A Cascaded Fuzzy Inference System for University Non-Teaching Staff Performance Appraisal

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Abstract—Most organizations use performance appraisal system to evaluate the effectiveness and efficiency of their employees. In evaluating staff performance, performance appraisal usually involves awarding numerical values or linguistic labels to employees performance. These values and labels are used to represent each staff achievement by reasoning incorporated in the arithmetical or statistical methods. However, the staff performance appraisal may involve judgments which are based on imprecise data especially when a person (the superior) tries to interpret another person's (his/her subordinate) performance. Thus, the scores awarded by the appraiser are only approximations. From fuzzy logic perspective, the performance of the appraisee involves the measurement of his/her ability, competence and skills, which are actually fuzzy concepts that can be captured in fuzzy terms. Accordingly, fuzzy approach can be used to handle these imprecision and uncertainty information. Therefore, the performance appraisal system can be examined using Fuzzy Logic Approach, which is carried out in the study. The study utilized a Cascaded fuzzy inference system to generate the performance qualities of some University non-teaching staff that are based on specific performance appraisal criteria.

Keywords—Performance Appraisal, Cascaded Fuzzy Inference System, University Non-Teaching Staff, Sensitivity Analysis, Gaussian MF, Fuzzy Rules

1. INTRODUCTION

The major assets of a university are manpower, money, machine and time. The manpower, while serving as the major driver of the other assets has three components, namely academic staff, administrative staff and technical staff. It is proven that the poor management of the university staff often leads to the poor procurement and management of the other assets. University staff performance evaluation considered as a very time consuming task. The research being reported in this paper takes a study of the performance appraisal of the non-teaching staff of a university.

Performance appraisal may be defined as a structured formal interaction between a subordinated and his superior. The appraisal also triggers to identify weaknesses and strengths of employee as well as opportunities for improvement and skills development. In most cases, per-

Manuscript received February 25, 2011; first revision July 21; accepted August 12, 2011.
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formance appraisal system is used by managers to evaluate the management of the effectiveness and efficiency of employees and/or other resources within the organization [1]. The quality of higher education can be improved with continuous emphasis on human resource development. Enhancing the quality of human resource will contribute to enhancing the standard of local higher education to the international level. University staffs are the main catalyst in achieving this objective because of their contribution in transforming the education process. Koslowski (2006) [2] mentioned in his article that currently, assessing the quality of higher education has become a major public concern due to increasing competitive pressure, finite individual and institutional resources, and increased demand for universal access. According to Rowley (1996) [3], academic staff includes teachers, researchers and managers who have a significant relationship with the learning process.

1.1 Problem

Conventional evaluation systems are representatives of structured systems that employ objective and subjective measures of evaluation. Objectives measures are quantifiable measures of performance that are typically defined by procedures. Subjective measures are less quantifiable: like leadership, presentation and problem solving skills. In some organizations the criteria for the evaluations are less quantifiable and subjective, for example in the higher education world. Usually managers, staff have a rather qualitative, or fuzzy approach. The fuzzy approach to performance appraisal allows the University to exercise professional judgment in evaluating its employees.

In majority of staff performance evaluation, the process usually involves awarding numerical values or linguistic labels to staff performance. These values and labels are used to represent the staff's achievement by reasoning using arithmetical or statistical methods. Generally these methods can be classified using nominal score and single numerical score. These numerical scores may refer to another numerical interval-value that refers to a certain category of achievement, which is equivalent to 100 percent value. However, in most situations the evaluation of staff performance may be influenced by the appraiser's experience, sensitivity and standards. Hence, the scores awarded by the appraiser are only approximations and there is an inherent vagueness in the evaluation. But, if we add emphasis to the evaluation by using fuzzy logic approach, the performance of the appraisal involves the measurement of ability, competence and skills, which are fuzzy concepts that may be captured in fuzzy terms. As a result, fuzzy logic approach can be implemented to manage the uncertainty information involved in non-teaching staff performance evaluation. The decision for promoting non-teaching staff needs further consideration in terms of a variety of criteria to ensure the quality.

1.2 Objectives

The objective of non-teaching staff performance appraisal in this proposed paper are: (1) To determine the University's strategic goal; (2) To identify the performance appraisal factors for evaluation; (3) To establish overall performance criteria and subdivision of each criterion; (4) To measure the degree of criteria satisfaction; (5) To establish evaluation hierarchy; and (6) To evaluate and validate the proposed problem.

1.3 Main Proposes

Many criteria must be considered for developing non-teaching staff performance appraisal method. Some of the criteria may be quantitative such as process skill; some may be qualitative, such as self motivation. Moreover, criteria may be conflicting and may have different importance weights for different decision makers. How to, thus, properly aggregate these criteria is and important issue.

- Each staff to be evaluated through a performance appraisal system that will be a systematic process which involved evaluating employee's perceived behavior evaluation and work achievement during the year of evaluation.
- The proposed method will be a working knowledge of the surveyed University.
- The appraisal system will have the ability to maintain the flexibility of human judgment.
- The structure of the model and the use of cascaded fuzzy logic will be described. The model is validated using data collected from an actual higher education Institutions, illustrating its high level of linguistic accuracy.
- Information is collected through the survey method. In this study interview method is conducted personally with a few decision makers who have the responsibility of making decisions for academic staff promotion. They are directors of service centers and department heads from a University at West Bengal.

