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Assessment of mechanical engineering final year projects using Fuzzy Multi-Attribute Utility Theory

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This paper presents an assessment method for the final year project theses of mechanical engineering students using Fuzzy Multi-Attribute Utility Theory (FMAUT). With the aid of FMAUT, the opinions of all the relevant staff members for thesis assessment are utilised to form an expert database. Final year theses are marked by two assessors using the current scoring rubric. The ratings given by the supervisor and assessor are conveniently converted into the final thesis mark with the aid of the developed approach, with the aim of reflecting the opinions of all the relevant staff members without increased workload. The advantages are increased clarities and reduced discrepancies. An example is given to illustrate the approach.

Keywords: Final year project, assessment, Multi-Attribute Utility Theory

Introduction

The Mechanical Engineering Course is one of the undergraduate courses offered by Curtin University. Each student must finish a project in the final year of the study on an individual basis, that is, one one project for one student. This project, which is called the final year project (FYP), is a systematic study and execution of an engineering problem, carried out to fulfil certain objectives. The entire work is done during a two semester period, and a thesis, which is also called the project report, is written. Each project is assessed based on three major components: thesis (45%), overall student competency (35%), and oral presentation (20%). The thesis component will be assessed by two assessors, one of which is the supervisor, and the other a staff member who is familiar with the specific area of the project.

The FYP contributes a substantial part of the overall assessment of each student. It can be regarded as a showcase of a student's four-year study and is important and useful in job interviews. Because of these, unbiased assessment is needed. Marks given by the supervisor and the other assessor are very important as they contribute a total of 80% of the final project mark. If there is a large difference between the supervisor mark and the assessor mark, the final project mark will not truly reflect the performance of the student.

Assessment of the FYP has always been an important issue in the engineering undergraduate program. Teo and Ho (1998) presented a systematic mechanism for the management of FYP, including project allocation, streamlined assessment using grading category, and the automated processing of marks. Tariq, Stefani, Butcher, and Heylings (1998) introduced a more objective, criterion-referenced project assessment scheme to replace the old subjective assessment scheme. Chan (2001) found from a statistical analysis that the reason for the discrepancies between the supervisor and assessor in project assessment was due to the excessively low marks given by the assessors. Woods and Chan (2003) presented a comparison of two quantitative methods of determining rater bias. Statistical analysis was also conducted by Karazi, Brabazon, Smyth, and

Molloy (2008). Henderson, Guijt, Breadmore, Carew, and Guijt (2009) found that inter-rater disagreement was likely regardless of guidelines, and that inter-rater agreement was improved for assessment teams composed of the same discipline. Assessment guidelines must clearly define all assessment criteria to avoid ambiguity and subjectivity. However, because of the variety of mechanical engineering projects and the significant human factors in the marking, it is difficult to achieve consistent and unbiased assessment.

In this paper, an assessment method based on Fuzzy Multi-Attribute Utility Theory (FMAUT) is presented, with the objectives of increasing the clarities and reducing the discrepancies in the assessment of mechanical engineering final year project theses. By using this method, a database can be developed that incorporates the expertise and opinions of all relevant staff members, with which the discrepancies in marking a final year project thesis can be minimised.

Approach

Overview

The complete FMAUT mark estimation process is shown in Figure 1. A database is developed that incorporates the expertise and opinions of all relevant staff members. The input ratings are converted to utility values based on MAUT. The mark index is obtained using the fuzzy algorithm, and the final mark is obtained using a regression model.

