PerformanceEvaluation of Institutes of Higher Learning: A hierarchical Fuzzy System Approach

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Abstract: **As the number of higher educational institutions is growing, the stakeholders i.e. students, parents and education managers feel the need to appropriately match the merit of a students in qualifying examinations with the relative performance ranking of the institutes. In this paper we present a hierarchical fuzzy logic based system to evaluatethe overall quality of academics of an institution of higher learning.This overall quality rating depends upon 4 main attributes:- teaching quality, research quality, infrastructure available in the Institute and performance of students. These academic quality attributes are dependent upon a number of other parameters. Thus the system for evaluating overall quality turns out to be a complex one. We propose a hierarchical system design approach that simplifies the system implementation. Hierarchical fuzzy systems are capable of dealing with rule explosion and complexity inherent in fuzzy logic based systems. In this paper we have implemented this approach in MATLAB. The hierarchical system implementation makes the performance evaluation an easy, quick and reliable task.**

Keywords- ***Overall quality, quality attributes, fuzzy logic, fuzzy modeling, teaching quality, research quality, infrastructure available, student performance.***

1. INTRODUCTION

In order to improve the performance of any system it is imperative that present performance of the system be known, weak areas and bottlenecks be identified, analysed and improved. Education Systems are very important to the growth of society. Since, their performance directly affects the social development and growth, it becomes very importantto improve the quality levels of education. In order to improve the quality of educational institutions, universities and its affiliated colleges it becomes essential that their performance be evaluated, compared, analysed and improved. This will ensure their desired contribution. Further students and parents also desire that they should be able to admit their wards in the institutions whose ranking appropriately match with their merit in qualifying examinations. The reverse is also true. The institutions with relatively higher performance ranking wish to admit students with relatively higher merit in qualifying examinations.

Lord Kelvin rightly said that"What cannot be measured cannot be improved". This is applicable to educational institutions and systems as well. Performance evaluation of a Higher and technical education institution is complex process. For providing measures for the improvement of education delivery in the academic institutions this must be measured and evaluated. Evaluation of this complex phenomenon requires the consideration and comparison of large number of complex parameters. As the number of institutions has grown very large it is very difficult for the students to compare and evaluate the academic performance of institutions. Similarly for the education managers the evaluation of institutions based on different set of parameters is very important so that they can suggest the measures and implement schemes and plans for the improvement of academics in the deficient areas. Another stakeholder of academic institution is industry which hires the produce(workforce) of it. Better the academic environment and overall academic quality better is the output i.e. better employable is the workforce. Hence evaluation of academic institutions is must in today's scenario.

One group of researchers has compared the relative efficiencies of 'comparable' institutions by using data envelopment analysis (DEA) [1-4]. Beasley's work [4] is an application of DEA to the problem of comparing university departments. McGuire et al. [5] use a Cobb-Douglas production function to measure efficiencies of 40 American research universities. Johnes and Taylor [6], on the other hand, investigate the performance of UK universities across a range of indicators. They employ regression analysis to determine if differences between universities in their teaching and research outputs can be explained by a set of variables. Fuzzy logic has been proposed to evaluate the performance of individuals and teaching quality [7, 8]. Huawang Shiet. al. [9] proposed a combination of grey evaluation method and group decision analytic hierarchy process (AHP) for teaching quality evaluation in higher institutions. Gupta [10] proposed a ranking and performance evaluation of Indian institutions of higher education based upon publication and citation data. There are good number of publications which have given research publications as the only performance measure to evaluate the performance of an Institute[11- 15].Malvezziet. al[16]proposed a tool developed to follow up and to evaluate the student learning using a fuzzy logic based model.Azzer and Shakti[17] proposed a fuzzy logic based approach to performance evaluation ofhigher education institutions. However their approach though was able to suggest the methodology yet it lacked the extensive coverage of the performance indicators (PIs) that affect the performance of university as a single unit.Ignoring the partial nature of PIs may lead to misleading conclusions about performance. A number of issues has to be considered while using PIs [18,19, 20]:

1. relevance, that is how accurately the PI measures true performance,
2. verifiability, that is if essentially similar measures or conclusions can be developed from the same data,
3. manipulability or cheat-proofness,
4. cost of collection (economic feasibility) and availability of data,
5. level of aggregation, that is the level of assessment,
6. institutional acceptability by the people of the relevance and fairness of the basis on which PIs are derived, and
7. relation to other indicators in measuring the same or similar aspects of performance.

This paper presents a hierarchical fuzzy logic based approach to evaluate the performance of institutes of higher learning. Hierarchical systems are capable of dealing with rule explosion and complexity inherent in large fuzzy logic based systems.Thus, enabling the practical implementations of large, highly nonlinear and complex systems.