1.4 Literature Review

Many researchers have used AHP in the personnel evaluation problems such as Taylor et al. and Islam et al. [4-5]. Although the aim of AHP is to capture the decision maker's preferences, traditional AHP still cannot reflect the human thinking style. Following the awareness and understanding of the concept of fuzzy sets, various studies were conducted to improve the application of fuzzy sets theory and fuzzy logic in areas of performance appraisal. Moon. et al. [6] proposed a methodology utilizing fuzzy set theory and electronic nominal group technology for multi-criteria assessment in the group decision-making of promotion screening. The study suggested that the methodology is a good method for a transparent and fair multi-criteria performance evaluation in military organizations. Pepiot. et al. [7] proposed a method, based on fuzzy logic, to recognize the value of competencies that are crucial to an enterprise. Jing. et al. [8] developed a computer-based fuzzy group decision support system (FGDSS), which included three ranking methods to provide more transparent information and help manager to make better decision under fuzzy circumstance. Andres et al. [9] proposed a linguistic performance appraisal from a competency management perspective, where there are different sets of reviewers taking part in the evaluation process that have a different knowledge about the evaluated employees. Paladini [10] presented basic concepts of fuzzy logic area used to structure an evaluation process of the performance levels of human resources who operate in both - industrial and service providing organizations.

1.5 Theoretical Review

This paper present a methodology based on cascaded fuzzy inference techniques (FIS) to enhance performance evaluation of non-teaching staff of a university. In many real-life applications, a complex process model can be decomposed into simpler, cascaded subsystems. This partitioning of a process leads to increased modularity and reduced complexity of the problem, while also making the analysis easier.

One of the main drawbacks to fuzzy modeling of systems is known as the 'curse of dimensionality', which is the exponential growth in the number of possible fuzzy rules as a function of the dimension of model input space. A hierarchical approach in which the original high-dimensional model is decomposed into series of low-dimensional sub-models connected in cascade, has been shown to be an effective way to overcome this problem since it provides a linear growth in the number of rules and parameters as the input dimension increases [11].

A special class of nonlinear dynamic systems type of study will be executed, that can be decomposed into cascaded subsystems. These subsystems are represented as Mamdani [12] fuzzy models. This class of systems is very important, as many systems are cascaded (e.g., hierarchical large-scale systems). Cascaded systems are less complex than a single fuzzy system.

If a system requires n input variables each partitioned into m membership functions, the total number of rules required to model the system by using one single fuzzy inference system is m^n. As the complexity of the problem increases, the number of required inputs increases too, requiring an exponentially larger number of rules. In order to deal with the problem rule-explosion, the development of cascaded fuzzy systems has been proposed. In cascaded systems, the number of rules increases linearly with the number of inputs rather than exponentially (Lee et al., 2003) [13]. Based on the analysis of importance of each input variable and the coupling between any two input variables, the problem of how to distribute the input variables to different (levels of) relational modules for incremental and aggregated hierarchical fuzzy relational systems was addressed (Duan et al. 2002) [14]. Campello and Amaral [15] presented a unilateral transformation that converts the proposed hierarchical model into a mathematically equivalent non-hierarchical one [2]. As a result of the uncertainty about the hierarchical model and non-linear relationship between different attributes and a goal variable, different cascade hierarchies will have different performance on decision making procedures. The option of using fuzzy output from previous layers as fuzzy input for the next fuzzy inference system presents the advantage of preserving the information about uncertainty. However, when the fuzzy set is too wide it fires several rules of the new FIS generating therefore a very uncertain result (i.e., very wide set). As indicated by Driankov and Hellendoorn (1995) [16] even areas of the fuzzy output (used as fuzzy input) with very low membership degree will fire rules and the resulting new output will be composed by sets that should not have been used. When the output is used as a crisp number with no uncertainty, only few rules will be fired reducing the uncertainty of the new result, but information is lost. As indicated by Drianlov and Hellendoorn (1995) [16], when the crisp output is obtained from the defuzzification of a non-convex set, the obtained crisp result is associated with a lower membership degree.

This paper present a methodology based on cascaded fuzzy inference techniques (FIS) to study performance evaluation of non-teaching staff of a university. This paper is arranged in as: section 2 discusses the proposed system, section 3 describes the implementation of the proposed system, section 4 gives the comparative analysis and remarks of the proposed approach. Finally, the conclusions and further research are outlined in Section 5.

2. PROPOSED SYSTEM

The main goal of this paper is to propose a new methodology to carry out performance appraisal of the university non-teaching staff. In order to analyze and organize the appraisal information from the University, a Cascaded FIS [17] with specific characteristics is proposed. Fig. 1 illustrates the components of the Cascaded FIS. The proposed Cascaded FIS is implemented using Mamdani-type inference and to defuzzify the resulting fuzzy set, the center of gravity (COG) defuzzification method is selected. The first step in using fuzzy logic within this model is to identify the parameters that will be *fuzzified* and to determine their respective range of values. The final result of this interaction is the value for each performance parameter. The important parameters were identified from the experienced personnel in a surveyed University and non-teaching staff performance was assessed for the proposed problem. It is natural for experts to have differing opinions about some parameters. To deal with this diversity, fuzzy logic is proposed in this paper.

