I started doing actual research on DSR appropriately approximately - I would say - 8 years ago, probably.

E: OK great. So, do you know how many papers you've published that follow the DSR paradigm, approximately, so you know it's really ...

P3: Methodological, including methodological papers?

E: Yeah. You can include methodological papers too.

P3: OK. I can - Let me just go on my website and I'll give you the exact number.

E: Thanks.

P3: Does it include what's under review?

E: Yeah. You can add them too. As I said it is only an approximate...

P3: No, no. That's not that it's not a problem - what you need.

E: No, no it's a yeah that would be good. (There was something said by the participant in the background that I answered to but it can't be reconstructed anymore) It's a - the only thing is - because it's about you know DSR and I want to, you know, analyse or get an idea of the actual expertise. You know - so - yeah you can add them, please.

P3: I call it something like. Let's say 12 or 13.

E: OK. That's great. Thank you very much. OK. These were just some general questions and now.

P3: Actually more: 14. There is some more. That includes conference and journal publications published and under review.

E: Yes, OK. Great. Thank you. Thank you very much and now I'll actually talk about the questionnaire you filled in and also the comments you sent me by email. So, you put actually a couple of comments in there. I'm just, you know, going through these comments briefly. There is not much to say from my side except that thanks a lot for pointing that out with the hypotheses - it's research questions - You are completely right and I've changed that in the document. Also that there is one problem in the first sentence in the questionnaire that I'm referring to the following concepts are only on the next page and I've changed that as well. Thanks a lot for pointing that out. Now it's getting more interesting. So, you said that it would be a good idea to actually put in some examples for these concepts that I mentioned in here and it's - well actually. It's just for clarification we - in this case - deliberately left them out for you to - or for us to see whether you have actually understand what we are talking about by only giving a name and a description because that's actually how we now found out that evaluation aspect and criterion is a bit vague for you. That's what you said. Isn't it.

P3: Ohm, yeah. I think so. I have trouble understanding you now so did you change anything on your side?

E: No. Oh, sorry, sorry, sorry, yes I did. I actually put a paper on top of my computer. Is it better now.

P3: Ok. Now I can here you again so please say what you just said - just the last bit.

E: OK. So what I said is that you pointed out that evaluation aspect and criteria is a bit vague. That's why it would have been good to get some examples. And I said that we left out the examples especially to figure that out - or to find out - whether you actually can understand the concept by it's name and it's description and - so it was really good to see that there is actually a problem with evaluation aspect and criterion - in your opinion - and - but I'll get to that soon. You also pointed out that some of the concepts are not orthogonal. I hope I pronounced it correctly. We'll get to that point too but maybe - do you already know what concepts you wanna refer to in that case?

P3: What I was talking about when I said there is overlaps between the concepts?

E: Mhm (yes)

P3: I think I was looking at - I think I wasn't sure actually - so it didn't appear to me too clear - like evaluation aspect and criterion as you said earlier and there was quote evaluation metric and there was quote evaluation result. So it wasn't just too clear to me. I mean since I - that's it basically. And then artefact, artefact design - it's just important that you don't have overlaps between the concepts I think that's what I said here.

E: OK. So, well we'll get to this point anyways. I think 2 things. Well I'll talk about that shortly.

P3: Here is a comment which some people might not too clear about. So you say artefact and then you have artefact design - I understand that difference - and then you have design realisation. And you say design realisation expresses an instantiation of a specific artefact design. So you could say that's an artefact. Something more or less tangible depending on what it is and (up there??) you say an artefact describes a tangible concept of something that is artificial, human made. So that would also pertain to an actual instantiation. So that's an overlap I think.

E: Right that's correct and I also thought you would come up with that point and you want to refer to that also maybe purpose and requirement.

P3: Let me have a look at that. So, requirement and purpose. That's a tough one, actually. How would you delineate. I don't see. Of course you have different conceptual definitions for both but it's blurry - let's put it that way.

E: I hope I can clarify that a bit now and I'll come to that shortly. It's just - you know these were your general comments you put into the email and I thought you wanted to talk about these but that, you know, clarified that and also said that these are the concepts where you had problems with and also that construct is missing - I'll come to that as well, shortly. OK, I'll now just - I'll pick some of the comments - ah - some of the concepts and your comments where I have some questions about. So, you talked about the most important concepts which is goal, purpose, constructs and evaluation. That's, I think that's I can also agree with that. The only difference is we used different names for them. So, when it comes to goal and purpose, which is the first - well it's the most important concept for you. So, there we have actually the difference between purpose and requirement here. And I guess that's one of the problems you had. So did you get the difference between purpose and requirement which I pointed out in the definition or is that unclear to you?

P3: Let me read first. So, requirement you are saying requirement expresses certain aspects an artefact design should inherent. It can be a requirement which describes a class of goals to be met a theory applies to or a specific artefact should fulfil. That's the one, the other one was the purpose. Where do I find that.

E: It's at the end, at the end.

P3: The very end. OK. To further define any of the concepts above, specifically a purpose can be expressed. A purpose identifies what a specific artefact requirement, evaluation technique... Ah OK. I could understand the difference and I would most probably agree with that. I didn't whatever list the requirements in the most important concepts because you were asking for the 3 most important concepts.

E: Yeah right. Do you think that goal/purpose is related to requirement? So, just to clarify what's our idea. Maybe it wasn't expressed well enough in the description but or definition. So, the requirement is when it comes to a scientific article that follows the DSR approach then the requirements - the things that have to be evaluated - ah, you can see it as a purpose, yes but it's also - it expresses what the artefact has to fulfil and this has then to be evaluated. Whereas the purpose on the other side only expresses and further defines the concept - sorry the artefact that is being discussed about.

P3: OK. Now I lost you. I listen carefully. Here is - let me tell you my understanding of the difference of the 2 and then you tell me if that matches with your thinking. OK? So any artefact should have a purpose. So the plane is for flying for instance. So that's the highest level of the artefact. What is the artefact for. That's its purpose.

E: Yes.

P3: And requirements are way more specific. So, from the purpose derive, if you will, requirements. And they can be very different requirements that might meet the same purposes.

E: OK.

P3: There are so many designs that might meet the same purpose.

E: Yeah.

P3: If, for instance, my purpose is to get from A to B then a car will serve the purpose and so will the plane. And there are very different requirements to a plane than to a car.

