SUBJECTIVE DECISION MAKING IN STUDENTS' ASSESSMENT USING TYPE-2 FUZZY LOGIC ADVISOR

M. A Owais
Computer Science & Engineering Department, King Fahd University of Petroleum and Minerals
Hafr Al-Batin College, P.O Box# 1803, Hafr Al-Batin, 31991, Saudi Arabia
mowais@kfupm.edu.sa

Keywords: Student Evaluation, Fuzzy Logic, Uncertainty, Cooperative Training, Senior/Capstone Project, Type-2 FLA.

Abstract: In this paper, we present and compare two-stage type-2 fuzzy logic advisor (FLA) to evaluate the students' performance in domains where subjective decisions are made. We test our proposed model for evaluating students' performance in Computer Science Department in two domains namely cooperating training and senior project assessment where we find these FLAs very useful and promising. In our proposed model, the assessment criteria for different components of cooperative training and senior project are transformed into linguistic labels and evaluation information is extracted into the form of IF-THEN rules from the experts. These rules are modelled using FLS, which then is used as a fuzzy logic advisor (FLA) to make decisions about students' grades. The evaluator's input for the system can be either singleton or non-singleton. Both type-1 and type-2 fuzzy logic based models are implemented and compared with individual expert's evaluation.

1 INTRODUCTION

A student's learning performance is measured by some evaluation means in all sorts of teachings. A student's evaluation is the process by which all relevant data about a student's work are collected and transformed into information for decision making (Cooley and Lohnes, 1976). In most of the cases, testing provides a measure of progression and success of a student's learning. To evaluate a student's performance, it is worthwhile to use a number of different ways rather than relying on a single formal exam (Donald et al., 1985). There are various formal and informal ways of evaluation including homework assignments, quizzes, projects, reports, formal exams, class participation, team activities, interviews, attendance, punctuality etc. Whatever the method, it is good to record fairly often how students are performing in each area. Another important aspect to note is that whatever method be used, the evaluation process should help students develop their proficiency in a subject.

At undergraduate or associate degree level, cooperative training and/or senior project are two most important mechanisms (tools) to develop the skills of a student. Cooperative (coop) training provides an opportunity for students to integrate and apply their academic learning with some real work experience in industry. While completing a senior project, generally a student develops some industrial project or solves some related industrial problem based on the techniques he/she learnt during his academic career. In both of the above cases, a student is exposed to the profession of his/her subject area by working in the field or solving a real problem for the industry. Normally, such a student is evaluated through different means e.g. submission of progress and final reports, on-site observation, assessing the proposed design, final presentation etc and marks are assigned for each of these activities. These partial marks (results) are weighed up in some way (using numbers or percentage) in order to decide the final grade of a student for coop training. However, we feel that the assessment in such domains (i.e. observing student's attitude towards work, quality of work output, initiative and creativity, presenting his work in final report and presentation etc) is quite subjective and mostly based on perception of an evaluator. The conventional methods for evaluation usually do not take into account the uncertainties in usage of words for assessment. This gives us the motivation for type-2 fuzzy set be used to model a word as it covers the word uncertainties by using the concept of footprint of uncertainty.

In this paper, an interval type-2 fuzzy set based Fuzzy Logic Advisor (FLA) is presented to decide the final grade of a student's coop training. We also compare type-2 and type-1 fuzzy logic models for evaluating coop training. This paper is organized as follows; in section 2 we describe background details about coop training and related work. In section 3 our fuzzy logic model for evaluation is explained. Section 4 presents experiments and results. The paper is concluded in section 5 mentioning the future work also.

2 BACKGROUND

2.1 Importance of Selected Domain

For assessing and improving students' learning, coop training and senior project are very important tools. Recent report (Peter, 2008) shows that the employers hold high regard for evaluation of senior projects and coop training because these enhance students' knowledge and develop their skills to work in real-world environment. Most of the employers advise universities/colleges to focus resources in assessing these components for improving students' learning.

2.2 Cooperative Training/ Internship

Cooperative (coop) training is a planned and supervised on-site training. It helps students to gain job-related work experience and skills that assists them in achieving their career goals. There are different student activities that are monitored during and after the coop training. Based on this monitoring, final grades are assigned according to the student's performance in each activity. In universities/colleges coop students are evaluated using different means. We use following four means to evaluate coop students at our college:

1. A student submits a number of progress reports to his/her internal supervisor during the coop training period.
2. A student is evaluated by his supervisor (external) at work. In addition, internal supervisor may also visit the student to monitor his/her performance in the field.
3. A student submits a final report to the university/college about his training.
4. A student presents his/her work in a presentation to internal and/or external supervisors, faculty members and other students.