The proposed architecture is based on the articulation of cascading fuzzy system of Mamdani type fuzzy inference system. It is based on a FIS module that contains five FISs sub-modules in cascade named "Fuzzy communication Block", "Fuzzy motivation Block", "Fuzzy interpersonal Block", "Fuzzy decision making Block" and "Fuzzy knowledge level Block". The "Fuzzy communication Block" FIS receives the characteristics (fuzzy inputs: *listening, oral communication, oral presentation and written communication*) from the evaluator; "Fuzzy motivation Block" FIS receives the characteristics (fuzzy inputs: *communication ability, negotiation ability, motivation, work culture, initiative, stress tolerance and vigilance*) from the evaluator; "Fuzzy interpersonal Block" FIS receives the characteristics (fuzzy inputs: *autonomy, self motivation, rapport building, behavioral flexibility, staff leadership, independence and sensitivity*) from the evaluator; "Fuzzy decision making Block" FIS receives the characteristics (fuzzy inputs: *adaptability, interpersonal skill, fact finding, analysis, risk taking and decisiveness*) from the evaluator while the "Fuzzy knowledge level Block" receives preferences/interests (fuzzy inputs: *problem solving, decision making, technical proficiency, professional knowledge, machine skill and process skill.*) from the user. The "Fuzzy communication Block" FIS generates categories and characteristics associated with the user such as *communication ability and negotiation ability* (fuzzy outputs); "Fuzzy motivation Block" FIS generates categories and characteristics associated with the user such as *self motivation and autonomy* (fuzzy outputs); "Fuzzy interpersonal Block" FIS generates categories and characteristics associated with the user such as *interpersonal skill, responsibility and adaptability* (fuzzy outputs); "Fuzzy decision making Block" FIS generates categories and characteristics associated with the user such as *decision making and problem solving* (fuzzy outputs); whereas the "Fuzzy knowledge level Block" FIS generates the particular user's interests (fuzzy outputs: *computer skill, knowledge transfer and analytical skill).* Each fuzzy input of the five FISs modules is represented through Membership Functions (MF) and the MFs chosen are considered *triangular, trapezoidal, gaussian,* and *gaussian-2.* These five FIS are in cascade; that is, an output (negotiation ability) from the "Fuzzy communication Block" FIS are inputs for the "Fuzzy motivation Block" and so on.

2.1 Explanation of Fuzzy Blocks

Fuzzy communication Block: Communication shows the extent to which the staff effectively conveys and receives ideas, information and direction, as well as effectively seeks to clarify and confirm the accuracy of their understanding of unfamiliar or vague terms and instructions. Clarity, oral or written communications should be evaluated.

Fuzzy motivation Block: Motivation defines the extent to which the staff builds and maintains work relationships and how they effectively address problems associated with their position. The evaluation must consider whether the staff is active in resolving workplace conflicts, the employee's willingness to undertake assigned tasks, organizational goals and endeavors.

Fuzzy interpersonal Block: This block shows the ability of staff to work in a group or as part of a team, ability to promote teamwork and harmony between all staffs and their ability to ensure that staff members are oriented to the job.

Fuzzy Decision making Block: This block shows the ability of staff to make good decisions on time, ability to adapt to change and be flexible and the ability to anticipate and avoid problems.

Fuzzy knowledge level Block: Job knowledge shows that how well the staff has necessary job skill and knowledge, has technical skills and knowledge, and that they understand how to operate machines.

2.2 Explanation of Parameter Membership Symbol

Measuring employee performance involves assigning a number to reflect an employee's performance in the identified dimensions. Technically, numbers are not mandatory. Labels such as "superior", "good", "average", "fair" and "poor" are used. But we could have just numbered them 1 through 5, and we would still need to decide what grade is appropriate for a given employee. It is often difficult to quantify performance dimensions. For example, "initiative" may be an important part of the motivation level. However, how exactly does one measure initiative. Academic administrators often face such issues when trying to evaluate a staff's performance.

Rating scale of input parameters is classified into five categories as follows:

Superior A membership symbol used for exceptional and unique performance.

Good A membership symbol used for exceeding expectations i.e., clearly and consistently above what is required.

Average A membership symbol used for meeting expectations and consistently meets the requirements of the job in all aspects.

Fair A membership symbol used for marginal performance i.e., something acceptable, but not consistent.

Poor A membership symbol used for unsatisfactory performance which does not meet the minimum requirements of the job.

Table 1 illustrates that the final output is COG, which is the center of the entire area (in the horizontal axis) of the output's MFs. By choosing the other defuzzification method, the output might yield other MF for the output than the expected one. Fuzzy inference system is of Mamdani type of inference because: (1) it is intuitive; (2) it has widespread acceptance; and (3) it is well suited to human input.

The relationship between inputs and outputs for the fuzzy IF-THEN rules are illustrated in Fig.

2, Fig. 3, Fig. 4, Fig. 5 and Fig. 6 and indicated the set of inputs considered to obtain the resulting output. The input variables to the “fuzzy communication block” in Fig. 2 are listening, oral communication, oral presentation and written communication with membership values poor, fair, average, good and superior and the output variables from the “fuzzy communication block” are communication ability, negotiation ability with membership values low, below medium, medium, midhigh and high. Similarly other fuzzy block framed in Fig. 3, Fig. 4, Fig. 5 and Fig. 6 can be explained.

Table 1. Characteristics of each of the cascaded FIS agents

	1st fuzzy block	2nd fuzzy block	3rd fuzzy block	4th fuzzy block	5th fuzzy block
Type	Mamdani	Mamdani	Mamdani	Mamdani	Mamdani
Number of inputs	4	6	6	5	5
Number of outputs	2	2	3	2	3
Number of rules	150	249	175	150	175
Defuzzification method	COG	COG	COG	COG	COG