E: That makes perfectly sense. Then the only thing that I also added to it is when it comes to the ontology is that the artefact fulfils this requirement and this utility relationship, that the artefact fulfils the requirement can then be evaluated or should be evaluated, actually in research.

P3: Ah, OK, so what you are saying is evaluation (???) So first of all was you interested in whether the artefact meets its purpose and then - as you look at the artefact - you are interested in whether it's a valid instantiation in relation to the requirements.

E: OK well that's a good point. OK evaluating that the artefact meets its purpose and then you go further - well you drill further down and you evaluate the requirements.

P3: Yeah. So, if you look at a plane, for an instance. So one requirement would be to design a plane so people can actually enter a plane. So, it's a requirement - it's not the purpose though. The purpose is, you know, flying somewhere - getting from place A to place B. So first of all you are interested in well, does the plane meet it's overall purpose but then at more specific level you are interested in whether it actually meets this requirement. So can you actually hop onto the plane. Can you start the engine? Can you (??)

E: And when you think about a specific instance, say - sorry - about a specific article then you say well, ok I have this overall purpose, yes, but that's not what we are interested in the paper - it's the requirement or you could write another article to say where you then say, ok, well, what you wanna evaluate in this paper is whether the plane flies.

P3: Look this is. The question is what you are doing in the article. Are you - so what's your key contribution. I should ask you probably that question. So what you think should a DSR article deliver? What is the outcome? Or what are the different types of outcome? So you need to think about that.

E: Well.

P3: Because here is the key issue. So, when you look at your, you call it ontology, so the various concepts you are looking at. This is very much artefact focused. So essentially you are looking at various properties related to the artefact. So, it's design, for instance, the artefact as such is significant, what were the requirements that were satisfied through the artefact and so forth. That is one specific type of contribution that you can actually make in the design science world. But you could also think about more abstract deliverables. For instance the requirements or some sort of principles about the class of artefacts and so forth. So what I'm saying you actually need to be very clear about the type of study you are talking about and what is the key deliverable. Because if the key deliverable is the artefact then I think we need both purpose and requirements.

E: Yeah. Well, actually it's about a summarisation of DSR articles in general. When it comes to principles you would like to identify then these principles can become your artefact in question.

P3: Mhm (Yes). OK. So if I have a meta-artefact for something that is a class of artefacts it is an artefact by itself that's what you said.

E: If you actually want to discuss that in a publication you could do that.

P3: Here is the thing. Look. I think if you talk about anything that we make, anything that we do, anything that we create is an artefact. So the paper as such is an artefact. A sentence is an artefact. The artefact you are writing about is an artefact. I think however if you use the notion of artefact in the context of design science research people think about certain about IT system or the design of a system, or a method or a specific construct. That's what they think of. They don't necessarily think about more abstract statements about how a tool build an entire class of artefacts. So they don't think in terms of principles or even theoretical statements. So this is why if I have a look at your ontology now it seems like, it appears as if it was about papers that produce concrete IT artefacts as in systems methods constructs instantiations.

E: Yes, but I actually - it should be possible to conceptualise any article in the end and that's also why there is - you said that the concept like, you know, artefact, artefact design and design realisation are not

orthogonal and the reason for that is that artefact itself is the super class - if you wanna see it that way and then as a subclass you have artefact design and you have the design realisation and the idea behind that is that design realisation - sorry - the artefact design is your generalisation already whereas the design realisation is the actual instantiation you then evaluate to proof, or to actually provide evidence of the artefact design's utility.

P3: OK. I get what you are saying. So let me repeat in my own words. So, any DSR publication you have an artefact, an artefact can be an artefact design, such as a principle, so the artefact design would be captured in terms of a principle. It can be a design realisation, so a concrete instantiation or it can be both. That's what you are saying. OK.

E: There is also a - The artefact design is - it can be a principle but it can also be a generalisation of a design of a digital library, for example. And then you have a certain realisation, which would be a specific digital library that follows the proposed architecture and by evaluating this design realisation you proof the utility of the architecture.

P3: Here is my key comment and that's why I said earlier in the paper I think constructs are required. I know that your understanding is that all of those are constructs artefact, artefact design, requirement and so forth. Now if you look at what you've done here - artefact design captures a lot as you say. It can be an entire architecture of digital libraries but it can be something way more specific. So personally what I think is important about DSR contributions is exactly how we communicate that artefact design, so the more abstract ideas about the design of artefacts and that gives us things and relationships between those things and that is what I would usually call construct. So now when you say when you have an artefact design that is a very high level perspective of that. So the question is how do we - this is what makes DSR articles valuable. How do we express such artefact designs and I think we should be expressing them through concepts being constructs and relationships between those and we need to have a better understanding of what such form of constructs in the context of design science research are. So this is to explain why I said construct - of course anything that you have here is in a way a sort of conceptualisation - a constructs is nothing as a concept. It just expresses the idea that it was deliberately constructed to meet a certain purpose, and for instance in terms of (??) constructs and so forth.

E: So, OK, So the idea we are following here is, well, actually, you know, again a construct you can also identify as an artefact and you can then further relate to a more precise understanding or you can just break it further down to get actually a conceptualisation of this specific construct or artefact in general but what you have said here is actually the relationship that's an important point. The relationships itself we kind of treat as a - so you can have a relationship from one object to the other object, which we would like to express - what we have done - we have expressed it by using properties and purposes that then further define a specific artefact or this you know part-whole relationship. Like different components of another component. OK but do you have to say anything about that?

P3: I understand what you are saying. Let me perhaps again clarifying the - how construct comes in. So if you look at what you are doing here - of course all the various component parts of your ontology. The artefact, the artefact design, constructs from the viewpoint of constructing this meta-theoretical framework but if you look then at the actual design research publications that use your terminology perhaps you will again have more specific constructs and actually say something about the design. So, the question if you now use the, if you were to use the notion of a construct as part of your ontology or not, I don't know if that's important. I guess I'm looking for some sort of analogy to what we are doing in - not design science

research - but regular research where we are trying to explain and predict and then work with constructs and (??) but of course there are different kinds of constructs. There might be some that serve the purpose of input variables there might be some that serve the purpose of output variables. So yeah anyway these are all constructs. I think I agree.

E: OK. Great. Thank you very much. So let me continue. OK. So. Artefact, artefact design, requirement, theoretical significance you ranked 5.