2.3 Senior/Capstone Project

Senior project gives students the experience of tackling a realistic problem. The intent is to show how to input theoretical knowledge gained into practical use by starting from a word description of a problem and proceeding through various design phases to end up with a practical solution. The project supervisor(s) guides the student in conducting a feasibility study, preparation of specifications, and the methodology for the design. Detailed design and implementation of the project are carried out followed by testing, debugging, and documentation. Similar to the coop training, we use four different means for evaluating a student's work during completing senior project. Except for the second point where supervisor assesses a student's performance by evaluating design methodology, complexity, level of achievement, quality of results etc of his/her project, the rest of the means are same as discussed in section 2.2 for coop training. Note that these evaluation criteria are flexible and generally based on policies from university or college (while in some cases evaluation depends on each individual).

After a number of years' experience, we feel that a perception-based evaluation model is more suitable for assessment of coop training and senior projects. We believe that the judgment for students' training at work, report writing (literary quality, quality of subject matter, formatting, structure etc.) and presenting the work during presentation (communication skills, organization etc.) are mostly subjective rather than objective. It is difficult to apply the objective methods to evaluate these student activities. Also we found that supervisors feel more comfortable while giving their judgment in terms of words (Excellent, Very Good, and Good etc.) than in numbers. To solve this problem, we propose the use of fuzzy logic to model the students' evaluation.

2.4 Fuzzy Logic

Fuzzy logic was first proposed and coined by Lotfi A. Zadeh in 1965 (Zadeh, 1965). The main motivation behind fuzzy logic was the existence of imprecision and uncertainty in the measurement process. Later, Zadeh also proposed the methodology of computing with words (CW) in which words are used in place of numbers for computing and reasoning (Zadeh, 1973; Zadeh 1996). The concept of CW is very important in human decision making systems as they employ mostly word in making decisions and judgments. CW involves a combination of natural language and computation with fuzzy variables. It mimics the perception-based decision making done by humans in an environment of imprecision, uncertainty and partial truth (Zadeh 1996; Zadeh 1999). The next subsections describe some of the important concepts related to fuzzy logic.

2.4.1 Linguistic Variables, Values and Terms

In fuzzy logic, linguistic variables accepts linguistic values which are words (linguistic terms) with associated degrees of membership in the set. Therefore, instead of considering length as a numerical variable that assumes a numerical value of 1.72 meters, it is treated as a linguistic variable that may assume, for example, linguistic values of “high” with a degree of membership of 0.92, "short” with a degree of 0.06, or "medium” with a degree of 0.7.

Linguistic variables accept values defined in their term set - their set of linguistic terms. Linguistic terms are subjective categories for the linguistic variable. For example, for linguistic variable age, the term set T(age) may be defined as follows:

T(age) = { "young", "not young", "not so young", "very young", ..., "middle aged", "not middle aged", ..., "old", "not old", "very old", "more or less old", "quite old", ..., "not very young and not very old", ... }

2.4.2 Fuzzy Sets and Membership Functions

Each linguistic term is associated with a fuzzy set, each of which has a defined membership function (MF). Formally, a fuzzy set *A* in *U* is expressed as a set of ordered pairs:

$$A = \{(x, \mu_A(x)) \mid x \quad in \quad U \}$$

In the above definition $\mu_A(x)$ is the membership function, which provides the degree of membership of x. This indicates the degree to which x belongs in set *A*, where *U* is the universe of discourse. Let’s illustrate these concepts using an example. Consider the “Literary Quality (LQ)” is a metric to measure the how well a student writes his report in terms of style, grammar, clarity etc. Figure 1 illustrates a linguistic variable LQ with four associated linguistic terms namely “Excellent”, “Good”, “Fair” and “Poor”. Each of four linguistic terms is associated with a fuzzy set defined by a corresponding membership function.

There are many types of membership functions. Some of the more common ones are triangular MFs, trapezoidal MFs and Gaussian MFs.

