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Heuristic Rule Based Fuzzy Inference System for Decision Support and Quality Assurance in Higher Education

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Abstract: An expert system is computer software that solves real world problems using human knowledge, problem solving and reasoning skills. This paper presents the development of an expert system based on Fuzzy Inference techniques to assist in assuring quality in higher education. Quality assurance in higher education is a complex multi criteria decision making process and the key conceptual challenge is elicitation and use of experts' vast domain knowledge that can be subjective and vague when expressed using conventional mathematical and statistical methods. The proposed Fuzzy Inference System modelled on human cognition and mentation process can prove to be an effective tool for decision making in such a scenario. Knowledge acquisition to develop this expert system involved questionnaire based reviews taken from domain experts and an extensive literature survey. Fuzzy rule database in MATLAB is used for representation of knowledge. The system inherently has a feedback mechanism to reflect the subtle variations in the weights of factors contributing to the quality of an institution.

Keywords: Fuzzy Logic, Criterion for Quality in Higher Education, Fuzzy Rule Generation, Trapezoidal Membership Functions, Fuzzy Inference System

1. Introduction

Higher education instils skills and teaches advanced knowledge that are vital for building a knowledge society. It is both the final link in the education chain and a source of new knowledge and training that supports the other levels of the education system. Around the world, changes in higher education systems and institutions are profound and accelerating. The expansion of education systems requires a rapid transformation in institutions, the supply of education, and teaching practices. To meet the challenge of this demand, higher education systems are undergoing a process of diversification and modernization. In this context, the forms of education governance are also in a period of transformation. In particular, higher education institutions need to develop their own institutional policies and strategic plans, and be in a position to demonstrate clearly the results of these. In order to respond to this new demand, institutions are obliged to build their own management capacity and implement better-performing information, monitoring and control systems.

Many countries are currently exploring the best means of designing quality assessment and assurance systems for their higher education sectors. They are struggling to understand the causal link between their engagement in teaching and the quality of learning outcomes. Exploring the correlation among inputs, processes and outcomes of higher education calls for pioneering and in depth quality evaluation instruments. There is a need to develop innovative approaches to allow higher education planners and policy-makers to not only monitor the implementation of their policies and procedures, but also helps the system to stay relevant both in terms of education and research. For this reason, a quality assessment and assurance for higher education seems to be an indispensable management tool.

1.1Criterion for Quality in Higher Education

Many definitions of quality in education exist, testifying to the complexity and multifaceted nature of the concept. The terms efficiency, effectiveness, equity and quality have often been used synonymously. Different approaches have been adopted by the researchers to define and evaluate quality in an educational institute. The identification of best practices to be implemented in an educational institute depends on many variables such as institutional goals, pedagogic requirements, global concerns, local contexts, nature of learners, competencies of staff, infrastructure facilities and governance requirements. It is observed that usually there is incongruence between how we teach and how students learn. All these add to the complexity of choice of best practices. What might be considered as best practice depends on our own limited knowledge, perspectives, contexts, interests and values. The attributes and values on which the practices are premised may be contested by others. In that case, many of the attributes on which the practices are premised will not hold. Secondly, attributes are contingent, context dependent and defy generic description. If these practices are to be useful at all, we need to identify the attributes that can be so restated as to be clearly seen to contribute to value addition to the institution or the stakeholders. Only then can they become context-free and less subjective. This requires a predominantly fitness for purpose judgement and there cannot be an ideal typification of best attributes applicable to all contexts.

From the early 1990s onwards the emphasis was shifted to formal assessments of quality in technical education to spur the institutions to adopt formal systems of quality management. Singh and Sareen [1] described Deming's cycle and its 14 points which are used to ensure the quality of technical education process. Kaur et al. [2] studied and presented a comprehensive list of the quality issues in technical institutions where implementation of ISO 9001:2000 may provide the management a frame work to continually improve the existing resources and process by setting up quality objectives, measurements etc. to achieve higher standards of quality in education. Tartaglia and Tresso [3] developed a Web-based automatic evaluation system for students of engineering faculties.

Temponi [4] analyzed the main elements of continuous improvement (CI) in higher education and the concerns of academia's stakeholders in the implementation of such an approach. Thakkar et al. [5] used a quality function deployment (QFD) which prioritizes technical requirements and correlates them with various customers' students requirements for the present Indian context. Voss and Gruber[6]studied and gave an insight into the desired qualities of the lecturers. They indicated that the students want lecturers to be knowledgeable, enthusiastic, approachable, and friendly. Mahapatra and Khan [7] gave a measuring instrument known as EduQUAL for evaluation of quality in Technical Education System (TES). Neural network models along with QFD have been proposed to assess the degree of satisfaction of various stakeholders in ES. He gave certain factors that are important for assessing quality in technical education.