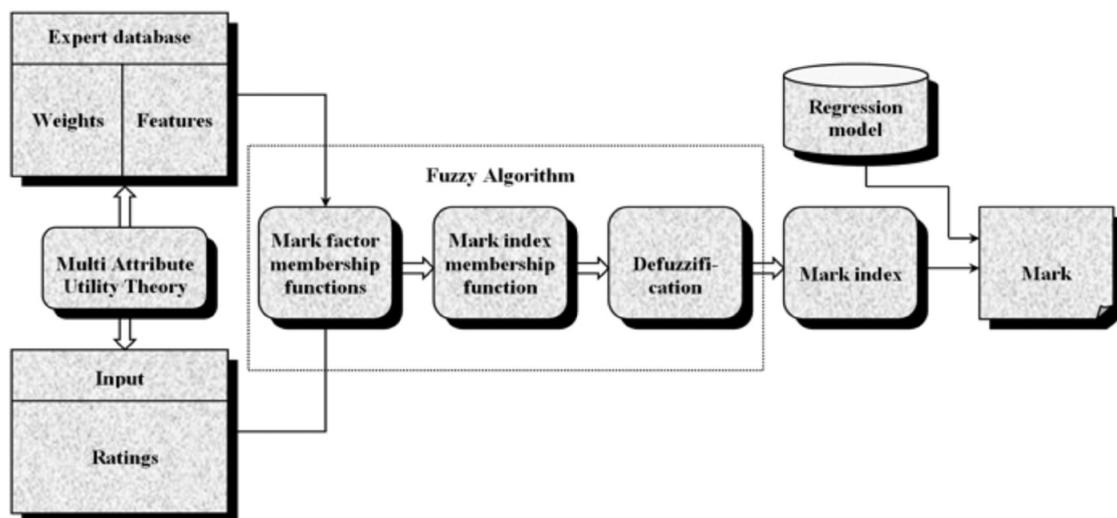


Figure 1: FMAUT mark estimation

Multi-Attribute Utility Theory (MAUT)

According to our current marking scheme, a FYP thesis is assessed from the following five aspects: technical content, grammar and readability, difficulty level, overall presentation and scientific merit. Each aspect is marked from 0 to 100 and the total marks are obtained by taking the average. When Utility Theory is used, these quantitative items can be regarded as attributes and the overall mark is determined by these attributes. The theory is then called Multi-Attribute Utility Theory (MAUT).

Each attribute can be set to several levels. A higher level has more contribution to the overall mark than a lower level, provided that all other attributes are fixed. When MAUT is used, a utility value is assigned to each level, which reflects its influence extent on the overall mark. A higher level has a larger utility value. In order to establish these values, an expert database is needed. This can be done by collecting data and using the experts' experience. With the utility values of each attribute, attributes can be compared and integrated. Therefore, a general utility value, called mark index (MI), can be obtained by combining utility values of all attributes. This mark index can reflect the actual mark.

Given the attributes, levels for each attribute need to be determined. The number of levels may vary from one attribute to another. However, in this study, for the assessment of FYP theses, five levels for each attribute are used following Likert Scale, that is, excellent, above average, average, below average and poor.

The next step is to assign utility values to the defined feature levels. Experts do not assign the utility value for each level directly. The value of the lowest level for each attribute, given by experts, always equals to 1, that is, $u_{i1k} = 1$ always holds true. The values for other levels are established according to the magnitudes compared to that of the lowest level.

These raw values are then converted into utility values by dividing the values of the highest level for each attribute:

$$U_{ijk} = u_{ijk} / u_{imk} \quad (1)$$

After this transformation, utility values are between 0 and 1. The characteristic of utility values makes it easier for later combination of utility values for individual attributes. The combined general utility values for all attributes can be considered as the mark index.

It should be noted that to correctly reflect the real situation, the importance of each attribute should not be equal. Therefore, a weight, which indicates the influence of each attribute on the mark, is given to each attribute in the mark model. The sum of the weight values for all attributes is 1, that is:

$$\sum_{i=1}^m w_{ik} = 1 \quad (2)$$

In order to compare design alternatives, multi attribute decision-making should integrate the utility values for each attribute into one general utility value – mark index. Without fuzziness, comparison and integration of the utility value for each attribute can be easily done with Multiplicative Utility Model (Keeney & Raiffa, 1996).

$$U(X) = \frac{\prod_{i=1}^m [W \cdot w_i \cdot U_i(x_i) + 1] - 1}{W} \quad (3)$$

$$1 + W = \prod_{i=1}^m (1 + W \cdot w_i) \quad (4)$$

$U(X)$ is a function of vector X . It means that $U(X)$ depends on the feature level of each attribute.

Fuzzy Multi-Attribute Utility Theory (FMAUT)

In FMAUT, w_i and $U_i(x_i)$ are fuzzy and are expressed by membership functions instead of real numbers. Thus, the result $U(X)$ is fuzzy and is expressed by membership functions of mark index instead of a general utility value (Ting, Zhang, Wang, Deshmukh, & DuBrosky, 1999).