2.4.3 Fuzzy Logic System

Fuzzy logic system is a system which has a direct relationship with fuzzy concepts (such as fuzzy sets, linguistic variables and so on) and fuzzy logic. The most popular fuzzy logic systems in the literature can be classified into three types: pure fuzzy logic systems, Takagi and Sugeno’s fuzzy system, and fuzzy logic system with fuzzifier and defuzzifier (Wang, 1994).

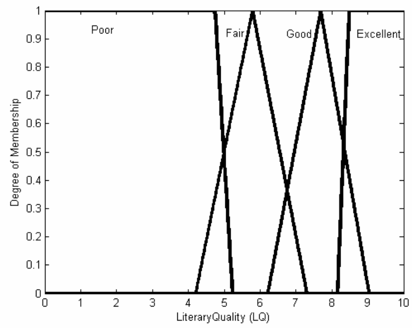

Figure 1: Membership Functions for Literary Quality.

Since most of the engineering applications produce crisp data as input and expects crisp data as output, the last type is the most widely used one. Figure 2 shows the basic configuration of a fuzzy logic system with fuzzifier and defuzzifier.

This type of fuzzy logic system was first proposed by Mamdani (Mamdani, 1975). It has been successfully applied to a variety of industrial processes and consumer products (Mamdani, 1974). The main fours components’ functions are as follows.

Fuzzifier: It converts a crisp input to a fuzzy set.

Fuzzy Rule Base: Fuzzy logic systems use fuzzy IF-THEN rules. A fuzzy IF-THEN rule is of the form "IF X1 = A1 and X2 = A2 ... and Xn = An THEN Y = B” where Xi and Y are linguistic variables and Ai and B are linguistic terms. The ‘IF’ part is the antecedent or premise, while the ‘THEN’ part is the consequence or conclusion. An example of a fuzzy IF-THEN rule is "IF Marks = Low THEN Grade =Poor". In a fuzzy logic system, the collection of fuzzy IF-THEN rules is stored in the fuzzy rule base, which is known as the inference engine.

Fuzzy Inference Engine: Once all crisp input values are fuzzified into their respective linguistic values, the inference engine accesses the fuzzy rule base to derive linguistic values for the intermediate and the output linguistic variables. The inference engine performs two main operations: aggregation and composition. Aggregation is the process of computing for the values of the IF (antecedent) part of the rules while composition is the process of computing for the values of the THEN (conclusion) part of the rules.

Defuzzifier: It converts fuzzy output into crisp output.

The details of the above four components can be found in (Wang, 1994).

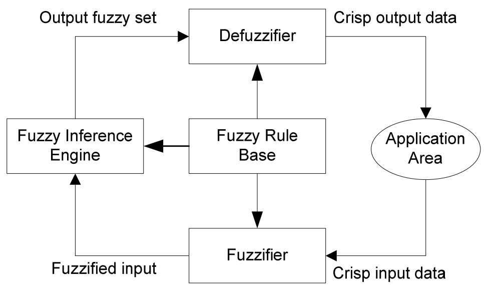

Figure 2: FLS with Fuzzifier and Defuzzifier.

Imprecise perception-based data can be best modeled by using type-2 fuzzy logic (John and Coupland, 2007). Mendel proposed using type-2 fuzzy sets and type-2 fuzzy logic systems to deal with the different types of uncertainties (Mendel, 2001). Type-2 fuzzy sets help us to deal with the uncertainty about the meaning of the words and uncertainties about the consequent used in a rule. Type-1 fuzzy sets cannot deal with this type of uncertainty because the degree of membership is considered as certain in type-1 fuzzy sets. Figure 3 shows footprint of uncertainty (FOU) for a Gaussian membership function having a fixed standard deviation, σ, and an uncertain mean that takes on values in [m1, m2]. The example shown in Figure 3 depicts a case where the FOU is uniformly shaded. It means that at each point in the FOU, the membership degree is one. This type of membership functions is known as interval type-2 membership function.

A fuzzy logic system is considered to be type-2 as long as any one of its antecedent or consequent sets is type-2. A detailed description of all the components of Figure 4 and uncertain rule based fuzzy logic (type-1 and type-2) system is provided by Mendel (Mendel, 2001).

2.5 Related Work

Fuzzy theory has vast applications in different disciplines from controls to machine learning to decision making. It has also been applied in the field of education (Ahmad, 2001; Kavcic et al. 2003). In (Montero et al., 2005), fuzzy logic based evaluation system, to decide critical students' final marks, is presented. They used type-1 fuzzy logic for evaluation purpose.

