Hierarchical Fuzzy Rule-Based Model for Teaching Performance Evaluation

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ABSTRACT

The evaluation of teaching process in Higher Leaning Institutions (HLI) is an important policy for measuring teaching performance. The output of this process has two primary purposes - teaching improvement and administrative decision making. Nevertheless, two issues have been raised; the instrument characteristic used to gather the values and the technique used in handling the survey data. In traditional practice, the ordinal scale is used for schematic marking and statistical technique was implemented to analyze the data. In this research, a hierarchical Fuzzy Rule-Based (FRB) model was designed for teaching evaluation process. This model incorporates an alternative way of thinking, which allows modeling complex systems using a higher level of abstraction originating from human knowledge and experience. It is argued that FRB approach is more flexible and may deal with imprecise data better. A hierarchical model for teaching evaluation considers the possible factors that influence a teaching evaluation weigh age. To ensure reliability and validity of output, the knowledge extraction must be done precisely with teaching and learning domain expertise. From this study, it is expected that the implementation of FRB system will provide an alternative way in handling various kind of approximate data in teaching evaluation.

Keywords: *Fuzzy Rule-Based, Teaching Evaluation, Membership Function Graph, Fuzzy Associative Memory*

1.0 INTRODUCTION

Computer technologies have becomes a need in today's world. The innovations of the high technologies give much contribution in assisting human activities especially in decision making process. For example, one of the applications is to facilitate administrators in performance evaluation. However, an application which accepts data as it is will not provide the needed output by the decision makers.

For instance, in evaluating instructor's teaching performance, it usually consists of several components in which each involved a number of judgments often based on imprecise data. The most used instrument in the evaluation is OMR forms with selection of ordinal scales answers. This imprecision arises from human judgment where human (*evaluator*) attempts to evaluate other human (*instructor*) performance. Arithmetical and statistical methods have been used for aggregating information from these assessment components. These methods have been accepted widely especially in many higher educational institutions although there are limitations to these traditional approaches.

Basically, there are two primary purposes for implementing the teaching evaluation process, namely administration decision making and teaching improvement

(McKeachie, 1997). The evaluation process are often involves complex steps and the outcome is a number that sometimes represent at the most, a rough ordinal level of the attribute. Michele *et al*. (2004) raises two issues related to the teaching evaluation process:

i. The characteristics of the instrument used to detect the values, and
ii. The techniques in handling the survey data, both of which depend on the specific attribute or context.

They argued that the current method of evaluating and categorizing instructor teaching performance using arithmetical and statistical techniques does not necessarily offer the best way to evaluate human performance and skills. Since the judgment may involve approximated data and linguistic terminology, therefore a method that can handle such kind of data is needed. One of the methods is Fuzzy Rule-Based (FRB). It is expected that reasoning based on FRB model will provide an alternative way of handling various kinds of imprecise data, which often reflects the way people think and make judgments.

The rest of the paper organized as follows. Section 2.0 present the related work about the Fuzzy Logic (FL), FRB and also the application of those approach. Section 3.0

describes the method and implementation of this proposed model. Section 4.0 discussed the results and findings that was achieved and finally, Section 5.0 will discusses and summarizes the done up to now and the contribution of the paper.

2.0 RELATED WORK

Fuzzy Logic (FL) is an extension of crisp two-state logic that provides a platform for handling imprecise knowledge. FL use fuzzy set that offers a set without sharp boundaries membership characteristics (Howard, 2005). The applications of FL rely on the representation and processing of knowledge using FL. Since human's judgment and reasoning are flexible, the information gathered may not be complete and may contain approximate value. Apart from that, in much real world application, fuzzy systems that make use of linguistic rules are appropriately suited to describe this natural behavior which is difficult to model mathematically (Zadeh, 1988). FL was primarily designed to represent and reason with some particular form of knowledge and is widely used in decision-making to cope with uncertainty. FL is a form of knowledge representation which is appropriate for notions that cannot be defined precisely, however, it depends upon its context. The linguistic symbols in a Fuzzy Rule-Based (FRB) approach facilitate the modeling of complex functions while retaining to a degree of human interpretability. However, a model clearly interpretable by humans often leads to a reduction in accuracy. Consequently, FRB concept was used to handle these inaccurate data.