Venkataramand Giridharan [8] designed a Technical Educational Quality Assurance and Assessment (TEQ-AA) System, which makes use of the information on the web and analyzes the standards of the institution. Mahapatra and Khan [9]designed a measuring instrument known as EduQUAL and an integrative approach using neural networks for evaluating service quality is proposed. The dimensionality of EduQUAL is validated by factor analysis followed by varimax rotation. Bahzad and Irani [10] developed a QA model for military institutions. The research seeks to assess, through a case study how newly established education institute assimilates quality assurance systems. Gheorghe et. al. [11] depicted the peculiarity of Quality Function Deployment method (QFD) applied to quality improvement in higher technical education. Wang and Liang [12] used SPC (control charts) technique for quality control or improvement of technical education.

1.2Expert system in Educational Institution

An expert system is a computer system that attempts to replicate specific human expert intelligent activities [13]. Typically, knowledge-based systems enable users to consult a computer system as they would an expert advisor to diagnose a problem and also assist in developing a solution or making a decision. Such a computer system can extract additional information from a user or domain expert by asking questions and updating it's existing database This is akin to a human expert's ability of reasoning and arriving at a solution based on his years of experience and knowledge. It can also answer questions asked by a user about why certain information is needed. It can make recommendations regarding the problem or decision at the end of a consultation, and it can explain the reasoning steps gone through to reach its conclusions when asked by a user [13]. Several expert systems have already been developed in various fields.

Tong et al. were among the first to make use of expert system type rules for wastewater treatment plant operation and control Fuzzy logic was used to provide a qualitative interpretation of the quantitative data. Later a simple expert system in prolog for the diagnosis of an activated sludge plant was designed. The applications of expert systems in water quality modeling were also evaluated and it was concluded that expert systems will increase the level of sophistication and proficiency of the model user. According to Gonzalez [14], expert systems have a number of distinct advantages as compared to other conventional solution systems. Some of them include use of heuristic programming where changes are very frequent. The fundamental concept of the separation of knowledge from the reasoning mechanism eases the process of modifying the knowledge. Knowledge based systems, by virtue of their heuristic nature, are capable of solving problem where information available is subjective, imprecise, vague and incomplete. This is an important feature because complete, accurate, objective and certain information on a problem is rarely available in real world problems.
The objective of the study is to develop an expert system for higher education which will support the policy makers and other stakeholders in decision making as well as assessing and assuring quality in the system.

2. Proposed Methodology

Decision making and quality assurance in education involves two main inputs to the evaluation process of data. First is the decision maker's perception regarding the importance of the indicator of quality. The second input is how the decision maker rates each indicator with respect to objective. However, it is very difficult to obtain exact assessments from the decision maker. The nature of these assessments is often subjective and qualitative. The quality indicators itself are vague, context dependent and subjective. Therefore expecting the decision makers to express their opinion in pure numeric scales does not allow any room for subjectivity. Subjectivity of human assessments and beliefs can be expressed by using linguistic terms such as "less important" or "highly likely." The fuzzy set theory and fuzzy numbers allow such qualitative expressions. A fuzzy logic based inference system is proposed to model the process of decision making and quality assurance in an academic institution.

2.1 Fuzzy Model

As the complexity increases, the ability to clarify (make precise and significant) decreases until it reaches a limit where accuracy and relevance become mutually exclusive characteristics. Reflecting on these questions, L. A. Zadeh in [15] introduced the concepts of Fuzzy Theory as a theory that sought the representation of vagueness and imprecision of human expressions of natural language. The introduction of fuzzy theory concepts offers a basis for thinking about vague concepts using a tool to model the knowledge. This tool considers reasoning that the main concepts of human thought are not numbers but linguistic variables. Linguistic variable is a kind of variable having a Fuzzy set as domain. For instance, the performance of students may be represented by a linguistic variable "Performance" assuming values "insufficient", "fair" and "good", corresponding to a fuzzy set.

2.2 Fuzzy Set Theory

Unlike in classical set theory when a membership variable might take only two values 0 or 1, accordingly x belong or not to a set A, in Fuzzy model a continuous grade of membership may vary in the interval [0,1], with the value of the function fA (x)representing the degree of membership of x in A. Such a function is defined as µA (x): X → [0,1]where A is formed by ordered pairs like A = ((µA (x), x) | x∈X). µA (x) reflects the confidence degree of a given linguistic variable applied to a particular element of a fuzzy set.

In traditional set theory, elements have either complete membership or complete non-membership in a given set. With fuzzy set theory, intermediate degrees of membership are allowed. The coding of the degree of membership to each of the elements in the set is defined as the membership function of the fuzzy set. The membership function is commonly depicted as a membership curve that consists of three main sections: the horizontal axis consisting of domain elements (usually real numbers) of the fuzzy set, vertical axis consisting of the degree of membership µA (x) in a scale from 0 to1, and the surface of the set itself which relates the degree of membership to the domain element. Triangular and Trapezoidal are the most frequently used membership functions.

