Exploring Paradigm Shift in Evaluation in Architecture Education

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Abstract:

The education system typically employs conventional methods of performance evaluation. Marks and grades are the inevitable factors for a formal education system. It also motivates students to improve performance. The purpose of architecture education is to develop a set of skills and thought process for design and creativity. The 'approach' to architectural education differs from school to school. The design subject is the main driving force and only indispensable component of any architecture education.

The performance of the student can be evaluated by statistical analysis by grades or marks etc. but marks or grades or percentages and the results may not be always correct [6]. Measurements and evaluating are inspirable and important parts of the educational process. However, evaluation of the student's performance based on a rigid scoring criterion may not be appropriate [5].

Use of rational techniques in the field of architecture evaluation should be used innovatively to overcome the discrepancies and problems associated with it. Soft computing techniques such as 'Fuzzy Logic' may provide you the option to explore the field. The aim of this paper is to highlight and explore the usefulness of fuzzy logic in the field of architecture education and further application of it as decision support system for architects and designers for space and architecture analysis. The paper will conclude with the new paradigm in architecture education and will explore its application in the professional field.

Keywords: Architecture Education, Fuzzy Logic, Teaching and Learning, Evaluation

1. LITERATURE REVIEW

The application of fuzzy logic in the field of building architecture/design/space analysis has started by very few researchers for the last few years. Its application in engineering and management fields has reached at an advanced level. I studied a few papers to understand the evaluation and fuzzy logic relation. In a paper, an author presented a case of student performance evaluation in laboratory using fuzzy logic and concluded that the classical method adheres to a constant mathematical rule: evaluation with fuzzy logic has great flexibility [3]. At the application stage, course coordinators can edit rules and membership functions to obtain various performance values, experimented on the result of a student's performance and compare result, and obtained through the classical and fuzzy method at last

[2]. The chief aim of education institutions should provide students with the evaluation reports regarding their test/ examination as sufficient as possible with an unavoidable error as small as possible so as to make the evaluation system more transparent and fairer to the student (Biswas, 1995). In another paper, results showed that the proposed system adjusts the original scores of students based on the complexity and importance of questions based on the fuzzy inference mechanism [2]. Implementation of the fuzzy logic for various activities of assessment of the student's performance such as evaluation of answer scripts of students in an examination (Biswas, 1995; Saleh, 2009[2]. Another research result reveals that the fuzzy logic provides flexible and robustness in the evaluation process (Jamsandekar & Mudholkar, 2013). A research demonstrated the fuzzy evaluation of academic performance of students of computer application course [1]. An analysis of the above references reveals that application of fuzzy logic the decision making remains transparent. The traditional method may be subjected to chance of bias while assigning the grade or marks for the students, which significantly influences the overall grades or result.

2. RESEARCH GROUP

2.1 Aim

As mentioned earlier, design is the most important subject in architecture studies, and each semester (except training and thesis semester) the student needs to study it. For this research, I have selected third-year sixth semester students and a group of design teachers to get grades/marks for the students of my institute. The aim of the research is to demonstrate a mathematical model using soft computing methods, i.e. fuzzy logic, based on linguistic variables and rule bases to show a flexible and rational method of architectural design evaluation.

3. FUZZY THEORY

3.1 Concept of Fuzzy Logic

Fuzzy logic was introduced by the American Professor Asgar Lotfi Zadeh, when he presented a paper on 'fuzzy sets' [2], which has been used for stating imprecise concepts. It is a way to represent linguistic vagueness. Fuzzy logic is very useful for addressing real-world problems, which usually involve a degree of uncertainty. So, it can be used for explaining many human expressions or feelings [3] or may be an opinion about qualitative aspects. The most important difference of fuzzy collections and classical collection is, actually, the way of connecting a member with the community. In classical collections, a factor can be a member of a community or not, while in fuzzy collections we can use the membership level [2]. In traditional or classical or crisp set logic, a thing can be 0 (zero) or 1 (one), but in fuzzy logic or continuous set, each statement can be assumed a value between 0 (zero) and 1 (one), and this depends on the level of each member which gains in terms of its attachments. Fuzzy collection eliminates the sophistication by destroying strike limit of member division, as changing from membership to non-membership seems gradually rather than being sudden [4]. The elements of fuzzy sets not only represent true (1) or false (0) value but represent the 'degree of truth' or 'degree of falseness' for each input. Fuzzy logic is a form of artificial intelligence (AI); therefore, it would be considered a subset of AI. Since it is performing a form of decision making, it can be included as a member of the AI:

$$A = \{(x_{1,}\ \mu_A(x_1)),\ (x_{2,}\ \mu_A(x_2)),\ \ldots,\ x_{n,}\ \mu_A(x_n)\} \quad (1)$$

where X_1, X_2,…, Xn are members of set 'A' and X_n is associated with 'fuzzy index' or 'fuzzy membership' µA(xn).

Alternative representation of the fuzzy set 'A':

$$A = \left\{\frac{\mu A(x1)}{x1}, \frac{uA(x2)}{x2}, \ldots\ldots\ldots\ldots, \frac{uA(xn)}{xn}\right\} \quad (2)$$

So, traditional or classical or crisp set values [0, 1] and fuzzy set values [0, 0.1, 0.2, 0.25, 0.3, 0.375,…, 0.9, 1.0].

3.2 Crisp Set versus Fuzzy Set

In crisp set theory, a very precise boundary is there to determine whether an element belongs to a set or not. The membership value in favour of the truthness of belongingness of an element/attributes is considered 1 or 0. For example, in a given set 'A', this function assigns a value µA(x) to every x ∈ X such that µA(x) = 1 if x ∈ A, and µA(x) = 0 if x ∉ A.

The crisp characteristic function can be generalized such that the values assigned to the elements of the universal set fall within a specified range [0, 1] and indicate the membership grade of these elements in the set. There is no clear boundary in between set 'A' and its universal set 'U' and thus we cannot draw it. Such a function is called membership function and the set is defined as fuzzy set. The membership function for the fuzzy set can take any value from the closed interval [0, 1] instead of either 0 or 1 like crisp set [7].

Fuzzy set 'A' is defined as the set of ordered pair A = {(x1, µA(x1)), (x2, µA(x2)),…, (xn, µA(xn))}, where µA(x) is the grade of membership of element x in set 'A'. Greater the µA(x), the greater is the truthness of the statement that element x belongs to set 'A' [2].

3.3 Membership Function

Membership functions are used in the fuzzification and defuzzification steps of a fuzzy logic system (FLS), to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic terms. An important characteristic of FLS is that a numerical value does not have to be fuzzified using only one membership function. In other words, a value can belong to multiple sets at the same time.

3.4 Fuzzy Linguistic or Verbal Variables

An algebraic variable takes numbers as value while a linguistic variable takes ‘words’ or ‘sentences’ as value. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural languages, instead of numerical values [2], [8].

4. ARCHITECTURE DESIGN AS A SUBJECT

For the evaluation of students design performance, criteria taken into consideration were in the form of various stages as follows:

Stage 1: Study, observations of secondary data (collection and analysis) and case examples. (data collection)

Stage 2: Concept/preliminary design (concept design)

Stage 3: Final drawing set plans, form, elevation, structure etc. (final design)

Stage 4: Final jury/presentation (expression of design idea, body language, clarity of thoughts). (design jury)

Design is a problem-solving activity; during the design process students have many objectives to achieve as stages of designing. The above-mentioned four stages are showing the overall ‘design process’ at a broader level, and each stage is an outcome of the combination of many small steps. For example, stage 1 (data collection) represents the introduction to design problem, orientation lecturers, study, observation and collection of secondary data, live case study and literature study. Similarly, stage 2 (concept/preliminary design) starts with finding out design data through data analysis and area calculation with due consideration of by-laws, context, climate, concept thoughts and theory etc. In stage 3 (final design), after finalizing the concept of design and design data students may proceed to detailed design set preparation like plans, elevations, sections and form of the building with emphasis of building structure, services, circulation etc. It is the most time-consuming stage and needs to take care of the detailing part. Stage 4 is the final jury/presentation of the prepared design set in front of an external expert and internal faculty members, and the jury will assess the overall understanding of the project to the students, completion of projects and expression of design idea, clarity of thought etc.