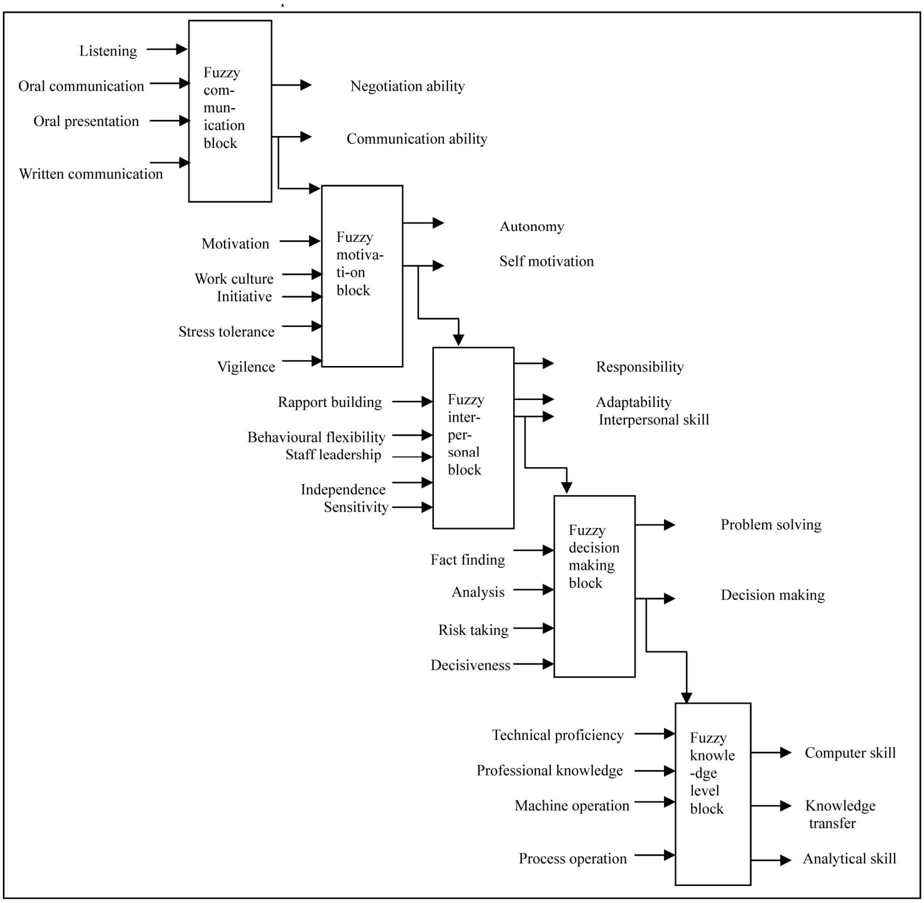

Fig. 1. The structure of the proposed Cascaded Fuzzy Inference System

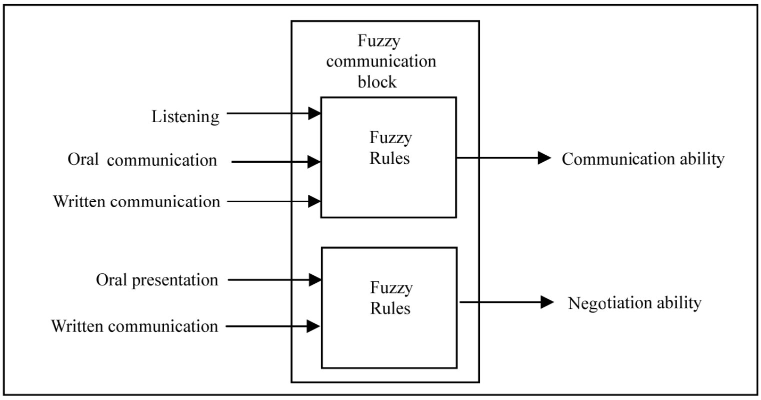

Fig. 2. Input/output relationship “fuzzy communication block”

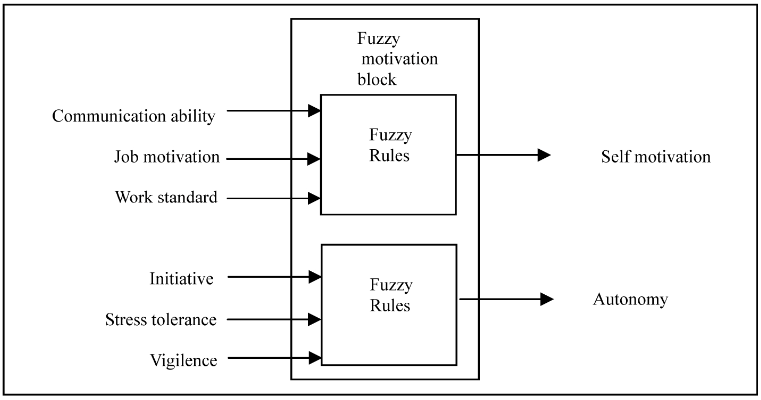

Fig. 3. Input/output relationship “fuzzy motivation block”

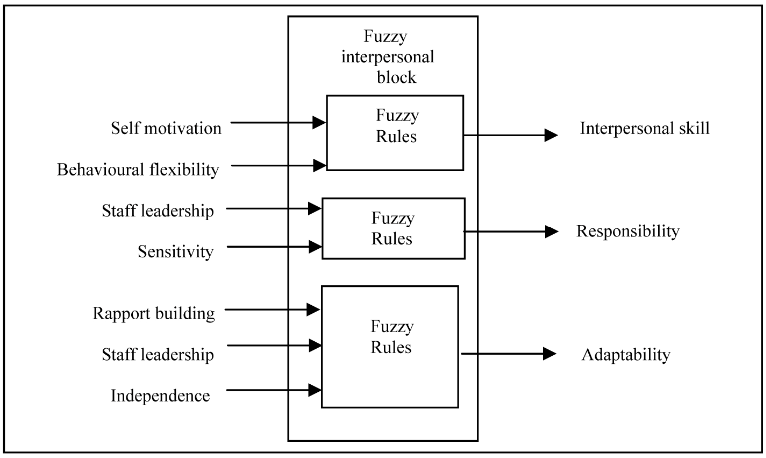

Fig. 4. Input/output relationship “fuzzy interpersonal block”