2.3 Trapezoidal Fuzzy Membership Functions

In Trapezoidal membership function, the decision maker's perception is solicited in area importance of each factor, and the performance of each factor. The trapezoidal curve is a function of vector x, and depends on four scale parameters a, b, c, d. The parameters a and d locate the"feet" of the trapezoidal and parameters b and c locate the "shoulders".

$$\mathbf{f(x,a,b,c,d)} = \begin{Bmatrix} \mathbf{0, x \le a} \\ \mathbf{\frac{x-a}{b-a}\quad a \le x \le b} \\ \mathbf{1, \quad b \le x \le c} \\ \mathbf{\frac{d-x}{d-c}, c \le x \le d} \\ \mathbf{0, \quad d \le x} \end{Bmatrix}$$

2.4 Fuzzy Inference System

Fuzzy inference system consists of three stages. In the first stage called fuzzification values of measurements, evaluations, tests, perceptions observed in a dataset are transformed into fuzzy variables. The second stage is the inference process where a list of if-then-else declarations called rules is used to map a fuzzy entry space into a fuzzy output space. After the inference process, the third stage of defuzzification performs an interpretation of such information. The base of rules is supplied by specialists in plain language or through questionnaires. They can also be based on operator control actions, based on the observation of input and output data. The inference engine is the core of the fuzzy system, and it embodies all the logic of the fuzzy inference system. According to [15], fuzzy inference models are particularly appropriate in cases that require decision making, as these applications depends on the knowledge and experience in the processes involved.

3. Design Methodology for Prototype Development

The proposed fuzzy inference system is modelled in FIS editor of fuzzy logic tool box in MATLAB. Figure 1 represents the summary of fuzzy inference system.

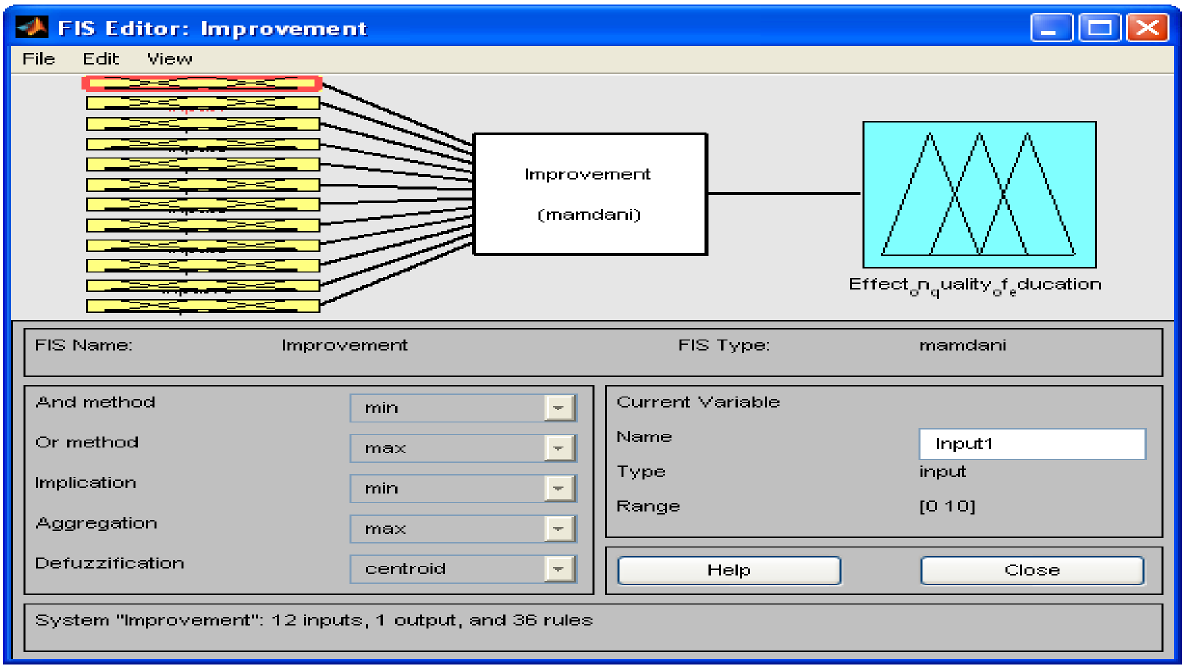

Figure 1: Fuzzy Inference System based on Mamdani Method

3.1 Knowledge Acquisition

Knowledge acquisition is the knowledge engineering job of acquiring and organizing the knowledge needed to develop an expert system. For the proposed Fuzzy Inference system, there were two sources of knowledge. First was an extensive literature review and second was in form of questionnaire designed to gather reviews from domain experts and academicians. There are large number of indicators or factors that can be analyzed to assure quality in higher education. In the proposed work, eighteen indicators of quality were shortlisted on expectations as well as perceptions related to quality of higher education. These indicators are the inputs to the Fuzzy Inference system. The respondents were requested to assign weight to each indicator answer in a scale from 0 to 10 (Table 1).