All four stages of the design process and many small steps/components, to achieve the goal of each stages, are not linear in nature, and one needs to/should look backward and revisit/redefine the component for the refinement and robustness of design proposal at the optimum level.

5. FUZZY INFERENCE SYSTEM (FIS)

Fuzzy logic is built on the strong foundation of the knowledge of experts, and it allows the processing and handling imprecise data. It is easy to modify an FIS just by adding or deleting rules. There is no need to initiate a new FIS from starting. A FIS consist of the following four modules:

- Fuzzification transforms the system inputs, i.e. crisp numbers into fuzzy sets, with the application of membership functions.
- Knowledge Base is IF–THEN rules based on an expert’s decisions and comments.
- Inference Engine simulates the human reasoning process [6]; it is a process of formulating the mapping from a given input to an output. The mapping then provides a basis from which a decision can be made [7].
- Defuzzification has the result of reducing a fuzzy set to a crisp single valued quantity or to crisp set [7].

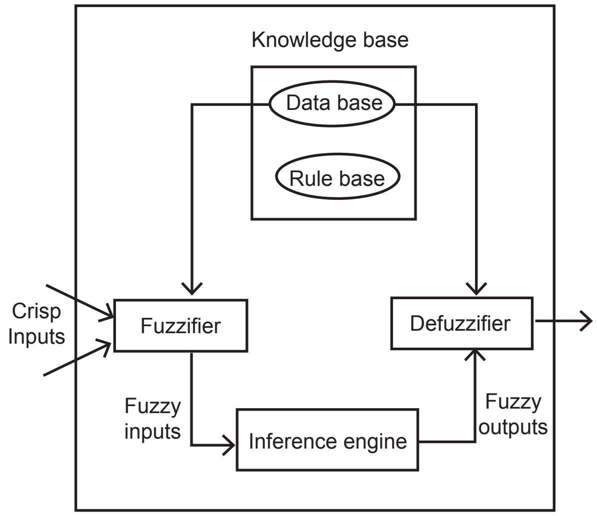


Figure 1. Basic structure of a fuzzy inference system. (*Source*: Ingoley and Bakal [2].)

5.1 Working with FIS

- In FIS, a ‘triangle-shaped’ membership function is used for all the criteria for converting the crisp set into a fuzzy set.
- For defuzzification, the ‘centroid method’ is used.
  - All four stages of design evolution are considered for the demonstration.
  - The range assigned to these four variables are 1–10 [3], [6].

6. METHODOLOGY

The fuzzy logic model comprises of following stages:

6.1 Crisp Value (Data)

The values of input variables may be collected from the subject coordinator from the record of the continual assessment/stages-wise evaluation [5].

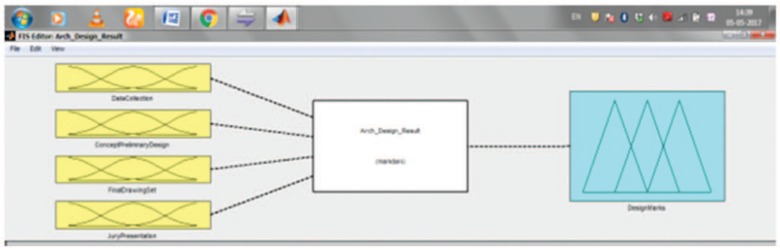
Input Variables

Internal Assessment of all 4 stages

6.2 Fuzzification (Fuzzy Input Value)

Fuzzification of four input variables is done by using variables which are similar to verbal human language such as poor, good, very good and excellent. Each input variables assigned a ‘triangle membership’ function defined by a limits as range.