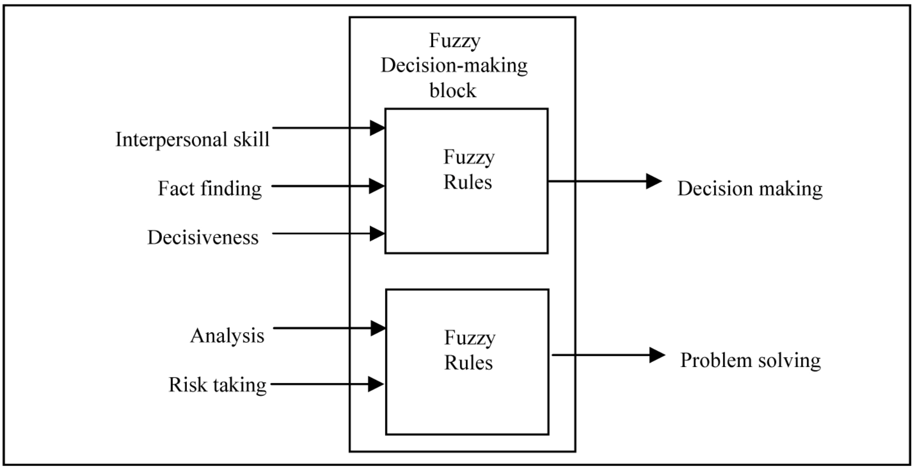

Fig. 5. Input/output relationship "fuzzy decision-making block"

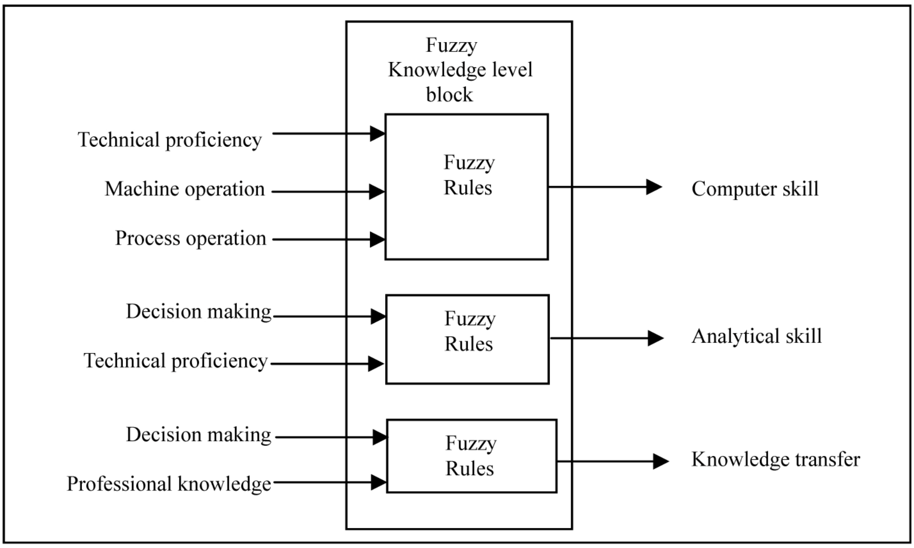

Fig. 6. Input/output relationship "fuzzy knowledge level block"

3. Proposed System

The proposed system has been simulated using the Fuzzy Logic (Matlab) toolbox. Each internal characteristic is fuzzified by using a Gaussian-shaped membership function for its corresponding fuzzy set. The ranges of values, as well as the shape of the fuzzy curves were set empirically, but can be changed by the user. A description of fuzzy input "listening" to the "fuzzy communication block is shown. The information included is range, number of MFs (NumMFs), and each of the MF's names (MF1="Poor"; which means the membership function 1 has the

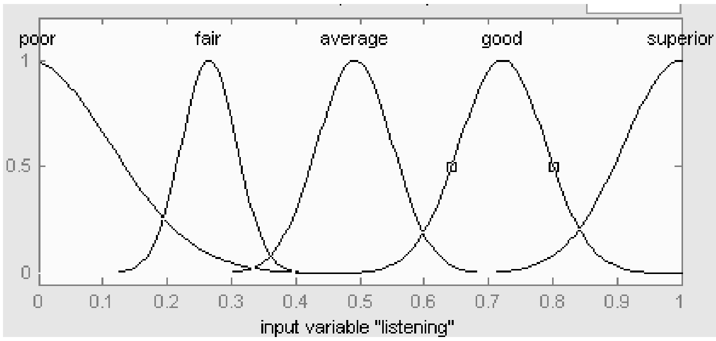

Fig. 7. Input 'listening' to fuzzy communication block

semantic variable "Poor"). It also indicates the type of MFs, as Gaussian type MF (gaussmf). The grade of membership is a precise, but subjective measure that depends on the context. The membership function is a graphical representation of the magnitude of participation of each input. It associates a weight value with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion.

A Gaussian membership function is defined by $G(u{:}m, \sigma)=exp[-\{(u-m)/\sqrt{2}\,\sigma\}^2]$,where the parameters m and σ control the center and width of the membership function. A plot of the Gaussian membership function is presented if Fig. 7 and Fig. 8. The MF parameters are located between brackets. A gaussian MF require 2 parameters as explained in Jang et al. [18]. The inputs indicating their MFs for the "Fuzzy communication block" are presented as follows:

Name: 'Listening'
Range: [0 1]
NumMFs: 5
MF_1='Poor': gaussmf [0.129 -0.01731]
MF_2='Fair': gaussmf [0.0431 0.265]
MF_3='Average': gaussmf [0.05887 0.492]
MF_4='Good': gaussmf [0.0676 0.7218]
MF_5='Superior': gaussmf [0.0898 1]

In the same way, the rest of the inputs indicating their MFs for the "Fuzzy communication block" are calculated. Once the variables of these inputs have been calculated, the variable for the outputs and their MFs are described in the following graph and data, for the "Fuzzy communication block".