Table 1: Data for finding the firing strength of individual parameter

Sr. No.	Quality Indicators																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	8	7	10	7	9	9	8	9	2	10	9	9	2	8	9	9	7	8
2	8	9	10	8	10	7	6	7	8	9	8	9	8	9	9	8	9	7
3	8	9	10	7	10	7	10	7	7	10	8	8	7	9	9	9	7	8
4	9	8	9	8	10	8	7	6	8	10	10	10	8	7	9	10	6	9
5	9	9	10	7	10	6	6	8	7	7	7	10	7	6	10	7	8	7
6	6	5	9	2	3	3	5	3	7	7	8	7	7	3	9	6	3	2
7	8	4	9	3	6	2	4	2	6	8	7	5	6	3	9	4	2	6
8	9	9	9	6	10	5	5	5	3	7	7	7	3	5	7	7	5	6

9	8	7	10	7	9	9	8	9	7	10	9	9	7	8	9	9	9	8
10	8	9	10	8	10	7	6	7	8	9	8	9	8	9	9	8	7	7
11	8	9	10	7	10	7	10	7	7	10	8	8	7	9	9	9	7	8
12	8	9	10	7	10	7	10	7	7	10	8	8	7	9	9	9	7	8
13	9	8	9	8	10	8	7	8	8	10	10	10	8	7	9	10	8	9
14	9	9	10	7	10	6	6	6	7	7	7	10	7	6	10	7	6	7
15	9	9	10	7	10	6	6	3	7	7	7	10	7	6	10	7	6	7
16	6	5	9	2	3	3	5	6	2	7	8	7	2	3	9	6	3	2
17	8	4	9	3	6	2	4	2	3	8	7	5	3	3	9	4	2	6
18	8	4	9	3	6	2	4	2	6	8	7	5	6	3	9	4	2	6
19	9	9	9	6	10	5	5	5	3	7	7	7	3	5	7	7	6	6
20	9	9	10	7	10	6	6	6	7	7	7	10	7	6	10	7	5	7
21	6	5	9	2	3	3	5	9	2	7	8	7	2	3	9	6	3	2
22	8	7	10	7	9	9	8	3	7	10	9	9	7	8	9	9	9	8
23	9	9	10	7	10	6	6	6	7	7	7	10	7	6	10	7	6	7
24	6	5	9	2	3	3	5	3	2	7	8	7	2	3	9	6	2	2
25	8	4	9	3	6	2	4	2	3	8	7	5	3	3	9	4	3	6
Sum	201	181	238	141	203	138	156	138	141	207	196	201	141	147	226	179	138	159
Mean	0.80	0.72	0.95	0.56	0.81	0.55	0.62	0.55	0.56	0.83	0.78	0.80	0.56	0.59	0.90	0.72	0.55	0.64

Table 2: Ranking as per firing strength

S.No.	Quality Indicators	Mean	Rank
1.	Use of latest technological tools/ ICT	0.80	5
2.	Effective Design and Implementation of Curriculum after assessing feedback from all the stakeholders	0.72	8
3.	Well Equipped laboratories	0.95	1
4.	Well developed and Comprehensive Learning Resources	0.56	12
5.	Training & Placement Opportunities	0.81	4
6.	Mentoring & Counselling of students	0.55	13
7	Faculty Student ratio	0.62	10
8	Use of effective and objective Student Evaluation Methods	0.55	13
9	Focus on holistic development of students including social skills, values and ethics	0.56	12
10	Qualifications and Experience of faculty	0.83	3
11	Pedagogical and Communication skills of faculty	0.78	6
12	Retention of Good faculty	0.80	5
13	Funding and Infrastructure support for Research activities	0.56	12
14	Development of Quality culture that facilitates Collaborative work and Information fluidity in the Institute	0.59	11
15	Effective Institutional Policy Design, Implementation and Monitoring using robust Quality Assurance System (internal as well as external)	0.90	2
16	Institutional Support for faculty career progression, training, and skill development	0.72	7
17	Financial scholarships to encourage bright students from economically weaker sections of society	0.55	13
18	Recognition and rewards for achievements and contributions of faculty	0.64	9

Average or mean rating for each indicator was obtained from the data acquired. The firing strength of rules from the fuzzy rule base in the inference engine is determined by the mean rating. For further analysis, only those quality indicators that have mean value above or equal to 0.58 are considered as shown in Table 2.

The corresponding weights of quality indicators are categorized into three fuzzy sets namely, "**low**" "**medium**" and "**high**" (Table 3) and modeled using trapezoidal membership function (trapmf)

Table 3. The input linguistic variable importance scale

Range	Trapmf Values	Fuzzy sets
Low	**-5 - 5** (-5,-4, 4, 5)	(0,0),(1,1),(2,1),(3,1),(4,1),(5,0)
Medium	**4 - 8** (4, 5, 7, 8),	(4,0),(5,1),(6,1),(7,1),(8,0)
High	**7 - 10** (7, 9, 10, 12)	(7,0),(8,1),(9,1),(10,1)

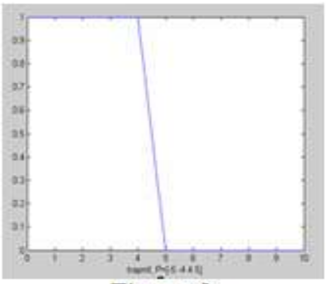
Figure 2
Membership Function of linguistic variable LOW

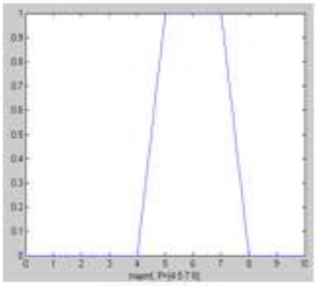
Figure 3
Membership Function of linguistic variable MEDIUM