P3: Sorry one more question. So if you say an artefact that's the superclass if you want - an artefact design, a design realisation are initiations or subclasses of that. Why do you integrate that in your ...

E: The important thing is that - because you know, when it comes to the conceptualisation you might not know right away whether you are talking about the artefact design or a design realisation, then you can still classify it as an artefact - in this case. And when you get more knowledge about a specific artefact then you might be able to say - OK well this is the design realisation used in the evaluation, for example. So that's why this superclass is there as well. And it's also - the ontology is actually constructed that way.

P3: No what I meant is why don't you indicate in the survey that artefact design and realisation are subclasses.

E: Ah, ja. That's actually a very good point. Thanks a lot.

P3: Because most people would wonder about the differences.

E: Yeah. I guess I tried to point it out but I didn't make it clear enough so. That's a good point. Thanks a lot.

P3: And I do understand what you said earlier about why you didn't put any actual examples however I think most people when - and I guess I'm repeating myself, when they just read artefact without an example they think that you were talking about something very specific. They won't understand that artefact design can also be something more abstract like a principle.

E: OK.

P3: I'm just saying that people might find the same confusion without it.

E: Yeah, no, I understand you completely. When it comes - when I wanna look up something on the internet and I - well, let's say I have write code - I have to do programming then it's always better when you have the example. I completely agree with that. You are right. Yeah, thanks for pointing that out. OK. So practical significance you think is a bit less important than theoretical significance. Is that correct?

P3: You know. It's. That is again a tough one. I think anything that we do in science should have some theoretical significance. It should be some contribution to our understanding of, in this case, how to build information systems artefacts. I also think that as we are in an applied discipline, we are looking at human made systems they need to have at least some approximate practical significance. Sometimes however we are doing stuff that is not of immediate practical value. And this is why there are some contributions which might not yet have practical significance but might have in the future. So if this was about behavioural research I would again say theoretical significance 5 and practical significance perhaps 3 or 2. I would always say we need some approximate value. So eventually it needs to be turned into something that's useful but sometimes not (immediately ??).

E: That makes a lot of sense.

P3: So that's why I made a difference - different.

E: Great. Sorry?

P3: No, no, that's fine.

E: OK. Thanks. So the other one is design realisation. Do you think it is possible to have - to write articles

that follow the design science research principle - ah paradigm - to not include a design realisation?

P3: Absolutely, yes.

E: You mean that there is no evaluation then or how would you evaluate a specific artefact design?

P3: I think when you talk about evaluation this is much about justification what we are doing. So of course the most straight forward way is I do have an artefact, let's say an algorithm that is the simple one because I can relatively easily evaluate that and see that it performs better than the algorithm we had before. So that would be design realisation. However I can think of some conceptual work building on systems theory where I propose constructs and relationships for a certain class of artefacts and I don't evaluate that empirical.

P3: I don't think that that's the ideal case. I'm just saying that it is well possible.

E: OK. Great. Thanks.

P3: I can give you an example - I can give you one example of something that I published - co-published with some other people myself. It's a journal article that was published in JAIS and it's a design theory. And the design theory doesn't have an evaluation. It does have a demonstration so in fact there is a design realisation in there. So it shows it's feasibility but you could well think of not even having that in that paper.

E: OK. Do you think it's getting published then?

P3: Towards it's end it proposes propositions that can then be subjected to actual testing but that was then done in a subsequent study.

E: OK. Very good. So, that means you have design realisation but no evaluation in this one - a demonstration. But a demonstration ...

P3: In that case we do have a demonstration but we don't have an actual evaluation. We have a little bit of justification because it will show at least it can be implemented. That is a first step but we don't have a formal evaluation.

E: So when it comes to demonstration would you say that's an evaluation?

P3: No that's not yet the evaluation.

E: OK.

P3: But there is certain things that you could perhaps evaluate about the demonstration and that is ... (break up) an instantiation. So if you think of something - some sort of abstract design principle and then you build a system in accordance to that principle it's not entirely clear that the principle is a valid instantiation of the principle. So you would have to evaluate that validity. Check this validity and see if the instantiation is a valid instantiation.

E: But a demonstration at least gives some evidence that it might be a valid one even though you didn't evaluate it rigorously enough.

P3: Well, it shows at least that it's feasible and that it can be instantiated, which is a first step and then you can continue to actually evaluate.

E: Hm. OK. Thank you. So the next thing would be main concept. So main concept I only - I only talk about main concept because I have a couple of issues with some other participants here. I'm not sure whether it's so easy to understand what is meant here so. Do you have an idea what's being meant with main concept.

P3: Yeah. I do. So, and I would probably - I can tell you why I said 4 in here and not 5. I said 4 because I wasn't - perhaps I should have given you a comment then because I wasn't sure if there is one main concept necessarily.

E: Yeah. That's it.

P3: So if you think. I mean most papers or some papers - if you talk about a technology - a new technology, for instance, you do have a main concept. So that is a concept behind a plane, for instance, some sort of key idea. That is a main concept. And that's important to capture. So sort of the main physical principle that is used or something like that but sometimes you might have 3 or 4 concepts that are related and that is your contribution. Let's say you are talking about ... (break up) ... but you are not proposing a design for an entire ERP systems but you are looking at a very specific part - you propose 4 important constructs that should be used in ERP development. So in that case you might not have a main concept in your paper. Ahm that's a tough one so I think you should have one or more key concepts. So you notice that I keep talking about conceptualisations and constructs so that is essential. So perhaps not the main concept but some key concepts or constructs that are the output of what you are doing - but when we are talking about that I think that will be closely related to what you understand as artefact design.

E: Yeah. No it's actually there is a - yeah - that's actually the thing, you know. So, this is the misunderstanding and it's a really big issue because - well, it's a big issue - it's not a big issue because we use it in a way we interpret it but it's - the name for this concept is just so wrong. The reason for that is that what you just said that it's actually the artefact design then and that's what I would actually see as the main concept as you have said already. The main concept we use in here is just some concepts that are used in the article that are important maybe to describe the artefact, that are maybe important to support the artefact or any - you know - it's just a general concept. It doesn't have to have anything to do with the artefact design. The reason for that is that we needed something - so it's actually something you have to define in the article and then you can use the concept in all different locations. Do you know what I mean?

P3: Not quite.

E: OK so.

P3: Give me an example.