Name: 'Communication ability'
Range: [0 100]
NumMFs: 5
MF_1='Low': gaussmf [7.18 -0.723]
MF_2='Below medium': gaussmf [6.687 30.2]

MF_3='Medium': gaussmf [5.093 50]
MF_4='Midhigh': gaussmf [4.55 71.59]
MF_5='High': gaussmf [10.62 100]

In the same way other inputs indicating their MFs for the other fuzzy block are calculated. Then we created the fuzzy IF-THEN rules for the "Fuzzy communication block" using the fuzzy rule editor, 150 rules have been framed for this fuzzy block. An indicative depiction of the fuzzy rules used for structuring fuzzy communication block is shown below:

1. If (listening is *poor*) and (oral_communication is *poor*) and (written communication is *poor*) then communication_ability is *low*
2. If (listening is *poor*) and (oral_communication is *poor*) and (written communication is *fair*) then communication_ability is *low*
3. If (listening is *poor*) and (oral_communication is *poor*) and (written communication is *average*) then communication_ability is *belowmedium*
4. If (listening is *poor*) and (oral_communication is *poor*) and (written communication is *good*) then communication_ability is *medium*
5. If (listening is *poor*) and (oral_communication is *poor*) and (written communication is *superior*) then communication_ability is *midhigh*

In the same way the inputs and output/s; and the data and graphics for the other fuzzy blocks, as well as their rules relationships; the fuzzy IF-THEN rules are framed.

4. Experimental Results

In this case, the proposed method is applied to evaluate the performance appraisal of non-teaching staff of a University in West Bengal. Ten non-teaching staff were examined and randomly selected for the present study. This is an example of the activation of rules relative to an

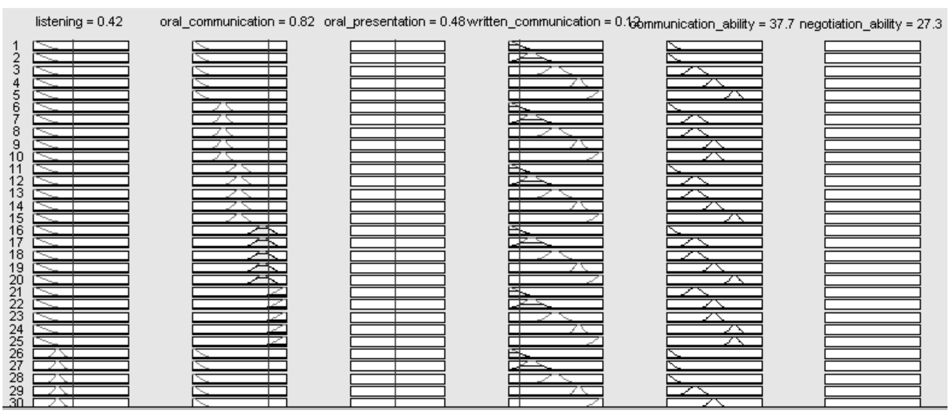

Fig. 8. Example of activation of the rules in "First" FIS and performance value of communication ability and negotiation ability for input variables listening, oral communication, oral presentation and written communication

aspect of staff performance appraisal for the “First” FIS, whose listening score is 0.422, oral communication is 0.82, oral presentation is 0.48 and written communication is 0.12 and as a result the output parameters such as communication ability is 37.7 and negotiation ability is 27.3. This result is obtained using a set of 150 fuzzy rules, some of which are shown in Fig. 8. An expert can easily modify the system’s parameters, including the set of fuzzy rules, in order to better reflect his/her criteria for assessing staff performance. In the same way FIS output values of the rest of the fuzzy block are calculated and the detailed results obtained for all the experimented ten staff is shown in Table 2, Table 3, Table 4, Table 5 and Table 6.

Table 2. The results of the “fuzzy communication block”

Staff	**Input variables**				**Outputs**	
Sl. No.	Listening (0-1)	Oral communication (0-1)	Oral presentation (0-1)	Written communication (0-1)	Communication ability (0-100)	Negotiation ability (0-100)
S1	0.42	0.82	0.48	0.12	37.7	27.3
S2	0.89	0.92	0.98	0.45	53.9	71.1
S3	0.98	0.95	0.99	0.73	89.2	87.5
S4	0.58	0.72	0.89	0.62	71.3	74.4
S5	0.36	0.72	0.85	0.09	36.7	32.8
S6	0.98	0.33	0.23	0.02	31.3	11.1
S7	0.59	0.39	0.79	0.52	48.1	73.1
S8	0.92	0.91	0.92	0.47	54.2	72.1
S9	0.95	0.32	0.38	0.56	70.5	38.4
S10	0.63	0.85	0.93	0.88	86.3	87.5

Table 3. The results of the “fuzzy motivation block”

Staff	**Input variables**						**Outputs**	
Sl No.	*Communication ability (0-100)*	*Job Motivation (0-1)*	*Work culture (0-1)*	*Initiative (0-1)*	*Stress tolerance (0-1)*	*Vigilence (0-1)*	*Self motivation (0-100)*	*Autonomy (0-100)*
S1	37.7	0.29	0.39	0.42	0.87	0.58	50	61.6
S2	53.9	0.81	0.82	0.43	0.34	0.92	74.6	58.3
S3	89.2	0.92	0.88	0.62	0.47	0.71	89.9	58.7
S4	71.3	0.59	0.52	0.55	0.99	0.65	58.5	71.8
S5	36.7	0.28	0.8	0.42	0.82	0.48	68.2	56.4
S6	31.3	0.98	0.77	0.78	0.73	0.85	73.2	72.8
S7	48.1	0.2	0.6	0.25	0.5	0.4	54.2	47.8
S8	54.2	0.88	0.82	0.68	0.48	0.78	75	55.6
S9	70.5	0.34	0.21	0.13	0.09	0.89	50.6	32
S10	86.3	0.41	0.19	0.49	0.59	0.99	50.5	71.6