The opinions about utility values may vary from one expert to another. Utility values are also vague and fuzzy. Therefore, a membership function for each level of an attribute should be defined in such a way that it will reflect the experts’ opinions about the utility values. For a triangular membership function, the minimum and maximum utility values for each level given by the experts form the two bottom points, and the average of the utility values form the top point. The following operations should be done for each level of an attribute.

$$\begin{cases} TL_{ij} = \min (U_{ijk}) \\ TM_{ij} = \sum_{k=1}^l U_{ijk} / l \\ TU_{ij} = \max (U_{ijk}) \end{cases} \tag{5}$$

The membership grades for utility values TL_{ij} and TU_{ij} are 0; the membership grade for utility value TM_{ij} equals to 1. This is based on the assumption that among the utility values given by the experts, the average of the values is more likely to denote the feature level than the minimum value or maximum value.

Membership functions for all feature levels of all attributes, based on experts’ experience, are stored in the model. For a thesis, if the levels for each attribute can be identified, the corresponding membership functions can be retrieved. A membership function is established for each attribute. These membership functions are combined together to make a membership function of the mark index.

Similar to the utility values of feature levels, weights can be expressed in the form of membership function because of their fuzziness. Experts give the weights $(w_{i1}, w_{i2}, \dots, w_{il})$ for attribute i , membership function of weight for attribute i can be constructed as follows.

$$\begin{cases} WL_i = \min (w_{ik}) \\ WM_i = \sum_{k=1}^l w_{ik} / l \\ WU_i = \max (w_{ik}) \end{cases} \tag{6}$$

WL_i, WU_i are the two bottom points of the membership function with a membership grade equal to 0 and WM_i is the top point of membership function with membership grade equal to 1. The result $U(X)$ is fuzzy and is expressed by the membership function of the mark index instead of a general utility value as

$$\mu(U(X)) = \frac{\prod_{i=1}^m [W \cdot \mu(w_i) \cdot \mu(U_i(x_i)) + 1] - 1}{W} \tag{7}$$

$$1 + W = \prod_{i=1}^m (1 + W \cdot w_i^{\max}) \tag{8}$$

The membership function of the mark index describes the relationship between the membership grade and general utility value (mark index). In order to obtain the quantitative MI, the MI membership function needs to be defuzzified. Two defuzzification methods are commonly used: Centre of Area (COA) Method and Centre of Maximum (COM) Method (Hellendoorn & Thomas, 1993).

In the COA method, the centre of the membership function is considered to be the expected MI. For triangle membership functions, it is the centroid of the triangle. In the COM method, the average of the minimum and maximum utility values is considered to be the expected MI. Usually, the results from the two methods are very close.

Conversion of mark index to mark

Since a thesis will be assessed by the supervisor and the assessor, the total MI is given by

$$\begin{matrix}
 & 1.2 & & & & \\
 \text{value} & \left\{ \begin{array}{l} \text{Poor} \\ \text{Below} \\ \text{average} \\ \text{Average} \\ \text{Above} \\ \text{average} \\ \text{Excellent} \end{array} \right. & & & & \\
 & \uparrow & & & & \uparrow
 \end{matrix} \tag{9}$$

where *p* is the percent contribution of the supervisor: this is usually around 50%.

After MI is obtained, it needs to be converted into the actual mark. This is usually done using a regression model.

An example

An example is used to illustrate the effectiveness of this approach. The opinions of five staff members were used to develop the expert database. Based on the utility values, the membership functions are derived. The lowest and highest MIs are achieved when all the attributes are rated to be poor (1) and excellent (5), respectively. When the technical content is rated to be poor, below average, average, above average and excellent, the membership functions are shown in Figure 2. The weight membership functions for all the five attributes are given in Figure 3.