This paper is divided into four sections; section 1 presents the motivation, section 2 of this paper introduces parameters or performance attributes which governs the performance of educational institutions. Section 3 presents a hierarchical fuzzy logic based system, itscomputer implementation in MATLAB, simulation and subsequent results. Conclusions are drawn in section 4.

2. PERFORMANCE ATTRIBUTES

Due to large number of attributes academic evaluation of institutes is a very complex and difficult to implement process. Further being subjective in nature it is very difficult to quantify the values of these attributes/ parameters. The attribute list presented here has been based upon[21] is, by no means, exhaustive but includes typical indicators. In order to evaluate the performance of an institute of higher learning /university we grouped the performance parameters into four major groups namely (1) Infrastructure available in the institution,(2) Teaching-Learning quality (3) Research work and its quality (4) Student performance.The Table 1 below lists these groups with attributes and parameters that contribute to each of the groups.

Table 1. Performance Attributes

2.1. *Infrastructure available in the institution:*--We identified the following main factors/ attributes in this category which have more impact on the university/ institution performance

Parameters	**Contributing Factors**
A - Labs and Workshops	(i) Number of Labs and workshops available for experiments. (ii) Availabilty of Latest instruments. (iii) Internet Facility (iv) Utilization of these laboratories and workshops.
B - Class Room and Tutorials, discussion rooms	Number of class room Smart Board, Projector, Tutorial, tables (per students other aids) their utilization.
C - Library (Book, Journals)	(i) Number of Books per student available (ii) Number of Computers per student available (iii) Sitting space (v) Journals- National /International (vi) E Journals (vii) Utilization
D - Other Facilities	Computer facility for students, Internet access and working hours, hostel and canteen facilities, Transport facility etc.

2.2. *Teaching-Learning Quality*:---In this category we selected following main factors that governs and affects the teaching-learning process quality of an institution

A-Teaching-Learning Process	(i) Depth of Knowledge(DOK) (ii) Power of Expression(POE) (iii) Command Over the Language(COL) (iv) Regularity(REG) (v) Punctuality(PUN) (vi) Delivery & Presentation skills. (vii) Fairness in evaluation of assignments/examinations.
B-Student/Teacher ratio	Ratio of teaching faculty like Professor, Associate Professor & Assistant Professor in the departments/Institute.

C-Teacher Training/Updation	(i) Training courses/ workshops organised Independentlyor incollaboration. by the institute. (ii) Workshops/Training programs attended by teachers.
D-Audio/Visual aids used /Teaching Techniques	(i) Seminars/expert lectures delivered (ii) Presentations on projector. (iii) Audio/visualaids used (iv) Class quizzes / Group Discussions organised.

2.3 ***Research Work and its Quality*****:**---In this category we identified following attributes which contribute to the performance of Educational institutions

A - research orientation	Research guidance (Number of M.Tech/Phd students qualified by faculty, persons engaged in researchand research environment.
B - research publications	Research papers (Conferences National / international, Journals, citations, recommendation, books, patents, Awards.
C - research projects, Conferences/ seminars national/international/local state level	(i) Number of Research projects. (ii) Number of National /InternationalConferences hosted by institute or attended by faculty. (iii) Industry tie ups and consultancy

2.4. ***Student Performance*****:**--- Following are the main attributes considered under this heading for evaluating the quality of an academic institution:

A - Placements	(i) Number ofstudents placed in various companies. (ii) Companies visited for Placements. (iii) Placement tie ups (iv) level of placements (pay package)
B - Pass Percentage	(i) Pass percentage in term end examinations/ completed course (ii) Merit positions (iii) University top positions.
C - Admission preference	(i) Student demand (ii) Admission cut off (iii) Total applicants, seats filled percentage, number of applicants could not get seats. (iv) % marks for the students admitted.

3. THE PROPOSED HIERARCHICAL MODEL

3.1. For the performance evaluation of institutions of higher learning, a system is developed using hierarchical fuzzy logic based approach. A fuzzy model can be represented with the help of block diagram as shown in Figure 1 below[22-26]. There are four major modules of the system. The fuzzification module transforms the crisp input(s) into fuzzy values. These values are then processed in fuzzy domain by inference engine based on the knowledge base (rule base and procedural knowledge) supplied by the domain expert(s). Finally the processed output is transformed from fuzzy domain to crisp domain by defuzzification module.