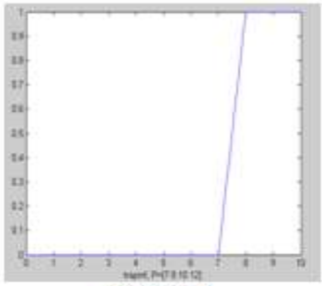
Figure 4
Membership Function of linguistic variable HIGH

Similarly three fuzzy outputs are defined using using trapezoidal membership function (trapmf) as shown in Table

Table 4.The output linguistic variable importance scale

Weak	0 - 40 %
Better	30 - 70 %
Superior	60- 100 %

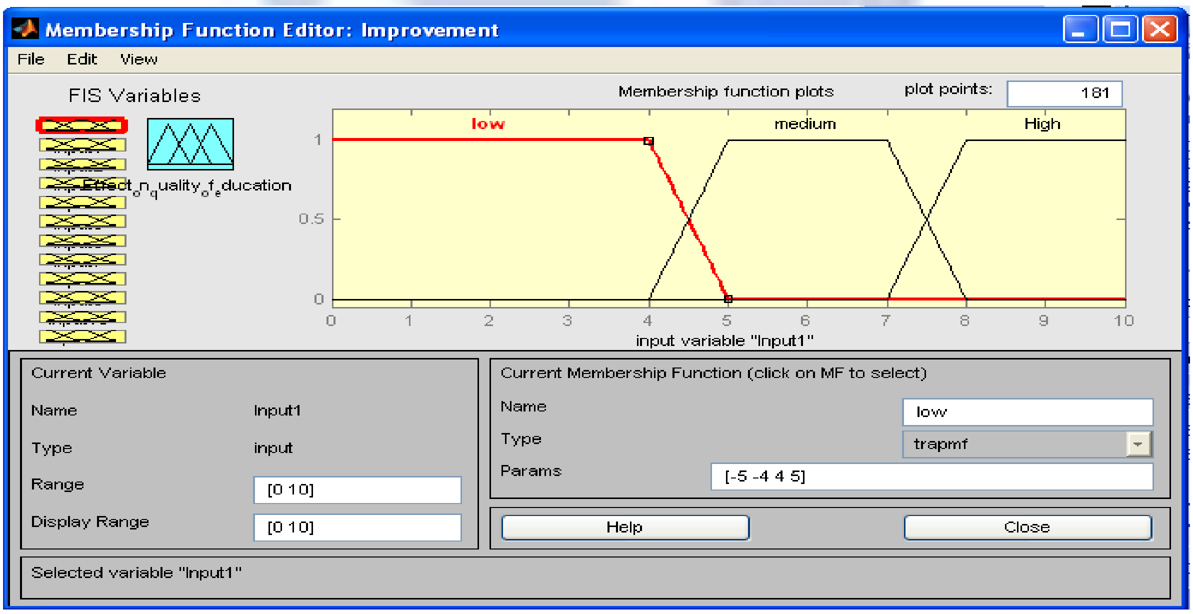

Figure 5: Membership function for input variables

Both the input and output linguistic variables are defined using Membership function editor in MATLAB as shown in figures 5and 6.

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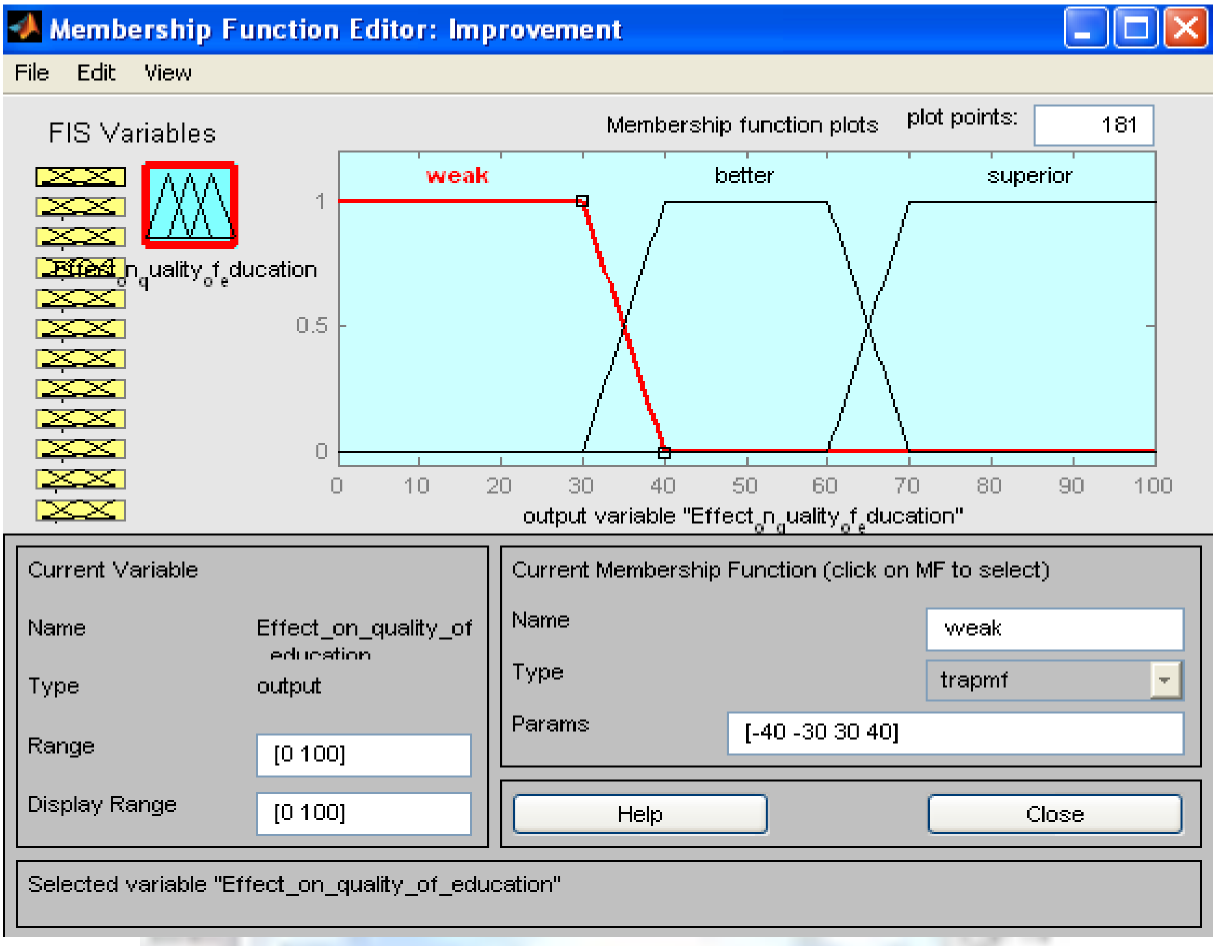