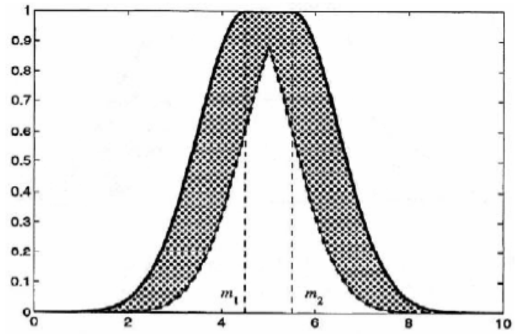

Figure 3: FOU for Gaussian Membership Function.

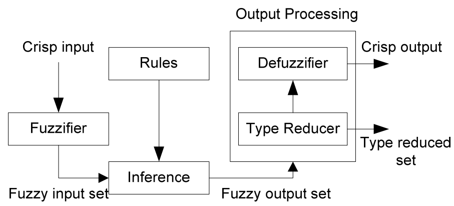

Figure 4: Type-2 Fuzzy Logic System.

In (Suarez, 2003), type-1 fuzzy set (membership function) has been used to manage students' performance in computer adaptive testing (CAT) administration process. In (Zhou, 2001), criterion referenced assessment techniques using fuzzy sets (type-1) are proposed for student project assessment. To our knowledge, type-2 fuzzy logic has not yet been used for students' evaluation, particularly for coop training evaluation.

3 PROPOSED FUZZY LOGIC ADVISOR

3.1 Assessment Components

As described in section 2.1, assessment of coop training and senior project is divided into different components. Each of these parts has number of criteria to be monitored and evaluated during and after training/project. Table 1 shows the four different parts (means) of coop training evaluation and their respective criteria to be judged by the evaluator. Assessment components and criteria for assessment for senior project are shown in Table 2. The final grade of a student is computed based on the outputs of four assessment components.

Table 1: Assessment Components and Criteria for Coop Training.

Assessment Component	Criteria for Assessment
Final Report (FR)	• Format and Structure • Literary Quality • Quality of Subject Matter
Progress Report (PR)	• Task Description • Format and Submission
Final Presentation (FP)	• Content and Organization • Speaking (Presentation) Skills • Response to Questions
External Evaluation (EE)	• Enthusiasm and Interest in Work • Ability to Learn and Search for Information • Relations with Co-Workers • Punctuality and Delivering Work on Time

Table 2: Assessment Components and Criteria for Senior Project.

Assessment Component	Criteria for Assessment
Final Report (FR)	• Format and Structure • Literary Quality • Quality of Subject Matter
Progress Report (PR)	• Task Description • Format and Submission
Final Presentation (FP)	• Content and Organization • Speaking (Presentation) Skills • Response to Questions
Supervisor Evaluation (SE)	• Quality of Design Methodology and Interest in Work • Level of Achievement • Quality of Results • Punctuality and Delivering Work on Time

3.2 Evaluation Model

We propose students' coop and senior project evaluation model based on knowledge mining (knowledge engineering) methodology described in (Mendel, 2001). The evaluation information is extracted in the form of IF-THEN rules from evaluators (experts) and these rules are modelled using FLS, which then is used as a fuzzy logic advisor (FLA) to make decisions about students' grades. We propose a two-stage FLA based on interval type-2 fuzzy logic, where each assessment component is evaluated using an independent FLA and then the results of these FLAs are combined to calculate the final grade of a student using a second-stage FLA. Figure 5 represents a two-stage FLA framework for coop training. A similar model can be drawn for senior project evaluation. Each of these FLA has internal structure as described in section 2.2.4 (figure 4).

3.3 Antecedent & Consequent Fuzzy Sets

In building a FLA we divide the whole range of all the input (criteria of assessment) and output (evaluation) attributes into number of fuzzy sets. We use four type-2 fuzzy sets namely Excellent, Good, Fair and Poor to represent each criterion of assessment and the output of assessment components of stage-1.

For our proposed model, we obtain this fuzzy set classification from experts. As we have already mentioned, different experts may provide different assessments, based on their experience, regarding a particular fuzzy set (e.g., Excellent) range of a specific input/output attribute. This causes uncertainty, as to which definition is more appropriate to consider when one wants to define antecedents/consequents while developing FLS. This observation led us to use type-2 fuzzy sets, which enables us to model uncertainty, caused due to different experts' opinion as just discussed, in the FLS by blurring the antecedents'/consequents' boundaries and defining the footprint of uncertainty (FOU). For our model, based on survey from a group of evaluators (experts) a range for above labels is chosen using a scale 0 through 10. Table 3 shows the mean and standard deviation values for these range labels based on our survey.