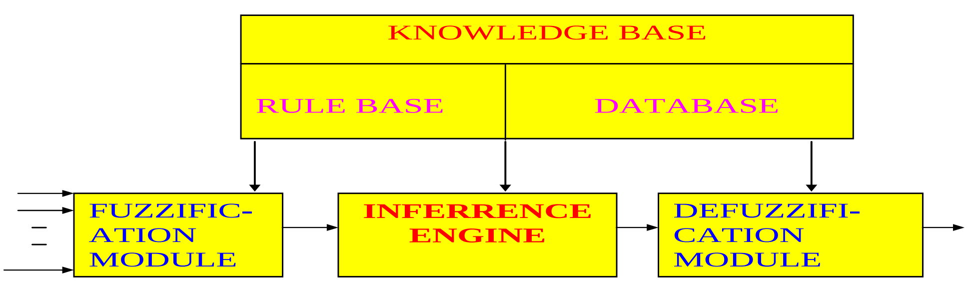

Fig 1: A Fuzzy System

A fuzzy model performs its computing in the following 5 steps [27]:

STEP 1.*Fuzzification Of The Inputs:*

Fuzzification is the process of transformation of crisp values to the corresponding values in fuzzy domain (fuzzy values). In this step fuzzifier takes the inputs and determines the degree to which they belong to each of the appropriate fuzzy sets via membership functions. The input(s) is always a crisp numerical value.

STEP 2.*Apply Fuzzy Operators*

Usually the antecedent of a given rule has more than one part, hence, the fuzzy operators (t-norms and s-norms) are applied to obtain one number that represents the result of the antecedent for that rule. This number will then be applied to the output function. The input to a fuzzy operator is two or more membership values from fuzzified input variables. The output is single truth-value. Two commonly used fuzzy operators are MIN (t-norms) and MAX operators (s-norms). We have used MIN operator in this work.

STEP 3.*Apply Implication Methods*

The shaping of the consequent based upon the antecedent is termed as implication. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set (i.e., output of a fuzzy operator). Implication is applied for each rule. There are large number of implication operators such as Mamdani, Larsen, Zadeh, Lukasiewicz,Godlien etc. [22, 23] available to the designers.

STEP 4.*Aggregate All Outputs*

Aggregation is process by which several fuzzy sets are combined in a desirable way to produce a single fuzzy set. Aggregation is obtained by combining all the fuzzy sets that represent the output of each rule into a single fuzzy set. Aggregation only occurs once for each output variable. For our model the input of the aggregation process is the list of truncated output functions returned by the implication process for each rule. The output of the aggregation process is one fuzzy set for each output variable.

STEP 5.*Defuzzify*

Defuzzification transforms the fuzzy values to crisp values. The input for the defuzzification process is a fuzzy set and the output is a single crisp number. Given a fuzzy set that encompasses a range of output values, one number needs to be returned thereby moving from a fuzzy set to a crisp output.

The process of defuzzification in fuzzy systems is not a standard one. There are numerous defuzzification methods available; however the most popular methods are [28-31]:

a) Centre of Gravity/Centre of Area/Centroid
b) Centre of Sums
c) Height defuzzification
d) Centre of largest area
e) Min-Max approach
f) Weighted average

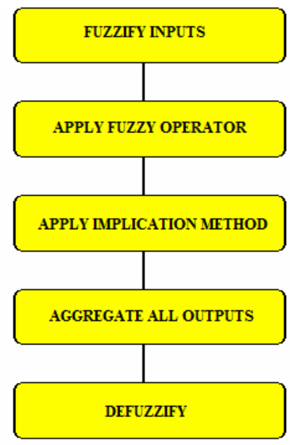

Fig 2: Fuzzy Inference System

The Inference Process

Three most commonly used inference mechanisms are [20], Mamdani, Larsen, and TSK style inference.We have used ***Mamdani-style*** inference system for our proposed hierarchical model.

3.2 Block Diagram Of Hierarchical Fuzzy Logic Based System

The complete block diagram of the proposed hierarchical fuzzy logic based system is given below in Fig-3. Each block in this figure is a complete fuzzy system in itself. First layer in this hierarchical system consists of four fuzzy systems having a total of 14 inputs. Each input is having four membership functionsis fed directly to fuzzy system to get the output. The output of these independent fuzzy systems namely TEAHCING QUALITY, RESEARCH QUALITY, INFRASTRUCTURE AVAILABLE and STUDENT PREFRENCE are given as input to the fuzzy system in the 2^{nd} layer whose output gives the overall quality of the institution. This system is designed for 14 different parameters contributing to the academic quality of an institution as input and its overall quality as output. Using this hierarchical model the complexity of the system is highly reduced as the total number of rules required for the similar single fuzzy system is approximately 268435456 which is reduced to 721 rules only.

