Fuzzy Logic Based Expert System for Academic Staff Evaluation and Progress Monitoring

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Abstract. Academic teaching performance is recognized as a top instrument in reducing student dropout. This paper proposes a fuzzy logic based expert system which helps the teachers perform their own evaluation of academic teaching and research activities, in order to match them to requirements for each study cycle (introductory, specialization, master). The developed expert system also offers a way of monitoring the progress of teachers’ performances and to provide additional explanations about which aspects still need improvement. The system was tested using artificial data. The results show the most appropriate teacher for every study cycle.

Introduction

Developing a strong academic system is a key factor in ensuring high quality education. The continuous performance evaluation of the academic staff contributes not only to the constant development of the teachers themselves, but also favorably impacts the students’ evolution. Students can greatly benefit from teachers who are well prepared, who apply innovative teaching methods, who are open and empathic, especially in the first (introductory) years. On the other hand, for students that are in their specialization years (3rd or 4th, or in master studies), a teacher with high research results and good knowledge transfer skills can be of more help. A match between student needs and teacher abilities is therefore necessary for obtaining successful academic outcomes, which can be translated into reduced dropout rates and low numbers of students with failed subjects. Conventional evaluations tools often rely on making computations between crisp values, whereas the majority of the performance indicators are qualitative. Recent approaches investigate and validate the use of soft computing techniques (fuzzy logic, neural networks, and genetic algorithms) in developing modern evaluation tools.

Related Works

Fuzzy logic based expert systems are long used in developing teaching and learning instruments. Recently, fuzzy logic based expert system were developed to evaluate teachers’ performance. All systems take into account both teaching and non-teaching skills, such as body language, implication level, student performance. The systems incorporate expert knowledge obtained from various sources, including questionnaires.

A fuzzy based teacher performance evaluation system with applications in higher education is proposed in [1]. The fuzzy system has fifteen different inputs, such as: research orientation, publication, teaching learning process, responsibility and punctuality, professional ethics, supervision, administrative skills, awards & achievements, needs & requirements, background factors. As most of these inputs are in non-numeric or linguistic form, the fuzzy expert system has to map the qualitative input data into linguistic output description: poor, satisfied, good, very good, excellent, and outstanding.

In [2], the fuzzy logic expert system is dedicated to eliciting and quantifying high school teacher performance. Human expert knowledge was extracted from experts in the field of education (principal evaluators). The considered input variables are: professional knowledge, instructional planning,
instructional strategies, differentiated instruction, assessment strategies, assessment uses, positive
learning environment, academically challenging environment, professionalism, and communication.
The results of the evaluation are expressed in linguistic terms: exemplary, proficient, needs
development, and ineffective. The fuzzy logic expert system was tested using artificial data.

Similar fuzzy expert systems for academic performance evaluation are presented in [3] and [4]. The
input values are taken from teacher self-appraisal forms, and consist of data regarding students’
feedback, attendance, and results, teaching-learning process, academic development of teacher, as
well as additional performance measures, such as extra-contributions, training programs, membership
in professional bodies, et al. The overall performance obtained via the fuzzy model is compared to
values returned by conventional methods, showing that a more realistic evaluation is obtained by
mapping qualitative variables into numeric results by means of a fuzzy inference mechanism.

Besides students’ feedback and results of the teaching-learning process, additional components
such as involvement in administrative or social activities or committee membership can be
performance indicators [5, 6]. The teacher assessment and profiling system developed in [7] uses
fuzzy inference to find the current impact of teachers, based on students’ evaluation. The profile of
every teacher is constantly updated. The profiling part is based on applying the Apriori algorithm to
find teacher to class, teacher to subject, teacher to semester and teacher to discipline associations.

The literature review pointed out the fact that the evaluation systems focus on computing the
current values of teaching, research and/or administrative components, without offering a way to
monitor the progress or to provide additional explanations about what still needs to be improved.

This paper proposes a fuzzy logic based expert system for the performance evaluation of academic
staff, based on teaching and research activities. The results are compared to a series of minimal values
for specific years of study (1st and 2nd year, 3rd and 4th year, master), and a recommendation for the
year of study to professor assignment is provided. The results are useful for the continuous
performance monitoring of teaching staff, for choosing the most appropriate teacher for every study
cycle (introductory, specialization, master), as well as for improving the quality level for teaching and
decreasing student dropout rates, especially among 1st year students.

The novelty of the proposed system is that it combines the two fuzzy systems together with a
decision module, with minimal values that can be adjusted, resulting in a complete expert system.
Furthermore, the proposed expert system points out the current status of the teacher under evaluation,
with respect to predefined minimal requirements, thus encouraging a proactive approach in
self-improvement.

The remainder of the paper is organized as follows: Section two describes the proposed evaluation
system, a series of implementation details are listed in Section three, while Section four discusses the
experimental results. The final section draws conclusions and presents future development directions.

Overview of the Proposed System

The academic performance evaluation system was developed using information from academic staff
working in technical universities and national rules and regulations that are currently applied in
Romania. The system associates crisp (discrete) input values for certain indicators of teaching and
research skills to years of study, so that the user can easily evaluate their own match against the
minimal requirements.