Figure 6: Membership function for output

3.2 Knowledge Representation

The knowledge acquired in an expert system must be represented in a way that ensures an accurate replication of the knowledge and the decision situation under study in a form useful for transferring the knowledge to a computer system. The goal of knowledge acquisition and representation is the transformation of problem-solving and decision-making expertise from knowledge source into a form useful for developing an expert system.

IF-THEN Rules are designed to represent knowledge in a fuzzy inference system. Each rule is a linguistic expression of the knowledge of the human expert and relates determined values of the input variable that lead to a diagnostic output. The rule contain premises or conditions in the IF clauses, and conclusions in the THEN clauses. These if-then rules statements are used to formulate the conditional statements that comprise fuzzy logic. A single fuzzy if-then rule assumes the form if x is A then y is B where, A and B are linguistic values defined by fuzzy sets on the ranges (universes of discourse) X and Y, respectively. The if-part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion. Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic e.g series of conditions can be linked by the logical operators AND and OR. AND means that conditions on both sides of the AND must be true in order for the rule to fire while OR means that one or both conditions must be true.

Rules for the proposed fuzzy inference system were designed in MATLAB fuzzy tool box Rule editor window (Figure 7).Rule was generated for each quality indicator based on minimum of x and y. Number of rules for each quality indicator depends on number of fuzzy sets. Mean value of expert opinion is used as firing strength or weightage for each rule. There are around forty-two rules that are active.