We associate triangle membership function with the labels Fair (***F***) and Good (***G***), and piecewise linear membership functions with labels Poor (***P***) and Excellent (***E***). The uncertainty about the words used in antecedents and consequents of rules and uncertainties about the rule consequents are captured in type-2 fuzzy sets using FOUs.

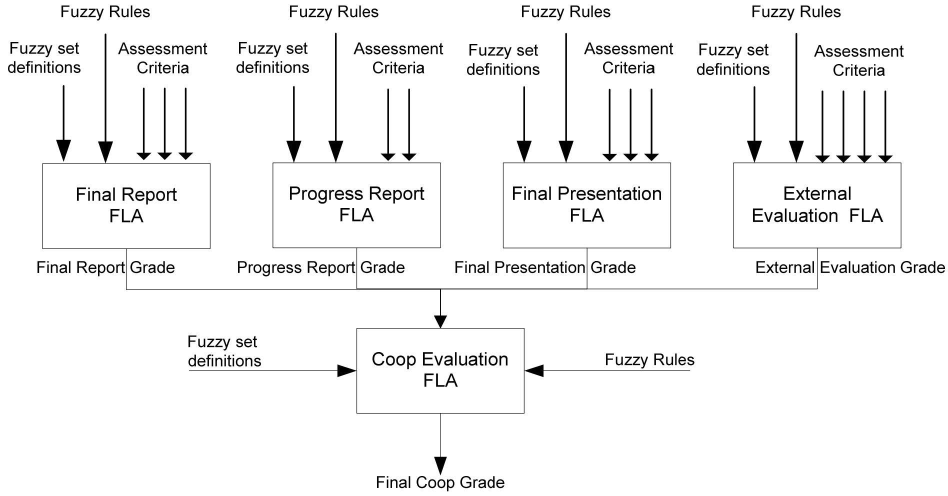

Figure 5: Two-Stage Type-2 Fuzzy Logic Based Framework for Cooperative Training Evaluation.

Table 3: Survey Results for Labels of Fuzzy Sets.

Label	Mean		Std. Deviation	
	Start	End	Start	End
	A	b	σ_a	σ_b
Poor	0	4.7389	0	0.4898
Fair	4.7056	6.8778	0.4978	0.4295
Good	6.6556	8.7222	0.4419	0.3153
Excellent	8.4889	10.0000	0.3296	0.0000

We obtain FOUs by specifying upper and lower membership function for each fuzzy set. These fuzzy sets are calculated based on procedure described in (Mendel, 2001). Figure 6 shows the FOUs for the four fuzzy sets for ρ=0.5 (50% percent uncertainty), where ρ is the fraction of uncertainty and $0 \le \rho \le 1$.

Similarly, for stage-2, the output of stage-1 will be used as input in the form of type-2 fuzzy set shown above. The output of stage-2 (Grade) is also divided into nine different fuzzy sets namely Exceptional, Excellent, Superior, Very Good, Above Average, Good, High Pass, Pass, and Fail. In our proposed model, the initialization of membership functions is done through singleton input.

The criteria of assessment (indicators of assessment components) are represented by type-2 fuzzy sets as we believe that these criteria are judged on the basis of perception of an evaluator.

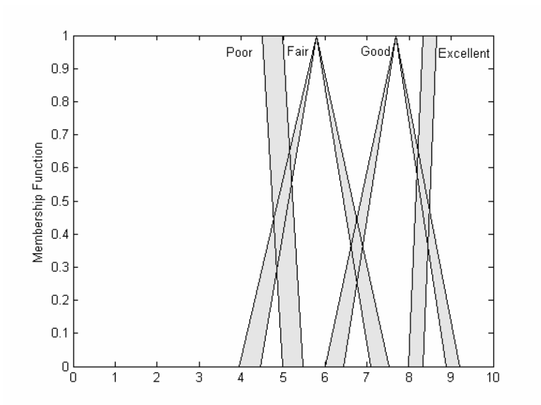

Figure 6: FOUs for Linguistic Labels.