Within thirty years, FL had developed from an abstract extension of conventional logic into a field with a whole range of practical applications. FL was employed in diverse engineering applications ranging from mass market consumer products to sophisticated decision and control problems. It is also applied most widely especially in the industrial systems control. This field deals with very complex, uncertain and cannot be modeled precisely, even under various assumptions and approximations. In addition, FL works well in systems that are non-linear, with irregular or multiple inputs or have conflicting constraints.

Salwa Ammar and Wright (1995) explored a fuzzy approach in performance evaluation. That study was aimed to observed information about client satisfaction and the use of FL to analyze the inherently imprecise data. As a result, they found that FRB system allows for more reliable and consistent interpretation of results. It also permits flexibility in analyzing the results. In advance, FRB comply with the membership ranges where it can be easily changed for any of the fuzzy sets. Moreover, the fuzzy rules can be modified to match different situations.

Apart from the wide range application of FL based in other domain (*i.e. transportation and manufacturing)*, fuzzy application in teaching environment also had created its niche. Michele *et al*. (2004) developed a fuzzy system for teacher and course evaluation model. The hierarchical model consists of 8 questions which cover internal factors that may have an effect on the teaching performance evaluation. This study was carried out to improve the statistical approach used in the existing teaching evaluation process. The traditional analysis results were compared with the fuzzy system result. Beside that, this research also performs various techniques for implementing the general schema of fuzzy model. The fuzzy system yields scores that are proven to be generally higher than those obtained using existing scale. Nevertheless, the principle of learning evaluation was not involved in this study. It is also stated that the procedure used in this study is simple and is similar to ordinary ordinal scale procedure. Therefore, it is suggested that an improvement and extension to other social context is to be made. Moreover, the determination of membership function and fuzzy rules generation relies much on human expert and experience. However, fuzzy system shows that it could be a valid and reliable tool to represent situation described by qualitative ordinal variables.

3.0 METHOD AND IMPLEMENTATION

The design of fuzzy system mainly involves two operations of knowledge base derivation and the selection of the fuzzy inference process to perform the fuzzy reasoning (Cordon, *et al*. 1999). The successful development of a fuzzy model for a particular application domain is a complex multi-step process, in which the designer is faced with a large number of alternative implementation strategies (Garibaldi and Ifeachor, 1999). Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. The advantage of fuzziness dealing with imprecision fit ideally into decision systems. The vagueness and uncertainty of human expressions are well modeled in the fuzzy sets and a pseudo-verbal representation, similar to an expert's formulation, can be achieved (Hasiloglu, *et al*. 2003). A general scheme of a fuzzy model based on the environmental variables is shown in Figure 1.

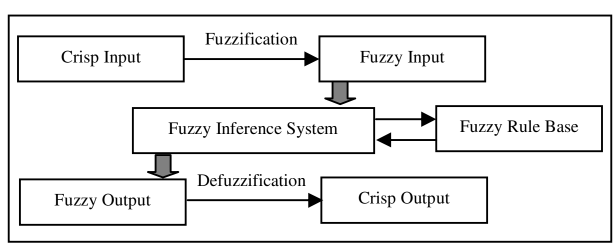

Figure 1: General Scheme of Fuzzy Model

Basically, the proposed hierarchical Fuzzy Rule-Based (FRB) model will become the main output of this study. The model covered four main principles that may influence the teaching evaluation process where each principle consists of several corresponding questions with ordinal selection answers.

3.1 Principles of a Teaching Evaluation

There are four main principles that are considered for teaching evaluation process.

Table 1: Selected Principle of an Evaluation

1	**Preparation**	i. Discussing teaching activities plan and assessment clearly (TAP) ii. Exhibited knowledge of the subject (EKS) iii. Well prepared for teaching session (PTS)
2	**Organization**	i. Teaching material and resource were helpful (TMR) ii. Using effective learning aids during the teaching period (ELA) iii. Teaching activities provided relevant learning experiences (RLE)
3	**Delivery**	i. Gave clear explanations and provided extra teaching materials (EEM) ii. Using various and effective teaching techniques (ETM) iii. Accessible for consultation hour (ACH) iv. Encouraged student's participations and interaction in teaching activities with enjoyable and supportive atmosphere (PIS) v. Stimulated student's interest in learning topics (SLT)
4	**Effectiveness**	i. Showed enthusiasm and concern for encouraging student learning (ECE) ii. Guided to achieve the understanding of subject matter (GAU) iii. Correspondence between actual and planned teaching activities (CAP)

Each principle contains several questions and each question has five choices of ordinal scale answers. The choices of the answer includes *very insufficient, insufficient, sufficient, good* and *excellent*. Table 1 shows the principles of an evaluation and the corresponding questions.