Fuzzy Inference System (FIS) with Input and Output

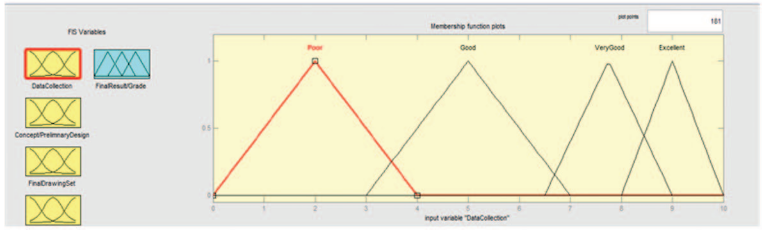


The Process of fuzzification of the four inputs and one output variables is as follows:

Defining input variables (design stages): grading /range by faculty according to linguistic variables:

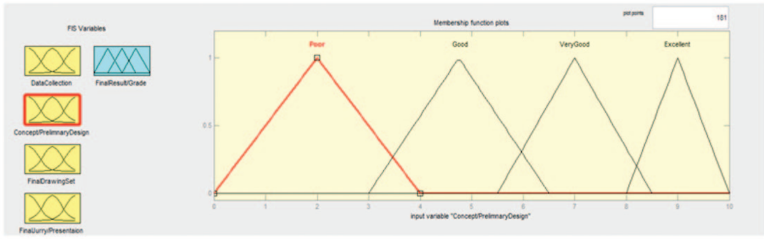
Data Collection/Analysis

S. No.	Linguistic Variables	Range
1.	Poor	0–4
2.	Good	3–7
3.	Very good	6.5–9
4.	Excellent	8–10



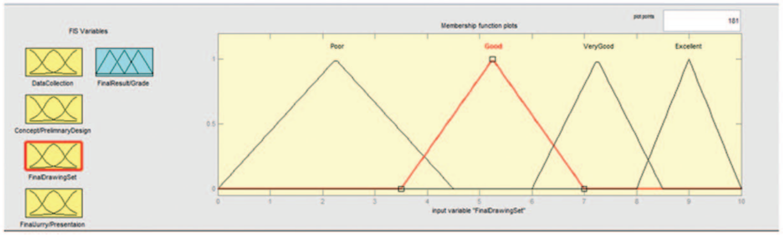
Concept/Preliminary Design

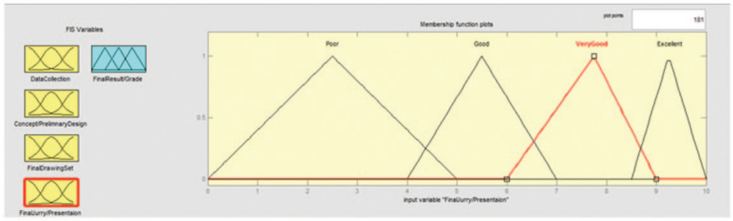
S. No.	Linguistic Variables	Range
1.	Poor	0–4
2.	Good	3–6.5
3.	Very good	5.5–8.5
4.	Excellent	8–10



Final Drawing Set

S. No.	Linguistic Variables	Range
1.	Poor	0–4.5
2.	Good	3.5–7
3.	Very good	6–8.5
4.	Excellent	8–10





Final Jury /Presentation

S. No.	Linguistic Variables	Range
1.	Poor	0–5
2.	Good	4–7
3.	Very good	6–9
4.	Excellent	8.5–10

Input Variables: Data collection, concept, final drawing set, final jury/presentation.