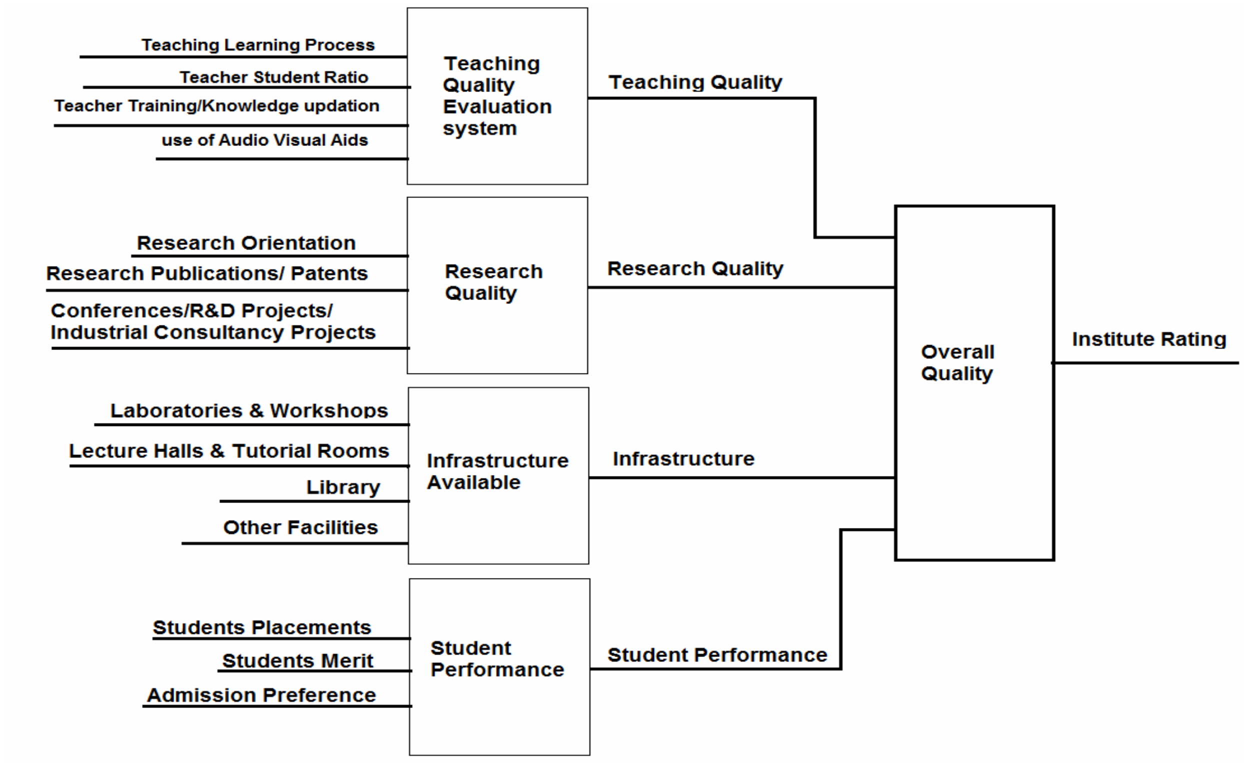

Fig 3: Hierarchical Fuzzy Logic Based System For Institution Rating

Figure 3 depicts block diagram of the complete fuzzy system.Each block of the figure 3 is a complete fuzzy system by itself. The first block named***teaching quality evaluation system*** has four inputs namely teaching learning process (TLPro), teacher student ratio (TSR), teacher training/updation(TU) and audio/visual aids or Teaching Techniques(TT) used. Its output is named as ***teaching quality(TQ)***as mentioned below in the Figure 4.

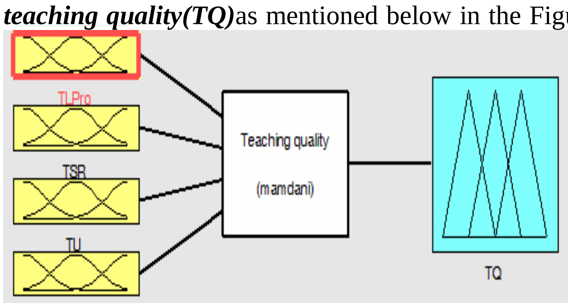

Fig 4: Teaching Quality Sub System

As far as the inputs to figure 4 are concerned, the universe of discourse for all these inputs has been fixed between 0-10 and this whole range of universe of discourse was partitioned into four membership functions as shown below in figure 4(a-d):