3.3 Fuzzy Rule Base and Defuzzification

In the rules formulation we follow the approach where all the possible combinations of antecedent fuzzy sets are employed (Mendel 2001). The consequents of rules are provided by the experts (evaluators) through survey. Each rule has a histogram of responses. Our proposed model is composed of five FLAs and each one has its own set of rules. The number of rules depends on the number of inputs and fuzzy sets associated with them.

Table 4: Partial Histogram of Survey Responses for Final Report Evaluation.

Rule No.	Antec. 1	Antec. 2	Antec. 3	Consequent				Type-1	Type-2	
				Exc.	Good	Fair	Poor	C_{avg}	C^l_{avg}	C^r_{avg}
1	Excellent	Excellent	Excellent	8	0	0	0	9.162	9.08	9.24
2	Excellent	Excellent	Good	6	2	0	0	8.783	8.69	8.87
3	Excellent	Excellent	Fair	4	3	1	0	8.17	8.06	8.28
4	Excellent	Excellent	Poor	0	5	2	1	6.533	6.4	6.67
5	Excellent	Good	Excellent	6	2	0	0	8.783	8.69	8.87
6	Excellent	Good	Good	3	4	1	0	7.98	7.87	8.09
7	Excellent	Good	Fair	0	5	3	0	6.943	6.81	7.08
8	Excellent	Good	Poor	0	4	3	1	6.298	6.16	6.44
9	Excellent	Fair	Excellent	2	5	1	0	7.791	7.67	7.91
10	Excellent	Fair	Good	0	6	2	0	7.178	7.04	7.31
11	Excellent	Fair	Fair	0	5	3	0	6.943	6.81	7.08
12	Excellent	Fair	Poor	0	2	5	1	5.829	5.69	5.97
13	Excellent	Poor	Excellent	0	3	4	1	6.064	5.92	6.2
14	Excellent	Poor	Good	0	3	4	1	6.064	5.92	6.2
15	Excellent	Poor	Fair	0	0	6	2	4.95	4.8	5.1

For example, for Progress Report FLA, the number of rules will be 4x4=16.While for Final Report FLA, there will be 64 rules. Maximum number of rules will be for External Evaluation FLA and Coop Evaluation FLA i.e. 256. An example rule for Coop Evaluation FLA will be of following form:

Rl: IF FR is $\tilde{E}$ AND PR is $\tilde{G}$ AND FP $\tilde{F}$ is AND EE is $\tilde{E}$ THEN GRADE is $V\tilde{G}D$ (VERY GOOD)

For later calculations, we find weighted average (C^l_{avg}) of the rule consequents of each rule using following formula (Mendel, 2001):

$$C^l_{avg} = \frac{\sum_{i=1}^{M} w_i^l C_{\tilde{G}i}}{\sum_{i=1}^{M} w_i^l} \equiv \left[\underline{C}^{\,l}_{avg} \quad \overline{C}^{\,l}_{avg}\right] \qquad (1)$$

In the above equation, $C_{\tilde{G}i}$ is the centroid of the ith consequent and w_i^l is the weight associated with the ith consequent for the lth rule. The centroid for type-2 fuzzy sets is calculated using the iterative procedure of the Karnik-Mendel (KM) algorithm (Karnik and Mendel, 2001). The consequent of each rule is treated as type-1 fuzzy set. Initially we did survey for small group of experts due to large number of rules. A partial histogram of final report evaluation FLA with three antecedents and a consequent, and corresponding weighted average response for both type-1 and type-2 is shown in table 4.

The final output of our proposed FLAs is a type-reduce interval set, having the following form:

$$Y_{TR} = [y_l, y_r] \qquad (2)$$

Where y_l and y_r are computed using following two fuzzy basis function (FBF) expansions (Mendel, 2001):

$$y_l = \frac{\sum_{i=1}^{M} f_l^i y_l^i}{\sum_{i=1}^{M} f_l^i} = \frac{\sum_{i=1}^{L} \overline{f}^i y_l^i + \sum_{i=L+1}^{M} \underline{f}^i y_l^i}{\sum_{i=1}^{L} \overline{f}^i + \sum_{i=L+1}^{M} \underline{f}^i} \qquad (3)$$

$$y_r = \frac{\sum_{i=1}^{M} f_r^i y_r^i}{\sum_{i=1}^{M} f_r^i} = \frac{\sum_{i=1}^{R} \underline{f}^i y_r^i + \sum_{i=R+1}^{M} \overline{f}^i y_r^i}{\sum_{i=1}^{R} \underline{f}^i + \sum_{i=R+1}^{M} \overline{f}^i} \qquad (4)$$