3.2 The Fuzzification Phase

This study utilizes a hierarchical fuzzy inference approach based on teaching evaluation principles. This principles comprises of four criteria; namely *Preparation, Organization, Delivery* and *Effectiveness*. Table 2 shows the input and output variables.

In the *Fuzzification* phase, Membership Function Graph (MFG) will be used to map the elements of input variable on to numerical values in the interval [0, 1]. The x-axis represents the variable while the y-axis represents the confidence value ranges from 0 to 1.0.

The *Trapezoidal Function* was used to represent the linguistic variable. Beside the main evaluation principles and the output, there are two intermediate output call *Pre_Output_1* and *Pre_ Output_2*. The output from each level will be an input value for the next level of fuzzy inference.

Table 2: Input and Output Labels

FUZZY VARIABLES		**LINGUISTIC TERM**
INPUT	**Preparation**	€ {very insufficient, insufficient, sufficient, good, excellent}
	Organization	€ {very insufficient, insufficient, sufficient, good, excellent}
Level_1	*Pre_Output_1*	€ {very insufficient, insufficient, sufficient, good, excellent}
	Delivery	€ {very insufficient, insufficient, sufficient, good, excellent}
Level_2	*Pre_Output_2*	€ {very insufficient, insufficient, sufficient, good, excellent}
	Effectiveness	€ {very insufficient, insufficient, sufficient, good, excellent}
OUTPUT ***Level_3***	**Teaching Performance (*Final Output*)**	€ {very insufficient, insufficient, sufficient, good, excellent}

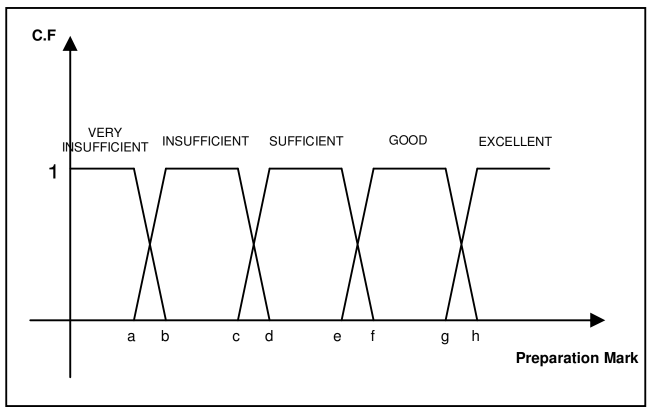

Figure 2: Membership Function Graph for Label of ***Preparation***

Figure 2 shows an example of MFG for *Preparation* developed by cumulating a total mark of the selected answer for those questions of each principle.

3.3 Fuzzy Inference Phase

A fuzzy inference engine resembles human reasoning in its use of approximate information and uncertainty to generate decisions. The most commonly used fuzzy inference technique is so-called *Mamdani* method (Mamdani and Assilian, 1975). It consists of rules, facts and conclusions. The fuzzy production rules connect premises with conclusions, condition with action. In this inference, expert's knowledge and experience were acquired and formulated accordingly to develop the appropriate rule to perform the system.