Output Variable: Grades/marks

6.2 Tool Used for Analysis

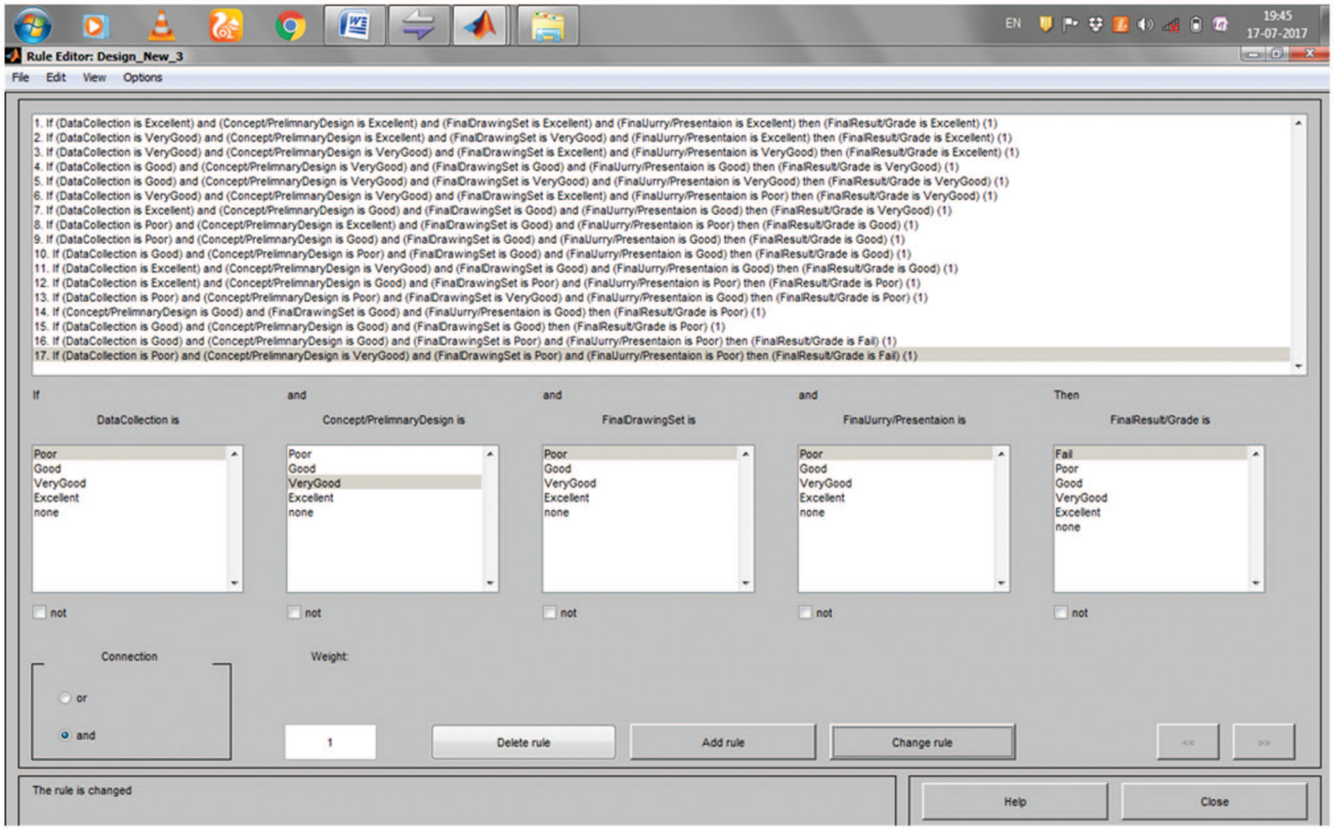
I have used MATLAB software R2014a version, Fuzzy logic toolbox provides graphical user interface and simulating FLS to get the system model for the process of fuzzification of the four inputs and one output variables.

6.3 Development of Fuzzy Rule and Inference Mechanism

The distinct fuzzy rules base for the design evaluation process for FIS are shown in Table 1.

