Use of Digital Ecosystem and Ontology Technology for Standardization of Medical Records

Maja Hadzic, University of Technology Sydney
maja.hadzic@cbs.curtin.edu.au
Tharam Dillon, University of Technology Sydney
tharam@it.uts.edu.au
Elizabeth Chang, School of Information Systems, Curtin University of Technology
elizabeth.chang@cbs.curtin.edu.au

Abstract

In this paper, we propose a Medical Records Digital Ecosystem (MRDES) that enables efficient use of medical records for the purpose of correct patient identification, diagnosis, appointments scheduling and the like, in everyday life as well as in emergency situations. Medical Records Digital Environment (MRDE) is populated by interconnected Medical Records Digital Components (MRDC). MRDC are combined together to support creation of a digital infrastructure that will provide standardized use of medical records within various regions, countries and even continents.

If medical records are to be recognized by different digital components at different locations, standardization of data needs to take place. Ontologies can be used for this purpose. Instantiation of the Generic Medical Record Ontology concepts result in Specific Medical Record Ontologies that act as personalized medical records. Ontology files are machine readable and are suitable to be used within MRDES.

One of the key MRDC includes medical record databases that contain personal medical records. Through use of ontologies for standardization of medical records from these different databases, one big virtual database is created that contains medical records of all people. Other key MRDCs are machine-readable personal medical records as well as screening components that read those records. The advantage is that one comprehensive format for the medical records is set within this digital ecosystem and this record can be accessed, read and understood regardless of what country this person is in. This advantage is of especial importance in emergency cases.

The significance of this research lies in the unification of the advances of the ontology technology and ecosystem paradigm for the purpose of establishing worldwide standardization of medical records.

1. Introduction

An electronic medical record (EMR) is a computer-based patient medical record. Use of EMRs has many advantages such as facilitating access of patient data by clinical staff at any given location, building automated checks for drug and allergy interactions, prescriptions, scheduling etc [10].

National Health Service (NHS) in the United Kingdom has been carrying out one of the largest projects for a national EMR. The goal of this project is to have 60,000,000 patients with a centralized electronic medical record by

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2010 [11]. Alberta Netcare project is a large-scale operational EMR system proposed in Canada [12]. Use of electronic medical records by US doctors is increasing slowly. Less than 10% of American hospitals have implemented Health Information Technologies [1], while about 16% of primary care physicians use Electronic Health Records [2].

The development of standards for EMR is at the forefront of the health care agenda. EMRs need to be made interoperable to enable practicing physicians, pharmacists and hospitals to share patient information. This is necessary for timely, patient-centred and portable care. Currently, there are multiple competing vendors of EHR systems each selling a software suite that is mostly not compatible with those of their competitors [10].

There are few standards for EMR systems as a whole. However, there are many standards relating to specific aspects of EHRs and EMRs. These include standards such as ASTM Continuity of Care Record. This is a patient health summary standard based upon XML. Records can be created, read and interpreted by various EHR or EMR systems [3].

Lack of a standard for interoperability among competing software options is one of the major barriers to adopting an EMR system [4]. Ontologies are a shared and formal conceptualization of a specific knowledge and can be used for data standardization [9]. In our case, ontologies can be designed to uniquely describe a personal medical record. The first aim of our project is to use ontologies in order to enable standardization of medical records data. According to the Medical Records Institute [10], five levels of an Electronic HealthCare Record (EHCR) can be distinguished: the automated medical record, the computerized medical record (CMR), the electronic medical record (EMR), the electronic patient record (EPR) and the electronic health record (EHR). As this information is interrelated and clear borders can not be drawn, we believe that medical record information should be kept in one comprehensive format. As ontologies enable information to be expressed on different levels, the second aim of this project is to use ontologies for the purpose of creating a single comprehensive formalized and standardized personal medical record that will contain all of the above mentioned information. One record can be used to uniquely describe the health condition of a person, their medical history, appointment schedules and the like. We believe in the global standardization of medical records. All hospitals, health institutes, patients etc. should work together in order to find mutually supportive roles and move towards this shared vision.

There is a need to design a digital system that will be able to understand the personal medical information from various regions, countries and even continents, especially in emergency cases. For example, the personal medical record of a person living in Australia needs to be recognized, understood, processed and acted upon in cases when this person is travelling overseas. A Medical Record Digital Ecosystem can be designed to provide a framework and infrastructure which allows effective and immediate identification of personal medical records.