Table 3: General Structure of Static Fuzzy Associative Memory (FAM) Table

Input_1 vs. Input_2	Very Insufficient	Insufficient	Sufficient	Good	Excellent
Very Insufficient	LT_1	LT _2	LT _3	LT _4	LT _5
Insufficient	LT _6	LT _7	LT _8	LT _9	LT _10
Sufficient	LT _11	LT _12	LT _13	LT _14	LT _15
Good	LT _16	LT _17	LT _18	LT _19	LT _20
Excellent	LT _21	LT _22	LT _23	LT _24	LT _25

Note: LT represents Linguistic Term

The fuzzy inference can be implemented using the *if-then* statements or Fuzzy Associative Memory (FAM) which is a sub task in *Fuzzy Inference* phase. There are two types of FAM table; the Static and the Dynamic FAM tables. The Static FAM table will represent a set of facts that was clearly defined during the knowledge acquisition task. It is illustrated by using matrix table as an example of general FAM table as illustrate in Table 3. In addition, *Preparation versus (vs.) Organization, Pre_Output_1 vs. Delivery* and *Pre_Output_2 vs. Effectiveness* matrix table should clearly justify. Static FAM table represents a rule such as

IF Input_1 = *sufficient* and
Input_2 = *excellent*
THEN Output = *LT_15*

This fuzzy rule determines the decision embedded into the system engine and should be validated from domain expert. Moreover, the human linguistic term involves in fuzzy rules enable the human-like fuzzy reasoning.

On the other hand, the Dynamic FAM table represents the minimum confidence value (*using AND operator*) for each matrix condition. W_x will represent the minimum value of each selected combination. Equation 1 represents the minimum value calculation.

$W_x = min\ \{Input\_1, Input\_2\}$ …… (Equation 1)

Table 4: General Structure of Dynamic Fuzzy Associative Memory (FAM) Table

nput_1 vs. Input_2	Very Insufficient	Insufficient	Sufficient	Good	Excellent
Very Insufficient	W_1	W_2	W_3	W_4	W_5
Insufficient	W_6	W_7	W_8	W_9	W_{10}
Sufficient	W_{11}	W_{12}	W_{13}	W_{14}	W_{15}
Good	W_{16}	W_{17}	W_{18}	W_{19}	W_{20}
Excellent	W_{21}	W_{22}	W_{23}	W_{24}	W_{25}

Table 4 shows the general structure of Dynamic FAM table. It will be used for all inference levels. FAM matrix represents far fewer rules and much easier to deal with. The FAM table stores the confidence value which is calculated previously in the *Fuzzification* phase. The confidence values in the FAM depend on the fuzzy operator used in the fuzzy rules. There are three basic Fuzzy Logic operators which are AND, OR and NOT. Table 5 shows the example of general combination between both tables.

Table 5: Combination of Static and Dynamic FAM Table

Input_1 vs. Input_2	Very Insufficient	Insufficient	Sufficient	Good	Excellent
Very Insufficient	LT _1	LT _2	LT _3	LT _4	LT _5
	W_1	W_2	W_3	W_4	W_5
Insufficient	LT _6	LT _7	LT _8	LT _9	LT _10
	W_6	W_7	W_8	W_9	W_{10}
Sufficient	LT _11	LT _12	LT _13	LT _14	LT _15
	W_{11}	W_{12}	W_{13}	W_{14}	W_{15}
Good	LT _16	LT _17	LT _18	LT _19	LT _20
	W_{16}	W_{17}	W_{18}	W_{19}	W_{20}
Excellent	LT _21	LT _22	LT _23	LT _24	LT _25
	W_{21}	W_{22}	W_{23}	W_{24}	W_{25}

Note: LT represents Linguistic Term

3.4 Defuzzification Phase

The *Defuzzification* phase transforms the fuzzy value into crisp value. *Defuzzification* involves finding a value that best represents the information contained in the fuzzy set. The *Defuzzification* process yields the expected value of the variable for a particular execution of a fuzzy model. This process will be implemented on each hierarchical level including intermediate output and final output level.

There are a number of Defuzzification methods such as *Centre of Gravity*, *Centre of Sums* and *Mean of Maxima*. However, the system in this study only focuses on centre of gravity technique (Cox, 1994). The implementation of gravity technique is as modeled in equation 2.

$$\mu^* = \frac{\sum_{i=1}^{n} u_i * \mu_{out}(u_i)}{\sum_{i=1}^{n} \mu_{out}(u_i)}$$ …. (Equation 2)