Table 1. The distinct fuzzy rules base for the design evaluation process for FIS

S. No.	Data Collection/ Analysis ()	Concept/Preliminary Design ()	Final Drawing Set ()	Final Jury/ Presentation ()	Final Result (Output) ()	Grade
1	Excellent	Excellent	Excellent	Excellent	Excellent	A+
2	Very good	Excellent	Very good	Excellent	Excellent	A+
3	Very good	Very good	Excellent	Very good	Excellent	A+
4	Good	Very good	Good	Good	Very good	A
5	Good	Very good	Very good	Very good	Very good	A
6	Very good	Very good	Excellent	Poor	Very good	A
7	Excellent	Good	Good	Good	Very good	A
8	Poor	Excellent	Good	Poor	Good	B
9	Poor	Good	Good	Good	Good	B
10	Good	Poor	Good	Good	Good	B
11	Excellent	Very good	Good	Good	Good	B
12	Excellent	Good	Poor	Poor	Poor	C
13	Poor	Poor	Very good	Good	Poor	C
14	–	Good	Good	Good	Poor	C
15	Good	Good	Good	–	Poor	C
16	Good	Good	Poor	Poor	Fail	F
17	Poor	Very good	Poor	Poor	Fail	F



Here, I have framed 17 rules. These linguistics rules are use 'IF–THEN' statements. The rules can also be modified or deleted easily here. If several rules are active to get the same output membership function, it is required to choose one membership value. Fuzzy decision or fuzzy inference is the process by which we can get the output membership function [5]. Many authors such as Zadeh, Mamdami etc. developed various methods for fuzzy decision making and fuzzy inference. In this study, we are using technique given by Mamdami.

6.3 Defuzzification of Fuzzy Output

$$\mu_c(y) = \text{Max}_n[\min\{\mu_{A1}(\text{input}(i)).\mu_{B1}(\text{input}(j))\}]\ n = 1, 2, ..., k \quad (3)$$

Though Equation (3) determines the output membership function value for each active rule, an 'AND' operation is applied between inputs. The smaller input value is chosen and its membership value is determined as membership value of the output for the rule. This method is repeated, so that output membership functions are determined for each rule. To sum up, graphically AND (min) operation are applied between input and OR (max) operation are between outputs.

$$y^* = \frac{\int \mu_c - (y).y.dy}{\int \mu_c - (y).dy} \quad (4)$$

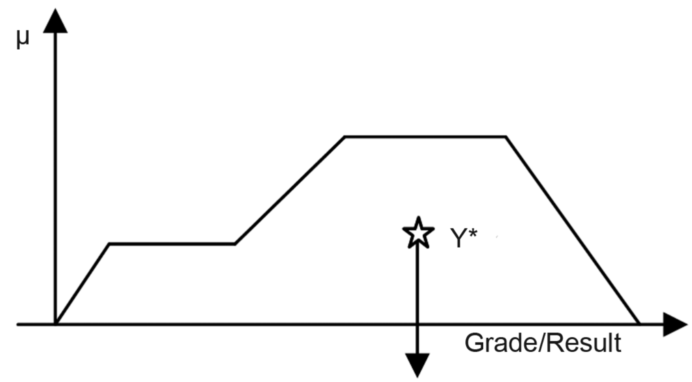


Figure: Defuzzification with Centroid method

The output variables 'V' will be the final outcome or the final result for the student. As per Table 1, input variables are represented as v_1, v_2, v_3, and v_4 and membership function of the four input variables are $\mu(v_1)$, $\mu(v_2)$, $\mu(v_3)$ and $\mu(v_4)$, respectively, for rule n = 1, 2, 3,…,k, then the membership function of the output variable V is given by the following equation.

$$\mu_v(y) = \mathrm{Max}_n\,[\min\{\mu(v_1), \mu(v_2), \mu(v_3), \mu(v_4)\}] \qquad n = 1, 2, 3, \ldots, k \quad (5)$$

The equation represents the value of membership function for output variable's final result for active rules for each input. The logical operator AND is used among the four inputs. Similar to the fuzzy linguistic variables of input, we have used the linguistic variables for output shown in Table 2.

Table 2. Linguistic variables for output

S. No.	Linguistic Variables	Grade	Range (Marks/ Numeric Value)
1.	Fail	F	0–4
2.	Poor	C	3–5.5
3.	Good	B	5–8
4.	Very good	A	7–9
5.	Excellent	A+	8.5–10

The relation between input and output variables according to the defined rules is checked using rule viewer. Rule viewer of the proposed fuzzy expert system for evaluation of architectural design is shown in Figure 2.