E: Yeah I give you an example: An example, for example, would be ... Just one second. I'll look that up because I'll refer right away to one of these summaries. Yeah, so, ensemble artefacts for example. It's one concept mentioned in the action design research paper by Sein et al.

P3: I didn't get the first part. What is the artefact?

E: Ensemble artefact. This term is used many times in the paper action design research. It comes to the artefacts that are being generated in well action design research and this is not - this is actually just, just a term used very often in this paper and it's related to the actual artefact but it's not the actual artefact, you know, it's not the main result if you wanna see it that way.

P3: OK. Let's talk about. Let me walk you through the - this would be an example that everybody knows - like a car - OK? So let's say you are writing the first - so the car is a very new invention and you are writing the first DSR paper on a car. OK? So you have an artefact. And this artefact in this case - you have 2 artefacts. So you have got an artefact design and you have got a design realisation. The design realisation is the actual car as it (???)?. And the artefact design would be essentially naming certain key - what I would call - constructs that are required. You could say components if you want. So you have tires you've got an engine, you have got cabin, you have got a steering device - things like that. That would be the artefact design. So then there are certain requirements, like people should be able to get into the car, to start the car, to drive the car, to steer the car and thinks like that. So theoretical significance and practical significance in this case are self-explanatory I think. And then let's talk about the main concepts. So I would say - and I'm not sure if that is what you think - the main concept is the concept of the car.

E: Yeah well, that's actually - the concept of the car is, well actually yes, yeah, no, right, because it's. So the artefact design is the constructs to be able - well, that make a car and the car itself it's what, ja, so that could be one of the main concepts but there might be more than one. Like for example ...

P3: Sorry, but then my question is how does it relate to the first 3 constructs that you got in your table. So you got artefact, it can be artefact design, it can be design realisation or it can be both. I buy that and now we got the key - how did you call that - the main concept. So the main concept would be a - basically the name of the artefact design.

E: Yeah, well. That's another good point. No, but another - you mentioned people, for example, in your description, you know - because people have to be able to drive the car - something like that. But people are necessary to describe your constructs and your design realisation and people is one of the main concepts because it appears a couple of times in the article. So that I would actually see as the main concept. It's just an important term used in the paper.

P3: But this is a ... (break up) ... we are saying. So that it needs a term but this is where you get in trouble because you have overlaps between the concepts and they are not, what we call, orthogonal.

E: Yeah. I know what you mean but then - and that's the reason is actually that it's named incorrectly. So if you wanna see - if you wanna have - use car as a name for your artefact design then obviously it's not the main concept - it's only the artefact design. But if you say - well, you are talking about a specific construct like, well, no, let's say you are talking about the engine you develop, which might be part of the car then the engine is the artefact design - or the let's say the design of the engine. The actual engine is the design realisation and the car itself then becomes a main concept because it's important to put the engine into context.

P3: OK. So the main concept is something that is broader or more complex than the artefact you are actually writing about and the what you are writing about will contribute to that. Is that the idea?

E: And it doesn't only have to be more abstract, it can also be more specific. It's just the term actually, a very important term.

P3: OK. Now you - how can it be more specific. So let's talk about the engine. So, let's say. And I give you a few examples. Perhaps that clarifies it. So you could have got an engine. And I would say the concept of an engine has a certain design. OK but let's say you are looking at the engine in relation to how it's used in terms of it's built into a car or a plane or whatever. It's that what you say - that's the domain you are looking at. You could say that the engine makes use of a certain physical principle then that would be combustion. So the concept of an engine builds on the physical principal of combustion and is part as a domain of cars or ...

E: Well, combustion on the other hand would be more

E: - that was more this base reference, which could be - it's a kind of kernel theory. Isn't it? This engine relies on.

P3: OK why do you call it base reference then because it's a reference to a paper or whatever.

E: Yeah, right. That's it. Because you usually refer to a paper where this is published, you know, like the theory of combustion.

P3: Yeah, but, but I'm pretty sure that when, you know, when Karl Benz built the first car he wasn't thinking, you know, referencing papers, he just made use of engines.

E: No that's right. I completely agree.

P3: Anyways.

E: It's still a paper. We are talking here about papers. But it's. I already found out that the term main concept is very confusing. So, and you just further supported this fact.

P3: Yeah. Very general comment. I think it is a good idea to reduce complexity of what you are doing here. So rather have some abstract terms that capture more than make it to detailed.

E: Hm. The interesting thing here is that I try, well we try to abstract it as good as possible but on the other hand when we then, this is the general, this is the ontology for this topic, you know, design science research publications and then we instantiate it and when it comes to the instantiations where we actually take a specific article and instantiate this ontology then we have to be able to be as expressive as possible because only then we can do reasoning over these articles or these ontology instantiations in the end. But I completely agree with you that one of our main ideas was to make it as abstract as possible to be as general as possible to support all different kinds of DSR publications. But yeah maybe, yeah OK, cool. I guess - anything you want to say about that because else I would just move on?

P3: No let's just continue with your survey.

E: OK great. So, you already said that evaluation technique and aspect doesn't make much sense to you or is not really, I don't know, or you just don't really understand by having a look at the definition what this is about. Is that correct?

P3: I'll look at that again. So evaluation...

E: So we have criterion, metric, result.

P3: .. expresses feature of a specific artefact or artefact instantiation that further will be evaluated against a number of identified requirements. So an example would be that the requirement that you need to be able to actually enter a car and evaluation aspect would then be a door they can build in some sense. That's a feature.

E: Yeah.

P3: OK. And you are saying in order to evaluate whether an artefact meets it's purpose, or no, satisfies its requirements I need to become specific as to what feature of the artefact meets that requirement. Is that the idea?

E: Can you repeat that. Sorry?

P3: OK, the key idea is that you explicate, you made explicit certain features of the artefact that can be then compared with the requirements. So you actually evaluate whether the feature meets the requirement it was defined.

E: Yes.

P3: OK I get that. I think that's important.

E: Then evaluation technique is obviously the technique used to evaluate the specific artefact, which could be anything like, I don't know, surveys, focus groups, so all the different techniques that are out ...

P3: Yeah I get that. I would - this is on a personal note. I know about the discussion about methodology, method and technique and things like that. So I'll would simply call that method and method can be something quite specific. So interviews for example - that's a method. So I would - I don't know where the technique is coming from but I think in order to be as simple and easy to understand for most people in the IS field just do method. And you can use various methods in one study. You do need some method to evaluate whether the aspect match the requirement.