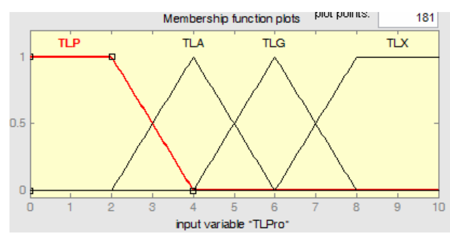

Fig 4(a): Teaching-Learning Process

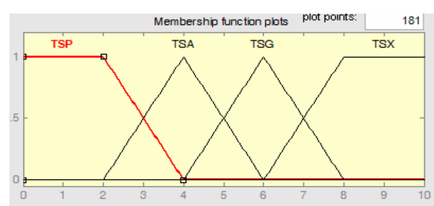

Fig 4(b): Teacher/Student Ratio

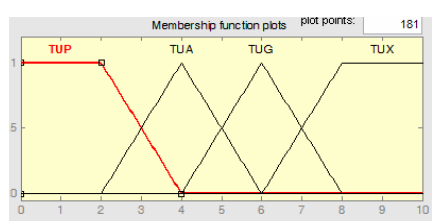

Fig 4(c): Teacher Training/updation

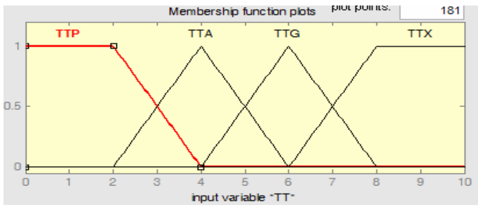

Fig 4(d): A/V aids used /Teaching Technique

Based upon these inputs the output variable of this block was considered to vary between 0 to 10. The universe of discourse for output was partitioned into three membership functions as shown in the figure number 4(e) below,. The output is designated as ***overall teaching quality(TQ)***.

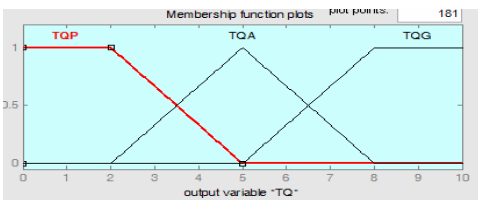

Fig 4(e): Out put Teaching Quality

The knowledge base of this module consisted of 256 rules and knowledge to this system was given in the form of if-then rules such as

if (TLPro IS TLP) AND (TSR IS TSP) AND (TU IS TUP) AND (TT IS TTP) THEN (TQ IS TQP)

if (TLPro IS TLG) AND (TSR IS TSG) AND (TU IS TUP) AND (TT IS TTX) THEN (TQ IS TQA)

if (TLPro IS TLA) AND (TSR IS TSA) AND (TU IS TUX) AND (TT IS TTG) THEN (TQ IS TQA)

if (TLPro IS TLX) AND (TSR IS TSX) AND (TU IS TUX) AND (TT IS TTX) THEN (TQ IS TQG)

—— —— ——

The next block in the figure 3 is ***fuzzy sub-system named Research Quality,***has three inputs namely Research orientation(RO), research publication (RP) and research conferences(RC) organized/ industrial consultancy/ Design and Development projects carried out. The output of this block has been designated as***Research Quality of Institution(RQ)***as shown in the figure 5 below:

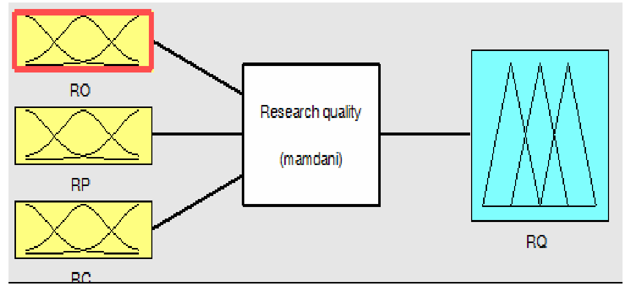

Fig 5: Research Quality Sub System

The range of universe of discourse for all these inputs has been identified between 0-10 and this universe of discourse was partitioned into four membership functions such as poor, average, good and excellent as mentioned below in fig 5(a-c)