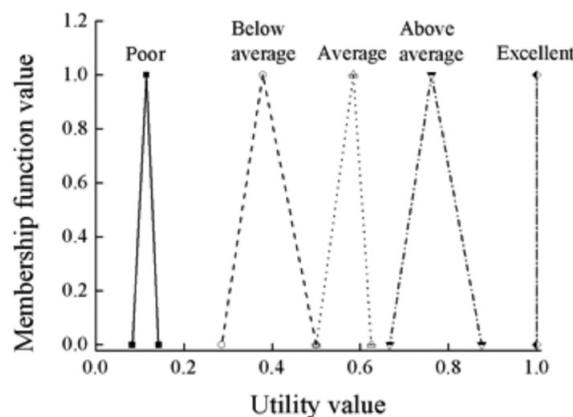


Figure 2: Membership function for average technical content

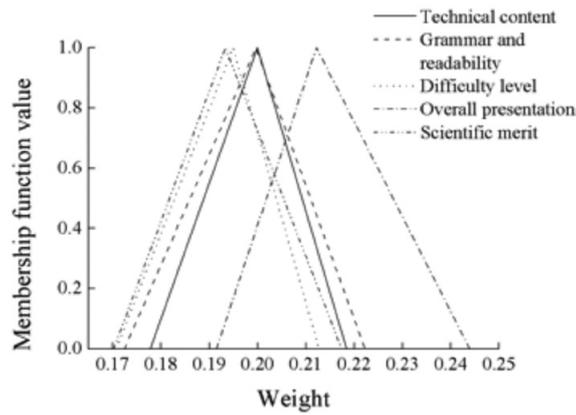


Figure 3: Weight membership functions

The MIs are calculated from the ratings using the membership functions. The membership functions for the lowest and highest MIs are shown in Figure 4. After defuzzification, the MIs are obtained.

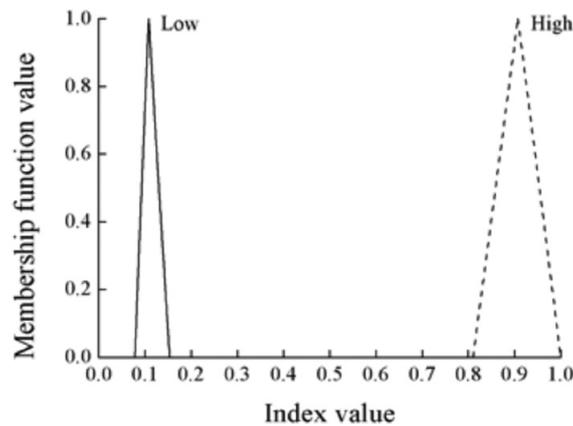


Figure 4: Membership functions for the lowest and highest MIs

The actual mark is related to MI by fitting the data to a regression model. A power model was chosen, which is given by

$$G_t = 105.6MI^{0.8} \tag{10}$$

As an example, the ratings and final mark of a thesis is given in Table 1.

Table 1: Ratings and final mark of a thesis

Item	Supervisor	Assessor
Technical content	4	2
Grammar and readability	4	3
Difficulty level	3	4
Overall presentation	4	3
Scientific merit	4	2
MI	0.74	0.57
Total MI ($0.5MI_s + 0.5MI_a$)	0.66	
Mark ($105.6MI^{0.8}$)	75	

Conclusions

This paper presents an innovative objective assessment method for the final year project theses of mechanical engineering students using FMAUT. With the aid of FMAUT, the opinions of all the relevant staff members for thesis assessment are utilised to form an expert database. The ratings given by the supervisor and assessor are conveniently converted into the final thesis mark with the aid of the developed approach. The advantages are increased clarity and reduced discrepancies between assessors.

Nomenclature

G_t	actual thesis mark
l	number of experts
m	number of attributes
n_m	number of levels for attribute m
MI	mark index
TL_{ij}	the lowest utility value of the membership function for level j of attribute i
TM_{ij}	the utility value of the membership function with membership grade equal to 1
TU_{ij}	the highest utility value of the membership function for level j of attribute i
$U(X)$	general utility value, mark index
$U_i(x_i)$	utility value of attribute i at level x_i
u_{ijk}	utility value defined for level j of attribute i by k th expert
W	scaling factor
WL_i	the lowest utility value of the membership function for the weight of attribute i
WM_i	the utility value of the membership function with membership grade equal to 1 for the weight of attribute i

WU_i	the highest utility value of the membership function for the weight of attribute i
w_i	weight for attribute i
w_i^{max}	max weight value among five weights given by experts for attribute i
X	vector $X = (x_1, x_2, x_3, \dots, x_i, \dots, x_m)$
x_i	specific feature level for attribute i
$m(U(X))$	membership function of mark index
$m(w_i)$	membership function of weight for attribute i
$m(U_i(x_i))$	membership function of utility value for attribute i

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