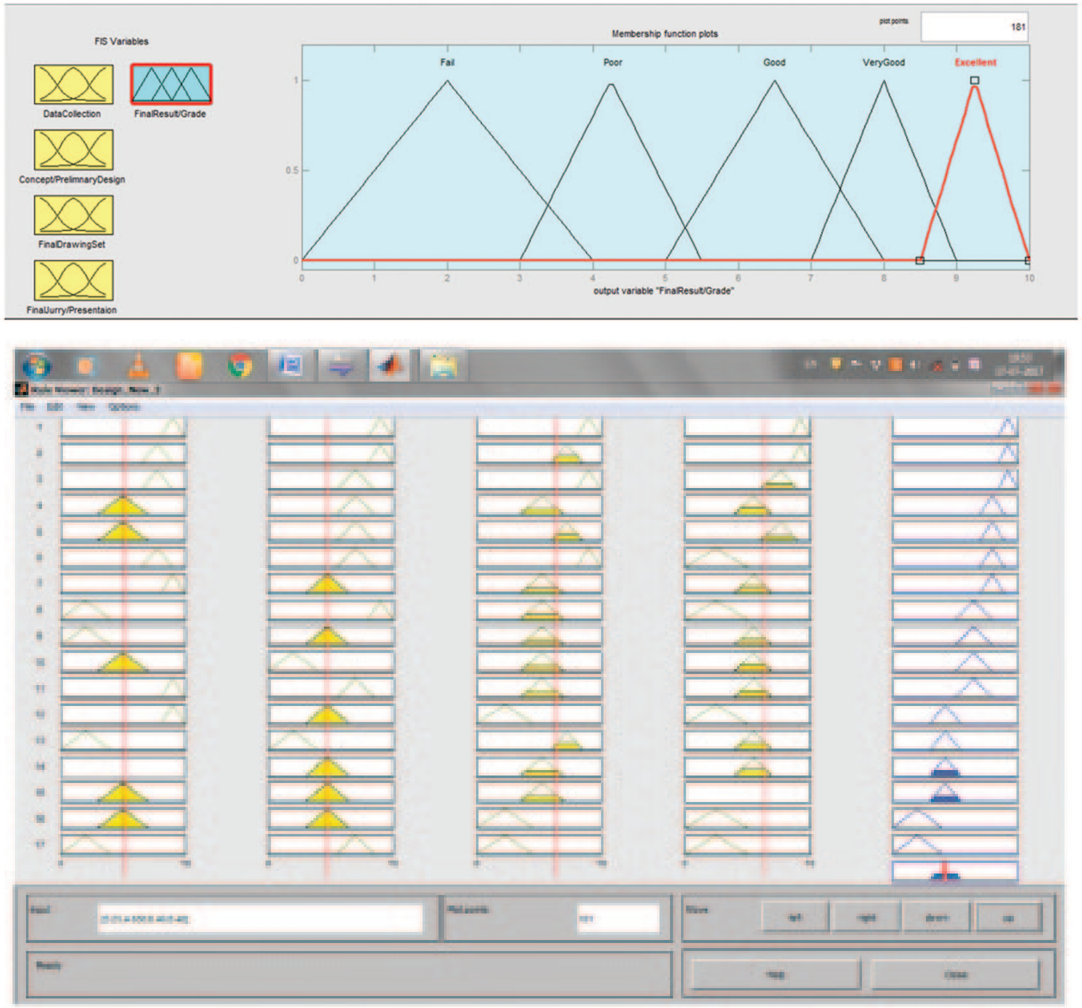


Figure 2. Rule viewer of the proposed fuzzy expert system

Surface viewer of the proposed fuzzy expert system for evaluation of architectural design for undergraduate students of architecture course is shown in Figure 3. We can see the different combinations of input variables and output results in the surface viewer.