It has been proven that effective EMR implementation and networking could save more than $81 billion annually through improving health care efficiency and safety. Those savings could be doubled through health information technology-enabled prevention and management of chronic disease. However, this can not be realized without implementing required changes within the health care system [5].

2. Digital Ecosystem

A digital ecosystem captures the essence of the classical complex ecological community in nature. Digital organisms (such as software or database applications, analogous to biological organisms) together with the digital environment (analogous to the biological environment) form a dynamic and interrelated complex digital ecosystem. Digital ecosystems transpose mechanisms from living organisms like evolution, adaptation, autonomy, viability and self-organization to arrive at novel knowledge and architectures [6].
Digital ecosystems are dynamic, complex and adaptive systems composed of interrelated parts. It interacts with its environment and is subject to resulting feedback effects. A digital ecosystem evolves over time adaptively to fit the pressures imposed on it.
A digital ecosystem transcends the traditional rigorously defined collaborative environment, such as centralized (client-server) or distributed (such as peer-to-peer) models into agent-based, loosely coupled, domain-specific and demand driven interactive communities which offer cost-effective digital services and value-creating activities that attract agents to participate and benefit from it.
A digital ecosystem is defined as a self-organizing digital infrastructure aimed at creating a digital environment for networked organizations that support the cooperation, knowledge sharing and development of open and adaptive technologies [7] and evolutionary domain knowledge rich environments.
The digital ecosystem infrastructure is a digital environment which is populated by digital components [8]. A digital component is any useful idea that is expressed by a formal or natural language. This idea is digitalized and transported within the ecosystem and can be processed by humans or by computers. A digital environment evolves and adapts to local conditions through the recombination and evolution of its digital components.
A digital ecosystem can be specifically developed for the medical community. Medical Records Digital Components (MRDCs) such as personal machine-readable records together with digital components that are able to read those records, populate Medical Records Digital Environment (MRDE). This results in a Medical Record Digital Ecosystem (MRDES). Another important MRDC are medical databases that store all personalized medical records as backup information. The format into which this information is stored is the same regardless in what region, country or continent this medical record database is situated.

3. Medical Records Digital Ecosystem (MRDES)

We believe that the medical community can be supported through optimal use of the information available through machine-readable medical records. This information can be accessed through use of digital components that will screen and read machine readable personal medical records. These personalized medical records are in the form of a medical card. Also, medical record resources contain machine-readable personal medical record information and serve as a backup for this information. These medical record resources can be networked within the system using a digital ecosystem paradigm.
We propose a Medical Record Digital Ecosystem (MRDES) as a Medical Record Digital Environment (MRDE)

populated by Medical Record Digital Components (MRDC). We believe that MRDE may be prototyped on a small region but should eventually be spread globally. MRDC may include various components but the key components should be:

- Medical Record Databases that contain personalized medical records (MRDC1)
- Screening components that read personal medical records (ATDC2). This information may be matched to the available information from the Medical Record Databases
- Machine-readable personal medical records (ATDC3)

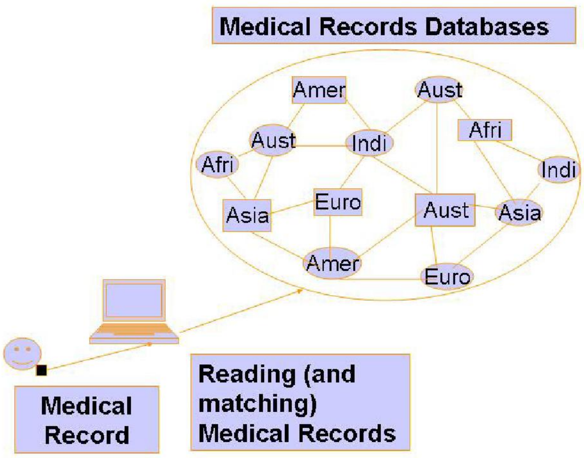

Figure 1: Medical Record Digital Components (MRDC)

In Figure 1, we show the three main components of the MRDES. Different medical records databases from different parts of the world form a network of interrelated parts. This network is conceptually regarded as one big medical record database that contains personal medical records of all humans inhabiting our planet. We call this component MRDC1. The second MRDES component (MRDC2) reads personal medical records from medical cards. This data may be matched against data from the networked medical record databases. Such screening components would need to be present in all hospitals and medical and health care institutions which would be in contact with patients. Also, emergency ambulances need to be equipped with these digital components in order to enable immediate access to patient medical record and make the most optimal decisions. Each person carries its machine-readable personal medical record in a form of a medical card. This is MRDC3 that is read by MRDC2 and may be matched against data from MRDC1.