For a type-2 fuzzy set $\tilde{F}$, we calculate $\underline{f}$ and $\overline{f}$ using following equations:

$$\underline{f} = \min\left[\underline{\mu}_{\tilde{F}1}, \underline{\mu}_{\tilde{F}2} \ldots\ldots \underline{\mu}_{\tilde{F}M}\right] \quad (5)$$

$$\overline{f} = \min\left[\overline{\mu}_{\tilde{F}1}, \overline{\mu}_{\tilde{F}2} \ldots\ldots \overline{\mu}_{\tilde{F}M}\right] \quad (6)$$

$$y = \frac{y_l + y_r}{2} \quad (7)$$

Finally, the defuzzified output of FLAs can be found by using following equation:

4 EXPERIMENTS & RESULTS

We implemented type-1 and type-2 fuzzy logic advisors (FLAs) using MATLAB fuzzy logic tool box. We compared our FLA with the existing coop/senior project evaluation system. In the existing system, same assessment components are used for coop evaluation but the usage of linguistic labels with the range is fixed. Using these fixed range assessment method, the overall performance of a student is assessed by simply adding their marks in different components. We implemented a fuzzy logic advisor based on the inputs of experts for range of different linguistic variables for evaluation (shown in table 3). Our system uses the rule-based fuzzy inference system to calculate the overall grade of a student which provides more accurate evaluation of a student as compared to existing method. We found that the uncertainties in the representation of criteria for assessment (linguistic variables) can be well taken into account by using type-2 fuzzy sets.

For verification of our model, we selected a sample of students' evaluation and compared the outputs of the individual's FLA with the output of our proposed consensus type-1 and type-2 FLAs. For this purpose same assessment components and criteria were used. Figure 7 shows a comparison for the outputs of individual and consensus type-1 FLAs for final report (FR) evaluation. This plot shows that the outputs of individual and consensus FLAs differ marginally for most of the students.

Figures 8 and 9 show the comparisons for outputs of individual and consensus type-2 FLAs for the same assessment component (FR) with 50% and 100% uncertainty. These two plots depict that the individual assessment lies in between the limits of consensus assessment (left-hand and right-hand curves) which reflects that type-2 based system captures all those uncertainties which are there due to words in surveys and consensus consequents.

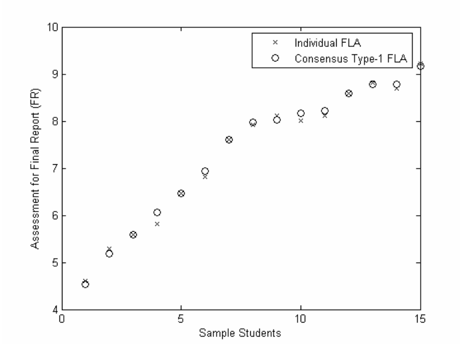

Figure 7: Comparison for Individual and Type-1 Consensus.

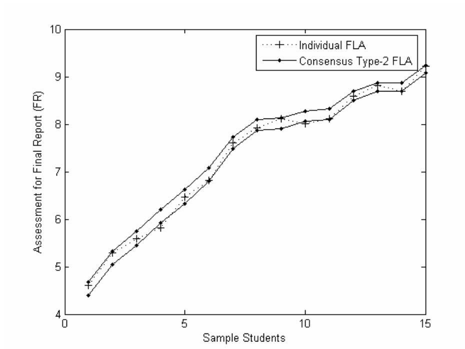

Figure 8: Comparison for Individual and Type-2 Consensus FLAs (50% uncertainty).

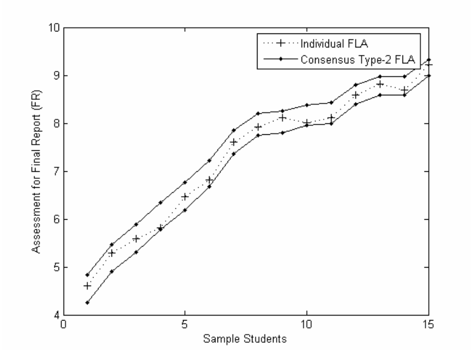

Figure 9: Comparison for Individual and Type-2 Consensus FLAs (100% uncertainty).