Table 4. The results of the "fuzzy interpersonal block"

Staff	Input variables						Outputs		
Sl No.	Self motivation (0-100)	Rapport building (0-1)	Behavioral flexibility (0-1)	Staff leadership (0-1)	Independence (0-1)	Sensitivity (0-1)	Interpersonal skill (0-100)	Responsibility (0-100)	Adaptability (0-100)
S1	50	0.92	0.29	0.97	0.71	0.83	29.8	77.6	84.7
S2	74.6	0.83	0.79	0.8	0.69	0.74	72.4	55	80.7
S3	89.9	0.59	0.62	0.99	0.89	0.28	64	52.6	85.1
S4	58.5	0.42	0.9	0.8	0.7	0.95	67.7	69.9	67.4
S5	68.2	0.2	0.3	0.1	0.8	0.9	43.6	64.9	50
S6	73.2	0.8	0.7	0.55	0.85	0.92	69.5	69.2	75.7
S7	54.2	0.78	0.86	0.79	0.99	0.79	61.3	54.5	87.7
S8	75	0.88	0.93	0.98	0.93	0.98	78.9	80.5	84.5
S9	50.6	0.39	0.49	0.53	0.72	0.51	49.1	51.5	70
S10	50.5	0.42	0.67	0.71	0.83	0.68	50.4	54.4	67

Table 5. The results of the "fuzzy decision-making block"

Staff	Input variables					Outputs	
Sl No.	*Interpersonal skill (0-100)*	*Fact finding (0-1)*	*Analysis (0-1)*	*Risk taking (0-1)*	*Decisiveness (0-1)*	*Decision making (0-100)*	*Problem solving (0-100)*
S1	29.8	0.28	0.38	0.82	0.92	65.9	63.4
S2	72.4	0.8	0.78	0.62	0.72	71.1	61.7
S3	64	0.92	0.99	0.29	0.39	39.5	51.8
S4	67.7	0.94	0.98	0.99	0.81	73.3	87.8
S5	43.6	0.71	0.66	0.83	0.63	50.9	75.4
S6	69.5	0.53	0.73	0.32	0.44	44.7	33.6
S7	61.3	0.63	0.58	0.78	0.98	73.2	73.2
S8	78.9	0.99	0.99	0.19	0.09	34	44.7
S9	49.1	0.33	0.27	0.52	0.61	37.9	32.7
S10	50.4	0.58	0.4	0.28	0.45	45.3	40.5

Table 6. The results of "fuzzy knowledge level block"

Staff	Input variables					Outputs		
Sl No.	*Decision making (0-100)*	*Technical proficiency (0-1)*	*Professional knowledge (0-1)*	*Machine operation (0-1)*	*Process operation (0-1)*	*Computer skill (0-100)*	*Knowledge transfer (0-100)*	*Analytical skill (0-100)*
S1	65.9	0.83	0.88	0.93	0.78	73	68.3	67
S2	71.1	0.92	0.68	0.68	0.58	67.7	70.1	75.1
S3	39.5	0.48	0.55	0.49	0.63	47.7	40.1	40.2
S4	73.3	0.85	0.63	0.73	0.76	71.1	70.5	73
S5	50.9	0.62	0.66	0.72	0.62	60.7	50.9	51.1
S6	44.7	0.48	0.51	0.89	0.94	67.6	45.3	45.4
S7	73.2	0.99	0.98	0.29	0.71	69.6	80.7	80.8
S8	34	0.72	0.52	0.49	0.42	43.4	34	46.1
S9	37.9	0.39	0.28	0.47	0.98	46.8	30.5	38.4
S10	45.3	0.87	0.27	0.49	0.72	62.7	29.4	50.7

5. COMPARATIVE ANALYSIS AND REMARKS

Besides evaluating the performance of our proposed problem, we also conducted a thorough comparative analysis between the proposed algorithm and other existing algorithms in past and recent literature. This will enable us to have a strong correlation among other existing well-known techniques. We developed the system using Mamdani-type inference because it is a commonly used fuzzy methodology that allows the judgments of domain experts to be expressed in intuitively "natural" membership functions and rules.

The accuracy of the model is based on a comparison with a statistical-based model (i.e., mean evaluation). A larger data set would provide more confidence in basing the assessment of accuracy against a mean value. The accuracy of the proposed system can be determined by comparing the crisp defuzzified output of the fuzzy agents i.e., predicted overall non-teaching staff performance evaluation with the mean performance evaluation of the same staff, based on the previously described Skills Development Tool for Construction of performance appraisal using suitable statistical model. The mean performance evaluation may be calculated based on the mean assessment of all the groups of staffs of different departments of a university and all the above mentioned categories combined, assuming an equal weighting of each. The percentage error for a given staff (i.e., data point) in the fuzzy logic model can be calculated using

$$\text{Percentage error} = \frac{[\text{Fuzzy logic model output- Mean output}]}{\text{Mean output}} \times 100$$

where Fuzzy Logic Output = value generated by fuzzy logic model after defuzzification and Mean Output = value generated by statistical model.