4.0 RESULTS AND FINDINGS

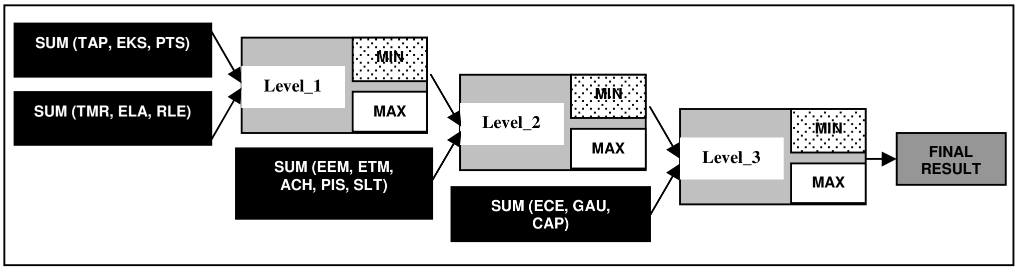

Figure 3: Hierarchical Fuzzy Rule-Based Model Architecture for Teaching Performance Evaluation

This section discusses mainly about the general architecture of proposed hierarchical Fuzzy Rule-Based (FRB) model and Figure 3 shows the Hierarchical FRB Model Architecture for Teaching Performance Evaluation.

Hierarchical FRB model design considers the possible factor that may influence the teaching performance results. The quality of the teaching evaluation results may be better and more reliable. As discussed in previous section, there are four principles parameters that become an input for this proposed model, namely *Preparation, Organization, Delivery* and *Effectiveness* and each of them consists of corresponding questions with five selections of an ordinal scale answers; *very insufficient, insufficient, sufficient, good* and *excellent*. The input value actually can be observed from existing evaluation system. However, this study only focuses on the fuzzy system engine and assumed that the previous system can be used as usual. The current evaluation tool (*ordinal scale form*) must be modified by dividing it into four sections and each section contains the corresponding questions.

This hierarchical FRB proposed model is divided into three levels which each level deals with couples of inputs. Beside that, there are two intermediate levels for pre result computation and a level of final result computation. The couple of input ranges between *Preparation versus (vs.) Organization (Level_1), Pre_Output_1 vs. Delivery (Level_2)* and *Pre_Output_2 vs. Effectiveness (Level_3)*. In addition, *Level_3* will produce the final result that will classify the instructor's perform to corresponding band. The results may be more accurate and of high quality as compared to conventional computation.

5.0 DISCUSSION AND CONCLUSION

This study focuses on the development of hierarchical Fuzzy Rule-Based (FRB) architecture model for performing a teaching performance evaluation process in higher learning institutions. The model emphasizes on the mapping of uncertainty data in performance measurement system which convert the data into fuzzy values that consist of labels and confidence values. The mapping process must be established first, in order to avoid erroneous membership function and rules being chosen which in turn may yield a flawed output. Moreover, FRB approach is a flexible technique for handling teaching's performance evaluation and presenting less problems regarding measurement methodology. Hence, FRB approach could be used as a link or a bridge between qualitative and quantitative analysis where it can homogeneously handles different elements to produce the numerical values. These values can be used in validating the developed procedure.

Furthermore, this new approach will have several benefits as compared to the current traditional arithmetical and statistical methods. First, with the development of FRB system, which is based on hierarchical FRB model, it offers more reliable and valid values for judging and categorizing an instructor according to the actual performance band. In turn, this system will produce more accurate teaching's performance evaluation as compared to human judgments. The output of this system can be used by top management as a basis for decision making relating to instructor's teaching performance and changes in institutional policy.

Second, fuzzy terms can be used to represent teaching performance evaluation that involves the measurement of capability, knowledge deliverables, know-how and skill. This is possible since FRB approach has the ability to imitate the way human make decisions i.e. by using linguistic reasoning. On the other hand, reasoning based on fuzzy approach offers another way of handling imprecise data, especially in making decisions and judgments. This shows that FRB application can be used as a platform for evaluating teaching performance in order to produce the valuable and quality results.

For further study, this system may be implemented using a web based version and incorporate suggested evaluation values. Furthermore, others artificial intelligence techniques can be used in this kind of application. For instance, expert system may be used to enhance the explanation facilities or neural network technique to forecast the potential of instructor's performances. Hence, it is important to note that the aim of the proposed system is not to replace the current system of evaluating performance but it may be used to strengthen and improve the present system of evaluation by providing additional information for appraiser to make decision in teaching performance evaluation and management of resources in an organization.

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