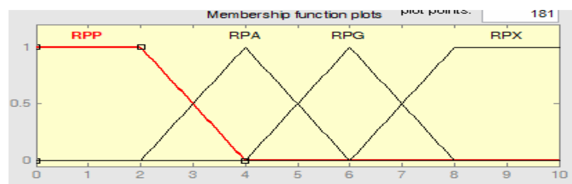

Fig 5(a): Research Orientation

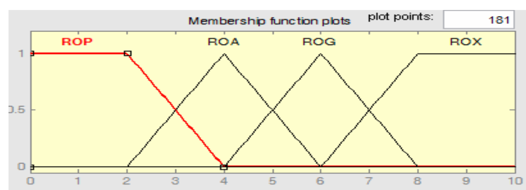

Fig 5(b): Research Publication

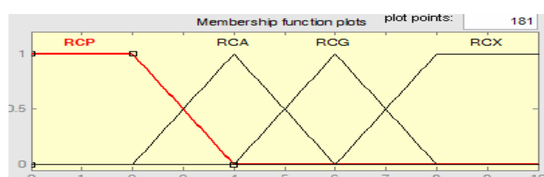

Fig 5(c): Research Conferences

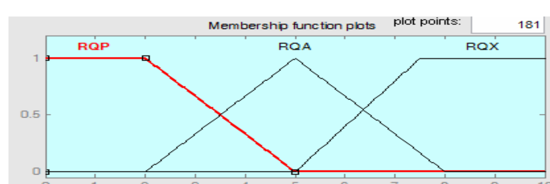

Fig 5(d): Output Research Quality

based on these inputs the output variable of these block was considered to vary 0 to 10 and output universe of discourse was partitioned into three membership functions as shown inFig 5(d)***Output Research Quality (RQ)***.The knowledge base of this module consisted of 64 rules.

Block named infrastructure available in the figure 3 is a fuzzy subsystem with four inputs namely Lab and Workshops(ILW),Classroom and Tutorials(ICT), Library(ILB) and Other Facilities (IF)availableand ***total infrastructure available(INFRA)as output*** as shown below in figure 6 below.

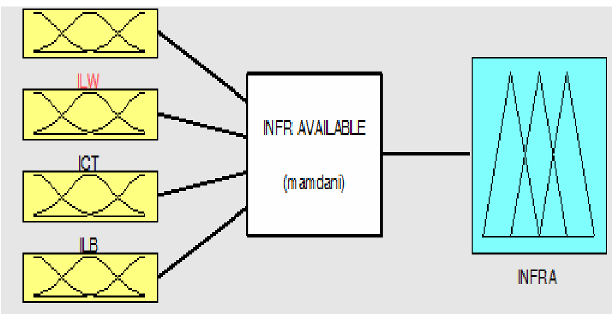

Fig 6: Infrastructure Available Sub System

The universe of discourse for all inputs (ILW),(ICT),(ILB) and (IF)has been identified between 0-10 and this universe of discourse was partitioned into four membership functions. Figure 6(a) shows the membership functions for input variable Lab and Workshop available to the students.

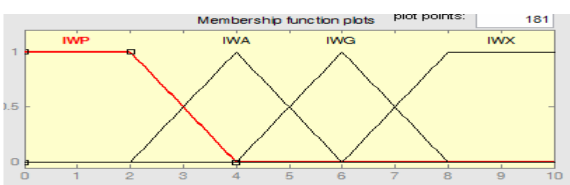

Fig 6(a): Lab and Workshops available

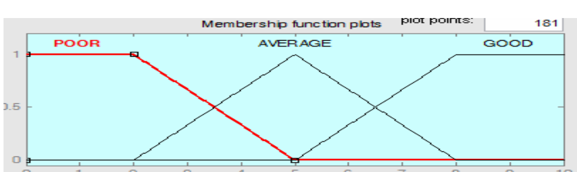

Fig 6(b): Out put INFRA available

the output of this system is total ***infrastructure available (INFRA)*** was considered to vary from 0 to 10 and output universe of discourse was partitioned into three membership functions namely POOR, AVERAGE AND GOOD as shown in figure 6(b). The knowledge base of this module consisted of 256 rules.

In figure 3 block named **Student Performance** is a fuzzy based sub system with three inputs namely ***student's placements (SP), students merit/pass percentage(SM), admission preference (SA) and overall student performance (SPO) as output***.

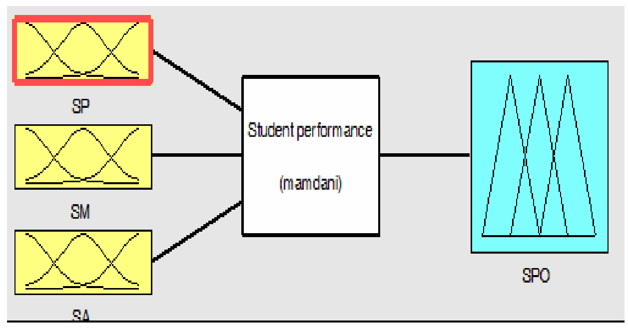

Fig 7: Student Performance Sub System

The range of universe of discourse for all the inputs mentioned above in the system has been fixedfrom 0 to 10 and this complete range was partitioned into four membership functions. Based on these inputs the output variable***overall student performance*** of this block was considered to varybetween 0 to 10. The output universe of discourse was partitioned into three membership functions. The knowledge base of this module consisted of 64 rules.