5.1 Sensitivity Analysis

A sensitivity analysis could reveal some sensitivity with respect to the parameters of the base case model (evaluation framework) to examine the impact on the accuracy of the model. During the sensitivity analysis, four different parameters is modified: (1)membership function shapes; (2) input aggregation methods for combining input variables, and implication methods; (3) result rule aggregation methods; and (4) defuzzification methods. Three different analyses were made using different membership functions shapes. At first all membership functions were fixed to *Triangular* shapes (sensitivity analysis I). Next the input aggregation and implication operator were tested using *Max-Product* (*Max* represents linguistic OR is used to combine the input variables, and *Product* represents the implication operator) method. In *Max-Product* method, *Max* is an aggregation operator, which takes the maximum value of each output set (for each rule) for a given output variable (sensitivity analysis II). At last *Mean of Maximum* (Mom method) was used for computing a system output on the basis of the term with the highest resulting degree of support. If the *Maximum* is not unique, the *Mean of the Maximizing* interval is computed (sensitivity analysis III). Table 7 shows the results of the system tested in the sensitivity analysis. Table 8 shows the sensitivity analysis comparative results, i.e., percentage error by category.

The data for validating and testing the staff performance appraisal result is shown in Table 7 and Table 8. to assess the performance of the staff against the set of parameters defined in this paper. This numerical matching criterion may be adopted for validation purpose which is based on the condition that the values obtained using the fuzzy logic model (base case, sensitivity

Table 7. Comparative analysis of proposed system with sensitivity analysis

Output parameters	**Base case**	**Sensitivity analysis I**	**Sensitivity analysis II**	**Sensitivity analysis III**
Communication Ability	37.7	38	37.5	30.5
Negotiation Ability	27.3	25.3	25.9	25
Self_motivation	50	50	49.9	50
Autonomy	61.6	61.8	61.5	50
Interpersonal Skill	29.8	30.4	27.5	25
Responsibility	77.6	76.7	81.6	96.5
Adaptability	84.7	83.3	88	96.5
Decision_making	65.9	65.9	68.2	75
Problem_solving	63.4	63.8	64.7	75
Computer_skill	73	78.8	74.1	75
Knowledge_transfer	68.3	67.6	73.1	94
Analytical_skill	67	67.8	71.3	75

Table 8. Sensitivity analysis comparative results-Percentage error by different analysis

Output parameters	**Base case**	**Sensitivity analysis I**	**Sensitivity analysis II**	**Sensitivity analysis III**
Communication Ability	16.83(-)	16.17(-)	17.27(-)	32.7(-)
Negotiation Ability	9(-)	15.66(-)	13.66(-)	16.66(-)
Self_motivation	32.38(+)	32.38(+)	32.11(+)	32.38(+)
Autonomy	1.17(-)	0.85(-)	1.33(-)	19.78(-)
Interpersonal Skill	10.72(-)	8.92(-)	17.61(-)	25.1(-)
Responsibility	13.77(-)	14.77(-)	9.33(-)	7.22(+)
Adaptability	2.26(-)	3.87(-)	1.54(+)	11.35(+)
Decision_making	28.91(+)	28.91(+)	33.41(+)	46.71(+)
Problem_solving	5.66(+)	6.33(+)	7.83(+)	25(+)
Computer_skill	13.77(-)	6.92(-)	12.47(-)	11.41(-)
Knowledge_transfer	1.84(+)	0.8(+)	9(+)	40.17(+)
Analytical_skill	3.68(-)	2.53(-)	2.5(+)	7.82(+)

Note: '+' means above statistical mean value and '–' means below statistical mean value

analysis I, sensitivity analysis II and sensitivity analysis III) should not vary by more than ±10% of an evaluation point as calculated using the statistical mean value. For example, if a staff (here staff Sl. No. S_1) obtains an evaluation of 30 using the statistical mean value and the base case fuzzy value as 27.3 (in Table 7 the Negotiation ability parameter value), then the percentage difference between the statistical and fuzzy logic model would be less than 10% (percentage difference between 30 and 27.3 which is 9%)) and accepted. Otherwise, if the said difference is more than ±10%, then reject the fuzzy value and stick to the statistical mean value.

6. Conclusion

As academic staff is related to the success and failure of higher education institutions, there is a need for recognition system that gives them motivation in work performance. A promotion will improve the staff objectives and performance. In general, promotion of academic staff in higher education institutions refers to a movement in the ranks. Conducting a more detailed analysis of our fuzzy expert system proved to be a valuable experience for us. We acquired a better understanding of how membership functions and rule sets interact. We learned that the process of empirically adjusting membership function parameters could be a very tedious and time-consuming task.

This paper presented how Cascaded fuzzy logic and fuzzy expert systems can be used to build performance evaluation models based on realistic data. A large number of factors affecting the staff's performance were identified and incorporated in the system. The membership functions and fuzzy rule bases were developed based on logical reasoning, without the availability of large data sets. The results obtained reflect that the proposed system can be used to improve the efficiency of University staff performance appraisal. The overall flexibility of the proposed framework will also allow rapid prototyping of novel applications. Data collection should incorporate a larger number of Institutions and/or academic programs to obtain a larger data set, which would allow researchers to explore other techniques such as clustering and neuro-fuzzy training to develop the membership functions and to train the fuzzy rules in the model. This research provides a basis for future work in predicting and evaluating the performance of University staff in general, given the numerous factors affecting the performance of the academic workforce. This proposal paper may be used for judgmental and developmental purposes in order to make good administrative decisions in higher education field.

Few areas related to the input variables should be explored: (1) the relative weightings of input variables; and (2) the way the input variables are grouped in the system. Each input parameters was assumed to be equally weighted. Also, each group of experts was assumed to have equal significance in evaluating the performance of the non-teaching staff. Future research should determine which tasks are most significant in determining a staff's performance and impact on academic department and which groups of respondents are best able to assess their performance.

The system presented in this paper provides a basis for future research on both higher educational staff performance evaluation and the use of further work on fuzzy logic in conducting such evaluations.

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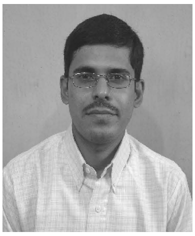

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