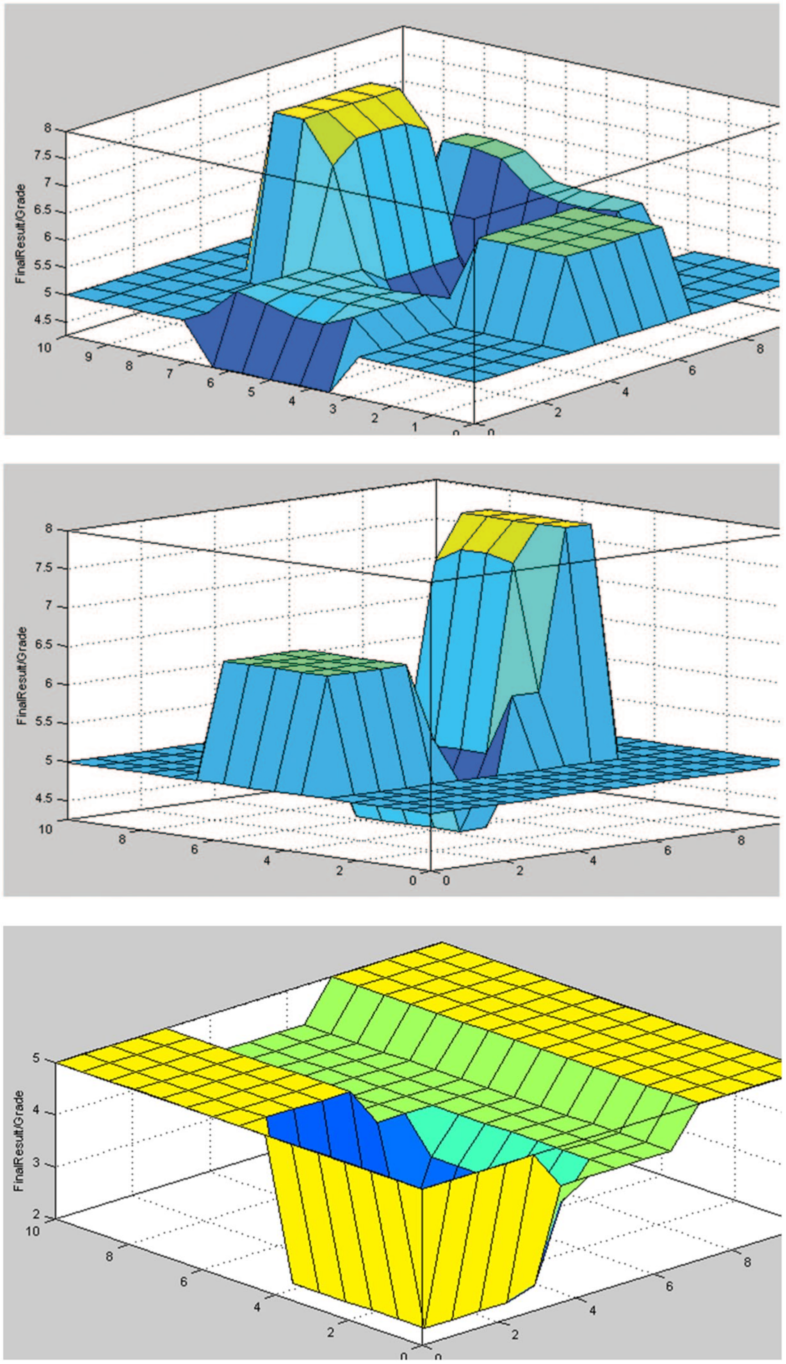


Figure 3. Surface viewer of the proposed fuzzy expert system

CONCLUSION

Most of the time it is difficult to interpolate the actual quality of the work in between grades. Also, in some cases quality may be defined in 'linguistic' terms such as poor, average, good, very good, best etc., which are associated with 'imprecision' and 'vagueness'. Here, an attempt has been made to explore the modelling abilities for the imprecise, vague and uncertain evaluation process associated with design evaluation. Every person has a tendency to practice a biased decision; we cannot overlook the biased decisions which may lead to irreversible academic result. With the application of fuzzy logic, the decision making remains transparent. The traditional method may be subjected to chance of bias while assigning the grade points for the students, which significantly influences the overall result.

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