E: Yeah, right.

P3: But.

E: Yeah, sorry.

P3: No, no it's good.

E: OK. And then we have certain results or conclusion drawn out of it and you can also apply for this specific method, you know - a survey or something like that - you might have a set of criteria, you know, you wanna evaluate and then by having these criteria you can actually also apply metrics for these criteria. It depends on whether it's possible or not but if it's possible to have a metric then you can express it that way.

P3: Let me think what are the correct... So an evaluation criterion is used to describe the utility of an artefact towards a specific requirement. Is this only about utility or is it something else - evaluation?

E: That's actually a good point. So, when it comes to design science research it's usually about the utility of the artefact you wanna evaluate rather than the truth.

P3: How about other things - like is it sustainable in terms of life cycle management for instance? Or is it a subdimension of utility. I'm just saying, I'm just not sure if you want utility in the conceptual definition of a concept. I'm just asking. Just think about that. OK. So, you, ok, this is complex. So, I have a set of requirements, then I defined certain aspects of the instantiation in order to see whether the requirement is met. How do I evaluate that according to a certain criteria that's associated with a certain metric. Puh, that's complex. Isn't it enough to have the evaluation aspect and then a metric for that? No it's not because one describes a feature and actually the evaluation criterion that would be the variable in the proposition that we would be testing. Right?

E: That's it. And then you have a metric to be able to, you know, get to a value for that.

P3: I think you might want to show this a little different in your survey and show if certain concepts are essentially subconcepts or the other one. So this is all part of the, essentially this is all part of the evaluation method in a way. I don't know. I think it's quite - I think - I understand what you saying and it does make sense to have both - being more abstract - being the requirements and being specific - being the evaluation aspects in the model but (??) simple.

E: OK so actually, the biggest issue we have here is the definitions and maybe as you already said the examples to it. OK so I have 2 last questions. Sorry that it takes so long. So, one thing is, you know, this base reference because it doesn't always have to be a kernel theory. It can be any reference to another article.

P3: Yeah I'm not happy about the reference because sometimes you might be using - making use of something that hasn't been published anywhere so it might be part of the contribution. So there is some you know underlying idea perhaps that you are using but as you say reference is actually your foregrounding idea that you reference another paper but that is not necessarily the case. The thing is that you are building on something that might be useful and sometimes it's been published somewhere and then of course you are reference it but sometimes not and the thing when you talk about an ontology it's not so much only about what's in the paper but what you actual need to do DSR and that is then of course reflecting in your publication.

E: Yeah. It's how do you actually refer to something that hasn't been published?

P3: You can make it part of your study. For instance ...

E: But then you don't have to reference to another person.

P3: OK. I give you an example. Let's say you are the first one who's building a combustion engine. So this is 19th century. So your concept - the concept that you are developing is that of an engine and the principle that you are using - if you will - is the physical principle of combustion. So, that is the kernel of your design.

Perhaps at that stage no one has written about that so that's part of your contribution so you don't have to reference that. If you right an article where you don't build on kernel theory you still use something or make it happen in a way, so I. Perhaps it makes sense to call it base reference or kernel reference or ... I get what you say and of course in 95% of the cases you would be referencing stuff because you ...

E: Else they would destroy you, you know, in the reviews you would get, most likely.

P3: I don't know why I said 2 there. Perhaps because - I would probably say - I think we should be developing abstract design knowledge and sometimes we might be able to develop that just through doing design and we don't need any kernel theory for doing that but in most cases we would be building on something so perhaps it's rather 3 than 2 but then again that's not about the importance if it should be an article it's more about the frequency - I don't know.

E: OK thanks. And then the most important concept for me in describing an artefact, you know, whatever - whether it's an artefact design or design realisation, whether it's a construct or a principle, it's always properties and purposes. So purpose you already identified as extremely important, obviously, and property - not so much.

P3: Now you are confusing me again because now, from what you said I understand that a property would be a property of the artefact design. So as such the property is essentially part of - or the property as a collection of properties is part of the artefact design so I think that belongs to the second category list in here.

E: To the second what, sorry?

P3: To the second category. So this belongs, if I understand this correctly, to the artefact design. I make it concrete again. The artefact design of an engine would ... (break up) ... about the component parts or relationships of an engine. So in a way the properties of the engine.

E: Well the components - I wouldn't say that's a property. I would say - maybe a property of the engine would be - I don't know - it's light weight.

P3: OK pardon. So that's fine but still then we are talking about the artefact design or the design realisation. So, for instance, when I talk about the artefact design of a certain concept and relationship that describes the artefact design then each concept being part of the artefact design has certain properties. And those properties can vary. So an engine can vary from heavy to light. A plane, for instance, it has a certain - or a car - let's do car again. It can have 4 or 6 tyres. So that would be properties of the concept of a car. I can then look at the subcomponents, for instance, the engine and I can talk about the properties of an engine and so forth. So that belongs to the artefact design more specifically to the concepts that tell us something about the artefact design.

E: That's it. The thing is that it's to be able to explain artefact design further you actually have to have these properties. You have to describe some properties because else it might be really hard to understand the artefact design because the only thing - the only way you can do that is having the actual artefact design and then say - OK we have these subcomponents you know, which are further ...

P3: So then I would move it up there. It belongs to those concepts that say something about the key deliverable being the artefact, its design, its realisation, the properties of its design and so forth.

E: So grouping I guess would have been a good idea.

P3: I think that that'll reduce the cognitive load of understanding what you are doing.

E: Yeah, OK. Cool. Great. Yeah thank you so much actually for taking the time. So these were all the questions I have concerning the survey and it was really, really great. I appreciate that a lot actually, that

you could take the time. It's not super easy, you know, to get people participating.

P3: No you are most welcome and good luck.

## Transcript Interview 2

P3: Yes.

E: This interview? OK thank you very much. I only just started now so that's good. OK. So, the question here is whether the summary fulfils the 5Cs and I've already got an email with some comments from you, so thank you very much for that but I'll just go through 5 points - through this 5 Cs and I have 2 or 3 questions per criterion. OK, so. I'll start with conciseness and the definition we use here is conciseness - A summary is concise if it does not contain irrelevant concepts and knowledge. My question is - Does the summary meet the criterion conciseness?