3.3 Simulation and Results

The above proposed model was implemented using fuzzy logic toolbox of MAT-LAB and all the blocks were integrated through another MATLAB script. Block named***overall quality in the figure 3*** is a complete fuzzy system with four inputs namely ***Teaching Quality(TQ), Research Quality(RQ), Infrastructure Available(INFRA) and Students Performance(SPO),*** and Overall Quality of institution/institute rating as output. The output of four fuzzy systems was given as input to the final fuzzy system as shown in the figure 8 :

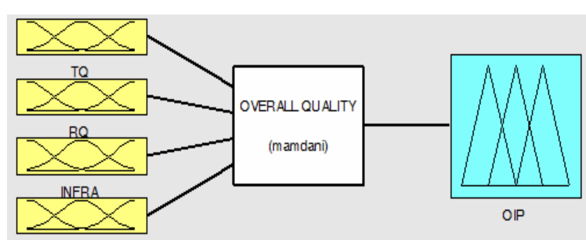

Fig 8: Overall Quality Sub Ststem

For the "OVERALL QUALITY" module the universe of discourse for all the 4 inputs ranged from 0-10 with three membership functions for each input, namely poor, average and good. Based on these inputs the output variable of this block was considered to vary between 0 to 10 and output universe of discourse was partitioned into six membership functions namely ***overall quality poor(OQP)***, ***overall qualitybelow average(OQBA), overall quality average(OQA), overall quality above average(OQAA), overall quality good(OQG), overall quality excellent(OQX)***. as shown below in figure 8(a)

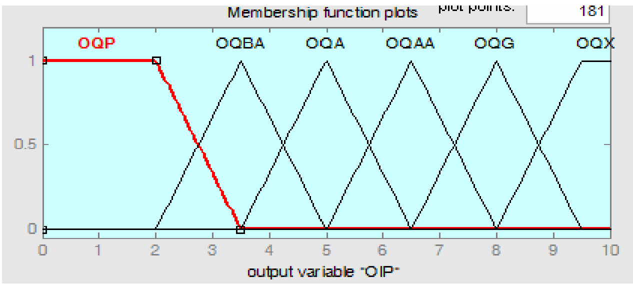

Fig 8(a): Overall Quality/ Institute rating

The knowledge base of this module consisted of 81 rules. The surface view of the overall quality of the system is given in the Figure 9 .

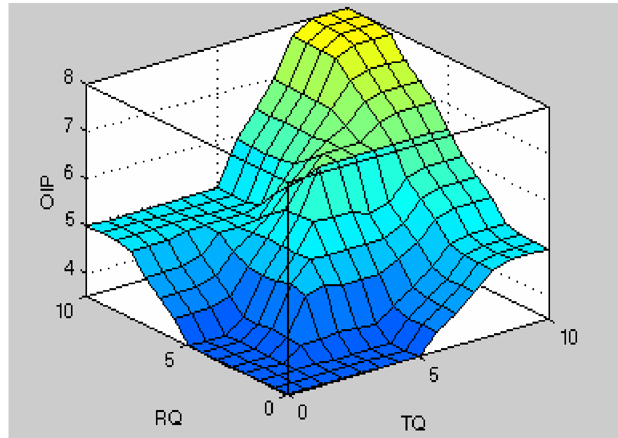

Fig 9: Surface View of the Overall quality fuzzy system

The performance of the system was evaluated on a given set of parameters e.g. for a given set of following inputs and the output was observed to be as given in figure 10.