4. Use of Ontology within ATDES

If the available information is to be unified among various medical record databases and accessed by digital components from various locations, standardization of data needs to take place. Ontologies can be used for this purpose. Moreover, the use of ontologies adds semantics to the model and enables meaningful interpretation of the data.

Medical record ontology can be used to keep personal information in a comprehensive format. Instantiation of the Generic medical record ontology concept results in Specific medical record ontologies that act as personal medical records. Personal records from MRDC3s as well as personal records from MRDC1s are kept in the format of Generic medical record ontology.

In Figure 2, we show the top-level hierarchy of Generic medical record ontology that can be used to represent medical and health knowledge regarding a particular person.

We believe that four main subontologies should be created. The first subontology contains knowledge and information that will help identification of a person (personal information subontology). The second subontology contains information regarding health conditions of that particular person such as regarding diseases this person is suffering from (health conditions subontology). The third subontology contains information about previous and current treatments (treatments subontology). This may be helpful in situations when a doctor is prescribing new drugs and trying to avoid drug interactions. The fourth subontology will contain information about a person's appointments with different doctors and for different purposes. Each of the subontologies is further branched in order to precisely define the required knowledge in regard to personal information, patient's health condition, treatments and appointments. Assigning values and attributes to the concepts of the Generic medical record ontology results in instantiated Generic medical record ontology (or Specific medical record ontologies) that act as personal medical records that uniquely describe health/medical conditions of a person.

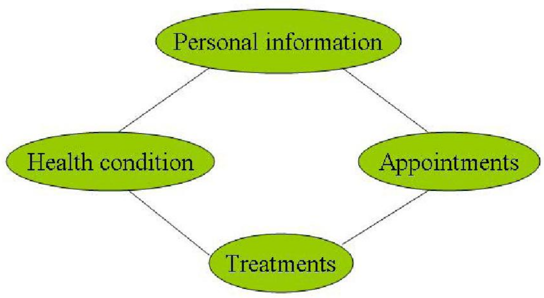

Figure 2: Four subontologies of the Generic Medical Record Ontology

We propose onto-agents as ontology-based intelligent leading software species that have strong reasoning capabilities which can manage, coordinate and collaborate between MRDCs. Onto-agents commit to the common Generic medical record ontology. This means they obey the agreement with respect to the semantics of the concepts and relationships defined in the ontology and agree to use the shared vocabulary in a coherent and consistent manner [9]. Because ontologies are stored as machine-readable files, onto-agents can read personal records defined as ontology files in MRDC3s making this information available for the user. Onto-agents can also do the matching of this information with the available medical records defined as ontology files in networked Medical Records Databases (MRDC1s) and to take actions according to the results.

5. Privacy Issue within MRDES

The privacy issue associated with access and manipulation of personal data from medical records is not to be neglected within MRDES. One way to deal with this issue is to authorize the use of MRDCs, in particular screening components (MRDC2) and medical records databases (MRDC3). Only authorized persons will posses screening devices. Furthermore, access to the medical record can be limited depending on the screening purpose. For example, the system may be designed in such a way that in order to access the information represented by the four different subotologies (personal information, health condition, treatments and appointments), four different accesses are needed. Some authorized people will have access to all four subontologies while others will have limited access. For example, a receptionist just needs access to the appointments subontology. Furthermore, within each subontology, access may be further limited. For example, a receptionist does not need to access information regarding previous appointments in order to book the next appointment. So, her/his access to the appointments' ontology may be further limited. We can see on this example that the hierarchical ontology structure supports not only data standardization and structuring but also brings in a better control over authorized data access. The same applies to the access of the medical records databases (MRDC1). Access to this information may be limited in accordance with person's task within the system. Moreover, records of each system access and use needs to be kept for referencing purposes.

6. Discussion and Conclusions

We proposed an ontology-based Medical Records Digital Ecosystem (MRDES) to provide an infrastructure for standardized and global use of medical records. This organization network activates a virtuous circle through dynamic integration of three key Medical Records Digital Components (MRDCs): the MRDC1 component embraces different medical record databases scattered around world that contain personalized medical records, the MRDC2 component reads personal records and possibly matches this data with personal records from MRDC1 while the MRDC3 component contains machine-readable personalized medical records. We use Generic medical record ontology to keep the medical information in a comprehensive format. Instantiation of the Generic medical record ontology concepts results in Specific medical record ontologies that act as personalized medical records.

The significance of the research lies in the unification of the advances of the ontology technology and ecosystem paradigm for the purpose of efficient use and global standardization of medical records.

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