P3: Well, with (???) repetition of what I wrote in my email, I think it is concise and I didn't not identify anything where I would say this is irrelevant. So from my point of view: conciseness, yes.

E: OK.

P3: I would say that's concise.

E: OK, great. So there are no unnecessary filled-in gaps in this summary. by the way, these brackets - they are all these filled-in gaps. Just to make that clear. I hope that's ...

P3: Yeah, no that's what's my understanding.

E: OK, so. There is no unimportant information in it?

P3: Well, considering. I base my assessment of importance based on how well it actually captures the key information provided in the article - and I think all the information you are providing here are provided in the article and since it's a summary I'd say no there is nothing irrelevant.

E: OK great thank you. So, next criterion is coherence. Coherence is - A summary is coherent if all the concepts and knowledge are well organised and related to each other. So, my question is - Does the summary meet the criterion coherence?

P3: Well, as I said in my email, I would say partly. So the things that I found non-coherent in a way is that if you look at the artefact description for instance, you find some statements which are only about design. So, look at the 3rd one, for instance, you say ADR consists of 4 stages, specifically problem formulation, and that's all related to your quote 1, whereas in other cases you also consider purpose and properties, for instance, so I think if someone reads that, they might be, you know, surprised to see that not every statement is based on the same quotes but that was just like my impression when I read it. So that's one citation and the other one is related to that was that it didn't become entirely clear to me what the definite, if you will, set of concepts is that you require to describe an artefact. So what is needed. Which of your quotes should occur in order, you know, to have a complete description of the artefact design.

E: OK. Thank you very much. So, that's coherence. So, do you think there are any, any specific filled in gaps that contradict another filled-in gap? So do you think that there are - there is information that actually, you know, contradicts each other?

P3: I did not find such information, however I have to say that I had troubles reading parts of it because - if you look at the artefact design description it sort of contains a lot and what I found is that you are basically describing a sort of a tree structure and ... So I didn't find anything. Let's put it that way. I didn't find any but I'm not sure if it was too clear to me when I read it.

E: OK. We'll get to this criterion anyways. OK, thank you very much. The next one is comprehensiveness. So, a summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in the article. Again, does the summary meet the criterion comprehensiveness?

P3: Well, I think yes. It does meet the criterion. It's I think - this is a little bit difficult because this is a long article and I know the article quite well but I didn't match step by step if everything that I think is important in the article is in there but it seems that it is. The one thing that I was little surprised was the definitions. And I'm not sure if the ensemble artefacts that you define there is the only concept that should be defined. That's the question. I know that you are focusing on the artefact and on the method and so forth so it might but. I mean if you look at the different you know concepts that are used to describe an artefact in the article - there might be more. That was just a feeling.

E: Do you have an idea what concepts you would include in your interpretation of what should be in the summary?

P3: Yeah, for instance, they write quite a bit about design principles emerging from the study and I think that is information about the artefact that is being developed and as such it should perhaps be defined.

E: OK. Thank you.

P3: Because there is no such thing as a clear understanding of what design principle actually is, so they have their own understanding but then again I can see it is difficult to express it in terms of the quotes that you have identified so it's more a hint and then deficit to you.

E: OK. Thank you very much. And concerning concepts, you know. So, well, we have talked about, you know, the main concepts to be represented in an article that covers DSR work, whether it's about DSR in general or it utilises DSR. Do you think there are some concepts that should be included but we have talked partly about that in the last interview already but.

P3: What do you mean? You mean additional concepts than you have considered?

E: Yeah. So now you have seen what concepts are - when you have a look at the key at the end of the summary and do you think there are some concepts that should be included?

P3: Well, I think that's quite a comprehensive list based on the discussion we had a couple of weeks ago I think I understand each and all of those concepts but I'm not sure if you wouldn't - if you couldn't make it easier to understand if you actually limit the number of concepts.

E: If you - sorry?

P3: If you limited - if you reduce the number of concepts. So, for instance, evaluation technique, criterion and aspect. That was one of the things we were talking about.

E: So you would limit them - do you have an idea? What's your opinion?

P3: What's my opinion. Well my opinion is that there are still some concepts that have an overlap in what they are describing and they could be perhaps reduced into one concept and the key problem I had with your summary. I think it's wonderful, it's concise, it's all in there, that's all good but you are using a rather large number of codes - from 1 to what is it? 16 and that really makes (break up) hard to read it and that's why I also suggested - now we come to clarity - that you might think of a tree structured presentation as in an XML file. So I'd say it probably covers all that's required but in terms of presenting it to an audience it might be too many.

E: OK, So, you mentioned evaluation explicitly: So do you - How far would you reduce it? You would have one concept?

P3: That's a tough one - partly because I now just looking at the concepts - not too sure - again I

understood it last time we spoke but the difference between evaluation criterion and aspect. That reads like - I know that there is a difference but it reads like the same concept. So I think, referring to some material property of the system and then some sort of measurements scale which you say if - on which you measure whether it's been met or not. So that's something I'm having trouble with.

E: OK, good. Thank you very much. The next one would be clarity. So, a summary is clear if all concepts and relations can be clearly understood. Does the summary meet the criterion clarity?

P3: Not really I think. You need - the thing is the combination of text and the codes in order to show what concept that is an instance of - at least for me was difficult to digest. If you take - let's say an hour to digest it and you know, look at it in some depth - of course you can start disentangling it and you read it again and then you would understand that it is another summary that captures all - well much what's in the article but if I take that much time I can read the article.

E: Yeah, right, OK. So do you have a certain section or sentence where you say, OK that's completely unclear to me or - well, it only becomes clear when I read it for an hour or so.

P3: Well, each sentence by itself is quite clear. But here is what happens when I read that, for an instance. Let's say when I'm looking at this and I don't read it from start to finish but I look at the artefact description for instance. It says - and look and the second statement - so, it says ADR, code 1, can be used for open ended IS research problems, code 10, that require repeated interventions in organisations, code 11. The sentence makes perfect sense to me. It says ADR can be used for all open-ended IS research problems that require repeated interventions in an organisation. If I read it that way but now it gives me the code. So, I'm interested - hey what do these codes mean. Are they of any significance? So I start scrolling down and I'm looking what these codes actually mean and I see OK 1 - that is an artefact design, 10 is about the purpose and 11 is about a property and I read it again and I say ADR can be used - so that's the artefact - can be used for open-ended IS research problems - 10 was, I'm looking at - the purpose - OK that makes sense to me - that require repeated interventions in organisations and then I would ask myself - so what specifically do you mean by property because requirement repeated intervention in organisations - is that a property, is it a boundary condition, is it a sub-category. So that's what I mean. So it doesn't each sentence by itself - that's just the way of how I can get access to it, is, I think, a little complicated.