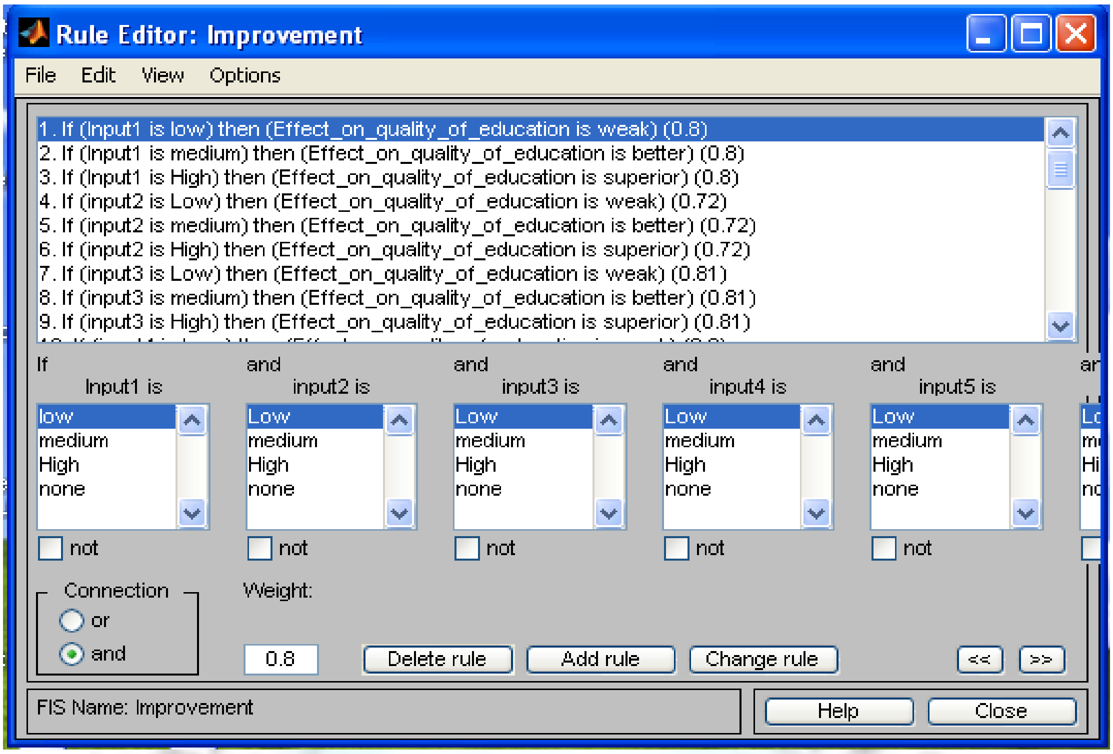

Figure 7: Rule Editor window

3.3 Verification and Validation

After designing the rule base for fuzzy inference system, rule viewer window (Figure 8 and 9) can be used to visualize the change in output i.e quality of education as the weights of various indicators of quality are varied. As an example if weight of each individual quality indicator was around 7 or 8, improvements in quality would be around 66 %.

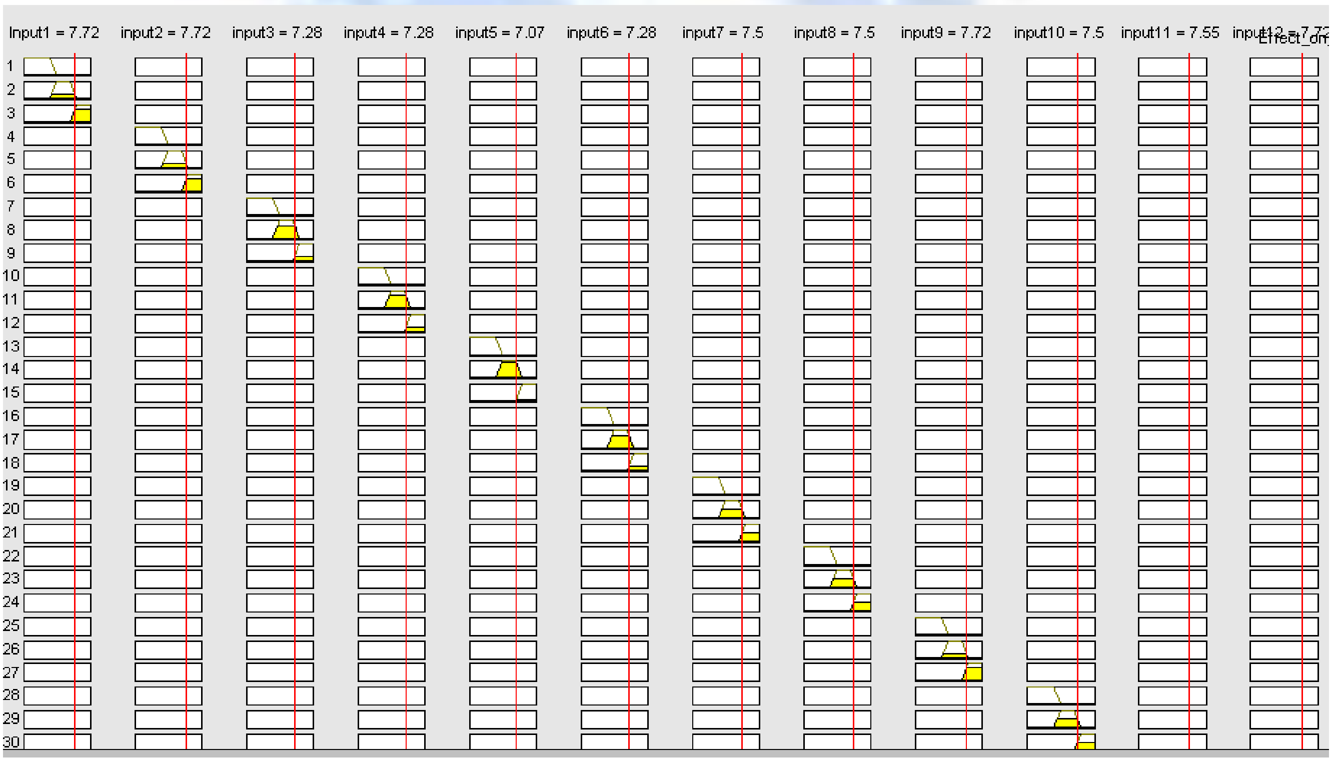

Figure 8: Rule Viewer (Effect of changes in Input)