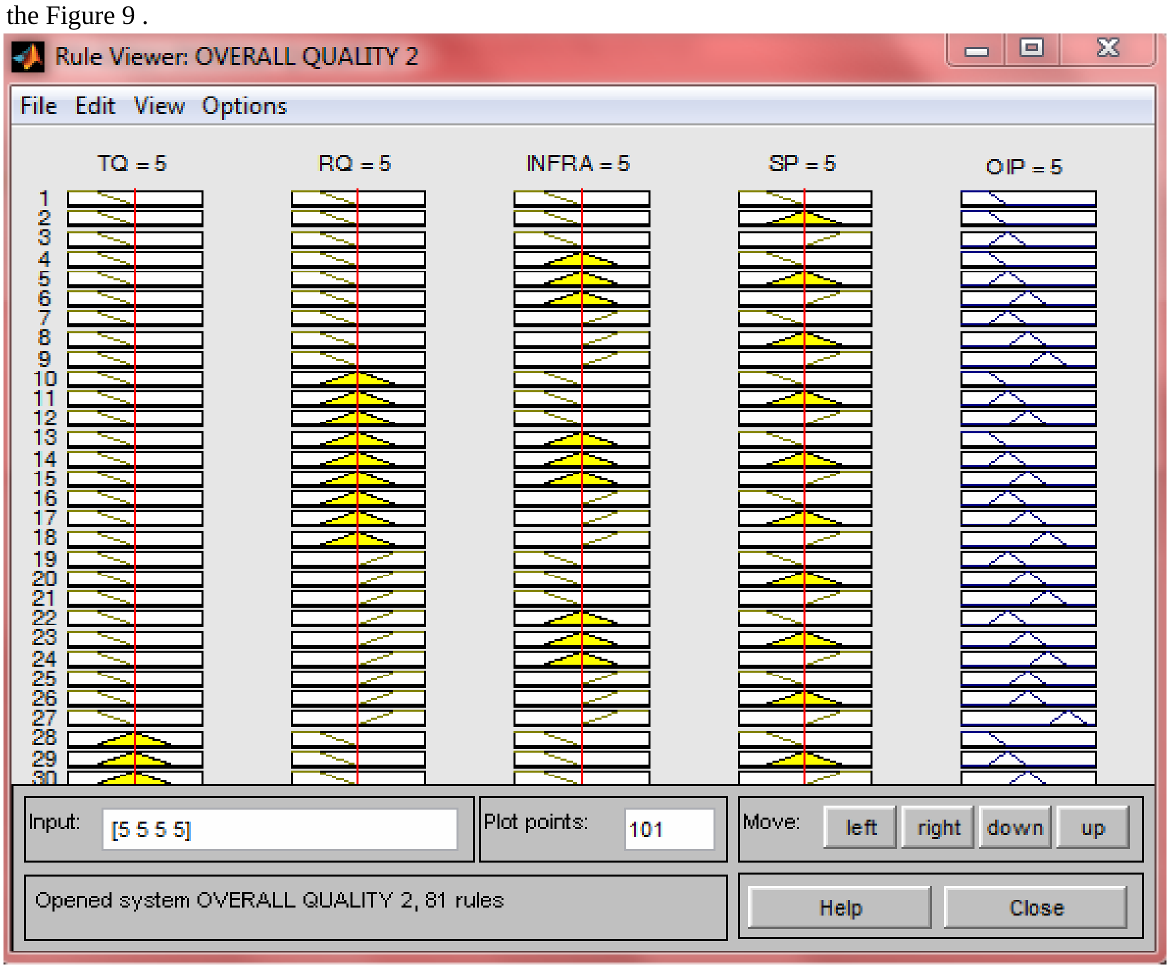

Fig 10: Screen shot of the rule viewer

3.4 Implementing Hierarchical Fuzzy System (MATLAB SCRIPT):

```
clearall;
clc;
x1= [5 5 88];
x2= [4 7 6 8];
x3= [6 8 9];
x4= [9 8 7];
x1 = x1';
fis = readfis('INFR AVAILABLE');
INFRA = evalfis(x1, fis,1);
x2 = x2';
fis = readfis('Teaching quality');
TQ = evalfis(x2, fis,1);

x3 = x3';
fis = readfis('Research quality');
RQ = evalfis(x3, fis,1);
x4 = x4';
fis = readfis('Student performance');
SPO = evalfis(x4, fis,1);
y4 = [INFRA TQ RQ SPO]';
fis = readfis('OVERALL QUALITY');

OIP = evalfis(y4, fis,1)
```

With a specific set of following 14 inputs:
[5 5 8 84 7 6 86 8 99 8 7]
The system computed 7.892 as the overall rating of the institute.

4. CONCLUSIONS

Performance evaluation system of institutes of higher learning is a complex process due to large number of input parameters. Since, these systems are highly non-linear, complex and subjectivesystems,enumerating performance with classical approaches is a very tedious task. Soft computing based approaches can efficiently handle such complexities and nonlinearities. Hierarchical systems are capable of reducing model complexity so as to deal with large number of input parameters. Fuzzy logic based hierarchical approach was preferred in this case as it efficiently reduced the number of rules compared to conventional fuzzy system approach. For the system under consideration the conventional fuzzy systemneeded about 268435456 number of rules. The use of hierarchical approach has reduced the number of rules to 721. Thus, reducing the system complexity significantly. This system with 721 rules is quitemanageable whereas it is very difficult to implement system with more than 268 million rules. The proposed system will be of practical use for the states having the universities affiliating hundreds of colleges.Performance evaluation of all these institutions will provide the academic rating of theseinstitutions which will help the students and their parents to choose the institution with higher performance according to the merit of the student. We believe that this proposed methodology will be helpful for the education institution managements to analyse their performance, identify their weakness and bottlenecks to initiate remedial measures so as to improve their performance; such that they are able to deliver quality education to their students, attract higher merit students, thus contributing their role as education provider for social growth and development. For the education mangers at university andstate/national level this system will be helpful in providing overall comparative rating of all the institutions operating under their domain to analyse the weak area, upon which they should focus in the future. Thissystem will enable them in preparing guidelines for future polices and guide the affiliated institutions about improvements to be done in future. Relative performance evaluation facilitates the close look and monitoring of the institutions not delivering quality education as per the expectation of society.

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