E: Yeah, OK. So, are there any filled-in gaps in the summary that are unclear?

P3: No, I think - as I said when you look at it carefully and you sort of memorise the codes then it's very straight forward but that's (??)

E: Ah OK. So what concepts do you think should be described in more detail to better understand them.

P3: Hm. I'm not sure if you need to describe concepts in more detail. So what I would - this is just on top of my head and I'm not sure if it makes sense but what I suggest is that you think of the way how you present the various statements about the artefact design because essentially what you are doing is to start with the overall concept like ADR and then you say, well in ADR we've got stages and then you define stages further - so essentially it becomes a taxonomy - not even a taxonomy. You could show it in terms of a tree structure. That's, I guess, what I'm saying and I would also think about the number of concepts in your ontology if you actually need all of those concepts. And also if you're - I don't know. I think that's my statement.

E: OK. Thank you. Does that depend - Or do you think it also depends on the audience whether these concepts or this information in the summary is clear or not?

P3: Absolutely. So one way to perhaps address that would be a superset and subsets of concepts. So, for

instance, this is a complete set and depending who you are communicating with you only shows a subset of that. I don't know. Perhaps.

E: OK. Thank you. So the last one would be correctness. So a summary is correct if it doesn't draw any incorrect conclusions including inconsistencies. So does the summary meet this criterion or the criterion correctness?

P3: So here is what I wrote in my email. I said, aren't what is said under thesis statement requirements or goals? That was my question. Let me go there again. Here is the statement. Aha OK. So that was one question I had. I would expect some statement and I'm now reading what I said in my mail about the ultimate purpose of the artefact early in the summary. Whereas you start - this article describes an artefact names action design research. This artefact fulfils the requirements to generate prescriptive design knowledge. Well it's in there, so perhaps my statement was a bit harsh. So you says something about the actual ultimate purpose. So, think that's OK and then I'm writing I don't understand why, for instance, in an organisation setting "is a property" - this is a boundary condition. Does it apply? I think that's more a boundary condition and not a property of the artefact of this method here.

E: Were are you referring to?

P3: Oh. let me search through the document again. - organisational, I misspelled.

E: Is it under artefact description?

P3: OK it's an organisational context and then is quote with 2 and 2 is a requirement. No, that's not what I was meaning.

E: No I think it's further down. Isn't it? So the property would be 11.

P3: Ah property is 11 so I'll look for 11. 11, 11. Oh yeah. ADR consists of building and evaluating IT artefacts in an organisational setting. Is it a property or is it a boundary condition of where the artefact applies - I don't know. And this is certainly not complete. So if I read this over and over again we might disagree perhaps on some of the coding. Such as boundary conditions. That's an important one.

E: Do you think that boundary conditions should be included?

P3: I think actually boundary condition is a category more than a concept. It's very abstract but that's really important - yes.

E: OK. So, the information in the summary is correct?

P3: I think yes and by enlarge, except the 2 or 3 little things that we just spoke about.

E: Also in terms of correctness but - that's alright. OK, thank you very much that's it already. So we were pretty quick this time.

# Transcript Interview 3

E: OK, So, thanks a lot for taking part in this study, again. I'll make that as brief as possible so it shouldn't take too long. It's again about the 5Cs concerning a multi-document summary. Is it OK to record this interview?

P3: Sure.

E: OK. Thank you. So, what you can see here is a summary of multiple articles that cover the topic or the artefact design of a design science research methodology and this is a comparison of these ontologies in terms of requirements, artefact decomposition and evaluation technique. OK, I'll just start with the first one. It's conciseness - So a summary is concise if it doesn't contain irrelevant concepts and knowledge. So, in your opinion do you think it consists of irrelevant concepts and knowledge?

P3: To not give you a yes or no question. So, when I look at the various, for instance, artefact decomposition or parts of concepts as you call it - so we have problem formulation, build an IT artefact, evaluation of an artefact and so forth. That's quite high level, quite abstract, so I think all of them are essential to the 3 approaches you are summarising. So from that point of view there is certainly nothing that is irrelevant. The question is more if this is enough.

E: OK, OK. So we'll come to that point anyways shortly. OK thanks. So is there any unimportant information in there - you think?

P3: Well, now I'm skimming through the entire document. Again, of course, it's rather abstract. I wouldn't say any of that is unimportant. All those are important component parts of a DSR methodology, which typically has build, implement, evaluate, communicate stages in it. So I don't think there is anything that is unimportant in there.

E: OK. Thank you. Let's go on to the next C, which is coherence. So a summary is coherent if all the concepts and knowledge are well organised and related to each other. So, is this summary coherent? If yes, why? If no, why not?

P3: Now, what you are doing here is you are comparing 3 different approaches in a sense and perhaps it would be easier to understand and also more coherent if you just did it one by one. It's more about clarity perhaps than coherence but it's difficult to see the coherence because the approaches are broken down into component parts and then there is something else in between if you know what I mean. So the presentation doesn't suggest coherence to the degree it could.

E: So it's actually. Just a clarification of how this summary is build up. It's actually - it identified the concepts that are similar and about each of these concepts it then presents where the similarity in each artefact can be found.

P3: Yeah I know I noticed that and I'm looking at the definition. Coherence: A summary is coherent if all concepts and knowledge are well organised and related to each other. So I think the concepts are well organised but since you look at the concepts in terms of 3 different approaches concept by concept it makes it a little - it obscures - the coherence doesn't come across as it could perhaps. And then (???) clarity, so your fourth point.

E: OK. Great. Thanks. So, coherence. Is there any information that might contradict each other or another

information in the summary?

P3: I didn't see any.

E: OK. Yeah. Ok, so let's go on to comprehensiveness. So a summary is comprehensive if it includes all the relevant concepts and knowledge conveyed in an article but also in a multi-document summary. OK, so, do you think this - all the information that should be mentioned in a multi-document summary is available?