5 CONCLUSIONS & FUTURE WORK

This paper describes a rule-based fuzzy logic advisor (FLA) to evaluate the cooperative training and senior project of students at undergraduate and associate degree level. We used the knowledge mining (engineering) methodology to develop this system where we gathered evaluation information from experts. The system is initially tested for a small group of students in computer science department at our college and we found it very useful for assessing students' performance in their cooperative training. Our type-2 fuzzy set model has the potential to capture the uncertainties due to words used in subjective evaluation of a student.

Future work involves further testing of the system for large number of students from different departments and investigating the use of the system for other courses/situations e.g. assessing group projects etc. Moreover, type-2 fuzzy sets will also be tested for representing final grades. There are some other issues which need to be considered in future e.g. deciding the optimal number of linguistic input/output variables for assessment components, working with non-singleton input from evaluators, and deciding the appropriate number of experts for survey response etc. In future these issues will be taken into consideration for improving the overall performance of the system.

REFERENCES

Ahamd, M. I. 2001. Assessment of Distance Education Quality Using Fuzzy Sets Model. In the *Proceedings of International Conference on Engineering Education*, Oslo, Norway.

Cooley, W.W., AND Lohnes, P. 1976. *Evaluation Research in Education*, Irvington Publishers, INC., New York.

Donald, J., Madsen, H., AND Hilferty A. 1985. *TESOL: Techniques and Procedures*. Newbury House Publisher.

John, R., Coupland, S. 2007. Type-2 Fuzzy Logic – A Historical View. *IEEE Computational Intelligence Magazine*. 2, 57-62.

Karnik, N. N., Mendel, J. M. 2001. Centroid of type-2 fuzzy sets, *Information Sciences*. 132, 195-220.

Kavic, A., Pedraza, R., Molina, H., Valverde, F., Cid, J., Navia, A. 2003. Student Modelling Based on Fuzzy Inference Mechanisms. *Proceedings of EUROCON*, Slovenia, 379-383.

Mamdani, E. H. 1974. Applications of Fuzzy Algorithms for Simple Dynamic Plant, In the *Proceedings of IEEE*. 121, 12, 1585-1588.

Mendel, J. M., Liang, Q. 1999. Pictorial Comparison of Type-1 and Type-2 Fuzzy Logic Systems, *Proceedings of IASTED International Conference on Intelligent Systems & Control*, Santa Barbara, CA.

Mendel, J. M. 2001. *Uncertain Rule-Based Fuzzy Logic Systems*, Prentice-Hall, Upper Saddle River, NJ 07458.

Montero, J. A., Alsina, R. M., Moran, J. A., Cid, M. 2005. Fuzzy Logic System for Students' Evaluation, *Computational Intelligence and Bio-inspired Systems*, *Lecture Notes in Computer Science*. 3512, 1246-1253.

Wang, L. 1994. *Adaptive Fuzzy System and Control: Design and Stability Analysis*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632.

Peter, D. H. 2008. How should colleges assess and improve student learning? *Liberal Education and America's Promise (Association of American Colleges & Universities)* - Report. January, 2008.

Suarez, J. 2003. Student Evaluation through Membership Functions in CAT Systems. *Revista Mexicana De Fisica*, 49, 371-378.

Zadeh, L. A. 1965. Fuzzy Sets, *Information and Control*. 8, 338-353.

Zadeh, L. A. 1973. Outline of a New Approach to the analysis of Complex Systems and Decision Process, *IEEE Transaction. Syst., Man, Cybern*. 3, 28-44.

Zadeh, L. A. 1975. The concept of a Linguistic Variable and Its Application to Approximate Reasoning-I, *Information Sciences*. 8, 199-249.

Zadeh, L. A. 1996. Fuzzy Logic = Computing with Words, *IEEE Transaction on Fuzzy Systems*. 4, 103-111.

Zadeh, L. A. 1999. Fuzzy Computing with Numbers to Computing with Words – From Manipulation of Measurements to Manipulation of Perceptions, *IEEE Transaction on Circuits and Systems – I: Fundamental Theory and Applications*. 45, 105-119.

Zhou, D., Kwok, R.C.W., Zhang, Q., Ma, J. 2001. A New Method for Student Project Assessment Using Fuzzy Sets. *20th NAFIPS International Conference*. 1, 25-28.