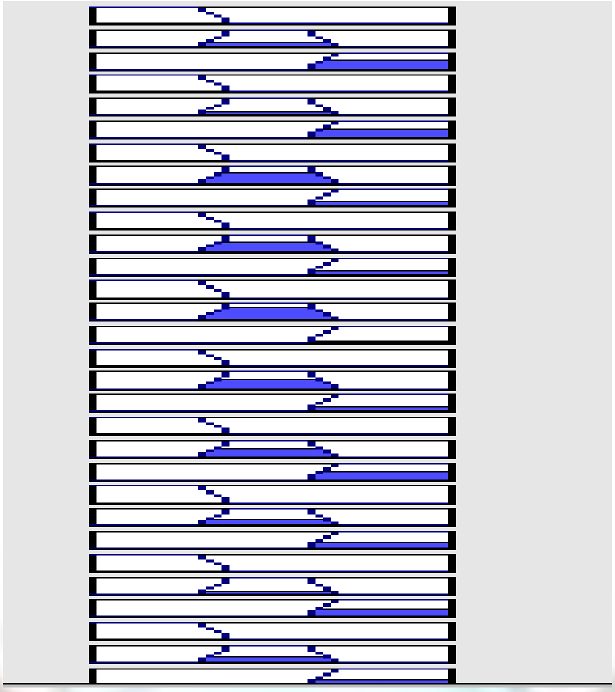

Figure 9: Rule Viewer (Output)

Surface viewer in figure 10 illustrates the effect of two quality indicators (Well Equipped laboratories and Effective Institutional Policy Design, Implementation and Monitoring) which are highly favored in the survey. The figure suggests that if both these factors are rated around 10, then the improvement in quality of higher will be around 70%.

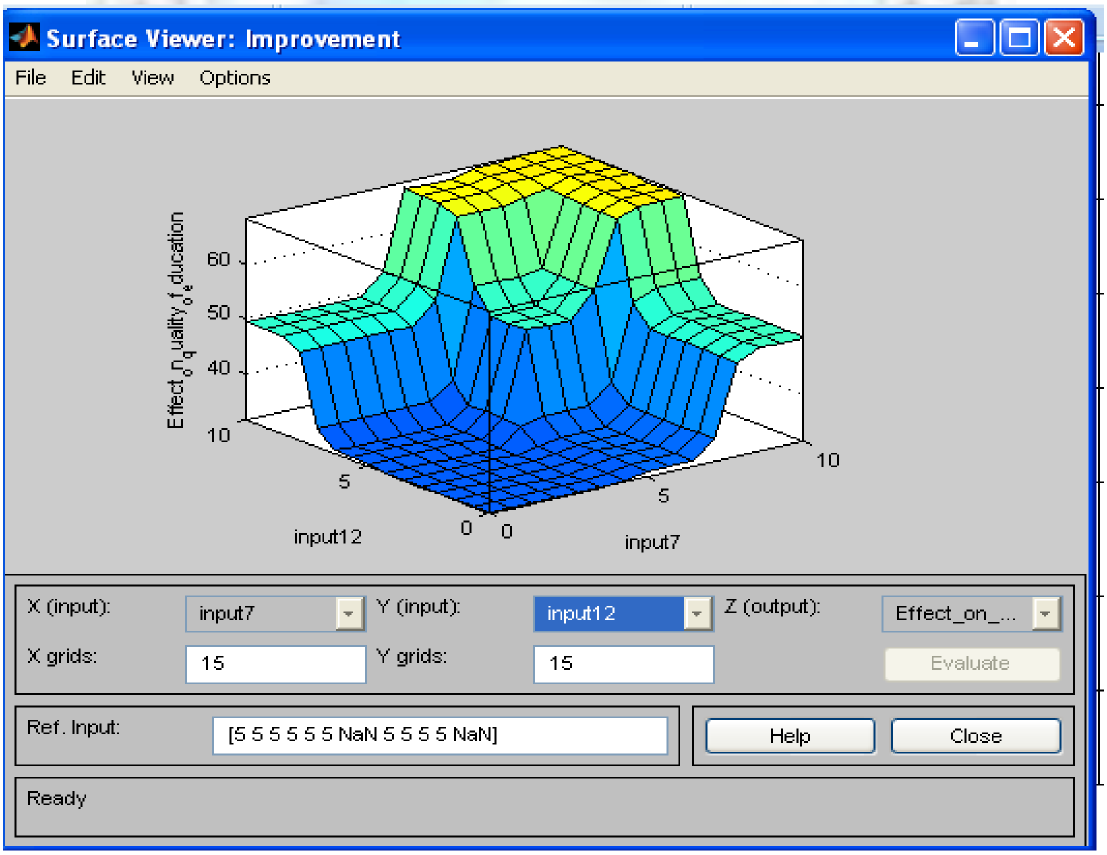

Figure 10: Surface Viewer-Surface relation between two most critical indicators & output.

Conclusion

In the context of diversification and sustained growth of higher education systems, the necessity for an assessment of formative character that would support the policy makers and other stakeholders in decision making was shown. The objective of the study was to develop a model of an expert system for decision support and quality assurance in higher education. Since such a model requires human perceptions as inputs there are chances of ambiguity, subjectivity and vagueness in the data. Moreover, some of the indicators can be analyzed and defined but often hard to measure. Therefore fuzzy logic based inference system was proposed to model the vagueness of human thinking and requirement of linguistic descriptors. Based on the knowledge acquired through literature survey and domain experts, indicators of quality were shortlisted and a fuzzy inference system was developed. Validation has been carried out using model and the final conclusion of the system was expected and consistent with the predictions of the domain expert.

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