P3: Look this is a little bit difficult to answer for me for a simple reason that I don't have all those 3 papers present but I know what's happening here - again you have identified concepts in a rather high level of abstraction and usually as more you abstract away from a certain method in this case it - each concept - each category subsumes a lot of things. So it's not likely that most of you find in those papers fits into some of these categories. So the question then becomes "is it detailed enough?"

E: OK.

P3: If I get really abstract I'm kind of comprehensive but I don't perhaps show important detail anymore.

E: So, what do you think is the right size of such a summary and what should such a summary contain?

P3: That depends on who the summary is written for. If I wanna apply a method like ADR for instance I would certainly require some more information than is provided here. If I wanna just get a rough overview to get an idea of what this is all about this would be appropriate but if you look in the actual paper and what it says about how the very stages interrelate and stuff - so there is more information than you provided in this document obviously. I think the recipient that's what determines the level of detailedness that you want in your summary.

E: OK. OK. Great. Thank you. So then clarity, the second last one. A summary is clear if all concepts and relations can be clearly understood? So can the information in there be clearly understood and if yes, why?

P3: Well, since we are all familiar with DSR it can easily be understood. In terms of clarity I'm not sure if the idea of what you call - what do you call it - a multi something is the best way to do so because you break up each approach into it's component parts and then there is something else in between but I think it will be clearer if you've said look ADR has a problem formulation stage that does this and that and then there is the building an IT artefact and then there is evaluate an IT artefact and then there is communication of the artefact and that is all an iterative process, then say that about the various approaches.

E: So you would split up.

P3: Yeah I want to have one simple summary - not too much formatting so tables and text and headings - so I think that obscures clarity. Simplicity leads to clarity. That's what I want to say. What I mean is parsimonious.

E: OK. So, I don't know. So, what paper do you think, in your opinion, you know - well - what paper didn't you read that much by now? Do you know what I mean?

P3: Yeah I know. The one paper that I read most recently is the ADR paper by Sein and associates.

E: OK. So, when you have a look at for example, soft design science methodology and, I don't know, have a look at a certain stage or have a look at section 2 in general - all these concepts. Do you think the stages in there are clear enough for you?

P3: OK let me have a look at that. So, it starts with problem formulation and you say inspire and create the general problem and the general requirements. I mean, having you know an information systems background, that tells me something - yes. So I would - but construct specific solution - so based on several requirements as in functional requirements identified our constructed specific solution. Then we've got an ex-ante evaluation and an ex-post evaluation so that's before and after implementation - right - and no

we've got a communication of the artefact - it says communication. So I think that's fairly - no what do I want to say - between intuit and abduce the general solution and design of solution ...

E: So that's the iterative process.

P3: Yeah, yeah. So this is fairly abstract and if you ask me so what are to build stages in DSR I would say, ja, you have the problem, you build something, you implement it, you evaluate it and through the evaluation you learn and you would reflect on what you have done, and then you might be able to extract some higher level knowledge. So I think what - so I think this makes sense to me. What I'm perhaps missing is that entire idea of extracting design knowledge. So for instance when you read the ADR paper or also what Peffers and associates write, you'll find something about, well you we tried to learn something about you know designing a specific class of artefacts. So the sort of extraction process of design knowledge - so I think that's missing - but the stages make sense to me but what, you know, when I'm talking about, when I look at DSR; what I find important is that we do design in order to make a contribution to the knowledge base and from my point of view that's the knowledge about design that we are abstracting - so the abstract. And that should perhaps be a stage that I wanna consider. Typically you requested earlier about comprehensiveness, so that's what is missing here.

E: OK. Great. Thanks. Do you think there is any unambiguous information in there? - ah - ambiguous - sorry.

P3: Ambiguous information. I didn't see any. I don't know what happened if I read it like again and again. But I - there again we share a certain life world, you know, in DSR. So we know this sort of terminology so - in my mind.

E: OK. Great. So the last one is correctness. A summary is correct if it doesn't draw any incorrect conclusions including inconsistencies. So, what's your opinion in terms of correctness?

P3: I didn't find anything that I would consider incorrect. No. I would say it's not entirely complete. So perhaps the message that is carried across isn't entirely correct. Because it is also - you know what I said earlier. But no I didn't find anything specifically incorrect in terms of what you say here - no.

E: OK. Great. So. That's it. Just one last question. When you have a look at section 3 - evaluation techniques. Can you comment on clarity here?

P3: Evaluation techniques - OK. So this section discusses evaluation techniques that were used to evaluate the artefacts. Similarities: The utility of all artefacts has been evaluated using retrospective application - that's what you did - All artefacts have been evaluated for compliance of the developed model with published literature - that's what you find in the articles - right?

E: Yeah, so both is about the articles. It's all about the articles.

P3: Then there is all the examples in there and then the differences. ADR has been evaluated using a published research project as well - yes. Not only evaluated - it is actually illustrated using that. ADR used retrospective application to confirm the emergence of the artefact from the interplay between design and ... research evaluation. I think that's - that makes sense. ADR also used retrospective application to confirm the ensemble nature of the artefact and the importance of the BIE cycle. Yeah, I can't really say so much about the SDSM, so let's skip that one.

E: OK so that's fine.

P3: And with DSRM.

E: Sorry there is one typo in there.

P3: Logical reasoning between 7 DSR publications and the process artefact. I think the logical reasoning is

actually what is also used to construct the artefact in the first place isn't it. So I remember that there is the big table where they show how the various approaches sort of fit into their model - right? Don't sure if that's evaluation or also informed their actual construction of the method they are proposing.

E: Yeah. It's back and forth.

P3: And then you have SDSM.

E: No that's DSRM, sorry. That's DSRM, that's a typo.

P3: Yeah. So I think that's all I can say about that at this stage because as I said it's been a while that I read those papers.

E: OK, no, great. I just wanted to have also a statement about the evaluation techniques. So, thanks a lot. OK. great, so that's it. I'm sorry that I took so much of your time and that I asked you again actually to evaluate that but this is actually - the final outcome of my studies is to be create these combined summaries. Well that's not the only one but that's one of the outcomes. So I needed to get an opinion from you on that, so thanks, thanks a lot. Vielen herzlichen Dank.

P3: You are welcome. I guess my key feedback is - try to make it as simple as possible - that is important.

E: Yeah. That makes a lot of sense. OK. Great. Thanks a lot.

P3: Good luck with your study. All the best.