Let $X$ be the multi-dimensional space of the user input values. For every $x \in X$ the system applies
the function $\Phi : X \rightarrow P$, $\Phi(x) = p$, where $p \in P$, and $P$ is the output feature space. Then, the
distance between $p$ and $p_{\text{min}}$ is computed:

$$d(p, p_{\text{min}}) = p_{\text{min}} - p$$

where $p_{\text{min}} \in P$ is the minimal accepted value for a certain region of the output feature space. The
nonlinear function $\Phi : X \rightarrow P$ is represented by the fuzzy reasoning process.
The diagram of the proposed system is depicted in Fig. 1. The user and the developer interact with the system by means of the dedicated interfaces. The inference engine processes the data from the knowledge base, consisting of input and output variables, as well as the rules of the two fuzzy systems used for evaluation. The information in the knowledge base be modified by means of the developer interface. The result of the evaluation is returned to the user, also through the user interface.

![Diagram of the proposed evaluation system.](image)

**Implementation Details**

The flowchart of the evaluation system is presented in Fig. 2. In the Data input section, the user inputs the numerical values for the five indicators for teaching activities, the four indicators for research activities, and selects the user from a dropdown list. The data is then processed by the fuzzy system for teaching activities and the fuzzy system for research, and the results are displayed (Results). In the Evaluation section, the results are compared to the selected set of minimal requirements. If the requirements are met, the user will be presented a congratulatory message. Otherwise, a message showing the differences between computed and requested values is displayed, as shown in Eq. 1. In both cases, an email containing the results is sent to the user. The user interface was designed in accordance with the flowchart in Fig. 2, using the MATLAB integrated development environment.

The computational flow of the system, the fuzzy reasoning that transforms the crisp input values into crisp output values, while working with fuzzy sets and operations with fuzzy sets, is hidden from the user. Implementation details regarding the two fuzzy systems and the evaluation and monitoring process are presented next.

**Fuzzy Systems for Teaching Activities and Research**

The system performs teacher evaluation based on teaching activities and research skills, by means of two dedicated Mamdani-inference fuzzy systems, using And method – min, Or method – max, Implication – min, Aggregation – max, and defuzzification – centroid. The input data for the system dedicated to evaluating teaching activities (Fig. 3) is: *Teaching methods, Explanations, Student interaction, Evaluation and Exam duties*, with values between 0 and 10. The two features that are computed by the fuzzy system are *Teaching skills* and *Implication*, with a universe of discourse between 0 and 100.

The universe of discourse for each of the nine input indicators (five for teaching, four for research) as well as for the four output features (two describing teaching activities and two associated with research) is covered with three Gaussian fuzzy sets, named *Poor, Average* and *Good*. The fuzzy input variable *Explanations* is depicted in Fig. 4.
Figure 2. Flowchart of the proposed performance evaluation system.

The rule base contains rules that connect all inputs and outputs, such as:

If (Teaching methods is poor) and (Explanations is poor) and (Student interaction is good) and (Evaluation is average) and (Exam duties is good), then (Teaching skills is average) and (Implication is good).

Figure 3. Diagram of the Teaching activities fuzzy system.

The research activities are evaluated by means of the second fuzzy system, with Conference papers, Journal papers, Books and PhD students as input variables, again between 0 and 10. The computed features are Research skills and Knowledge transfer. One of the rules in the rule base of this fuzzy system is:
If *(Conference papers is poor) and (Journal papers is good) and (Books is average) and (PhD students is average)*, then *(Research skills is good) and (Implication is average)*. (3)

![Figure 4. Input variable Explanations for the Teaching activities fuzzy system.](image)

**Decision between Features and Year of Study**

The decision problem consists in mapping the resulting values for teaching and research indicators onto stages of the academic process: 1\(^{st}\) and 2\(^{nd}\) year, 3\(^{rd}\) and 4\(^{th}\) year, master. The beginning years, and especially the first year, is when the student dropout rates reach peak values. In Romania, more than a quarter of the students enrolled in the graduate and master programs do not finish their studies [8]. One way of controlling the dropout rates is to assign teachers with high levels of teaching skills and implication to 1\(^{st}\) and 2\(^{nd}\) year students. On the other hand, when the educational level rises (higher demands, specialized curricula) in the 3\(^{rd}\) or 4\(^{th}\) year, as well as in Master studies, it’s important to have teachers with high international visibility based on their research results, expressed as high values of research skills and knowledge transfer.

The minimal requirements for each educational level can be modified through the developer interface, to best suit the specific needs of their institution.

The decision results is provided to the user, through the user interface, and automatically sent to the user email box.

**Monitoring Teachers’ Progress**

Every teacher has the possibility to monitor his progress. One can choose to use the expert system every time a value for the input indicators *(Teaching methods, Explanations, Student interaction, Evaluation, Exam duties, Conference papers, Journal papers, Books and PhD students)* is changed.

The system can also be used as a tool in periodic evaluations requested by the university. For Romanian faculty staff members, yearly internal evaluations are performed, and their results are used to determine next year’s teaching load, supplementary financing for the university and other performance indicators required by national committees.

**Experimental Results**

The system was put to test using artificial data. Fig. 5 shows a capture from the user interface, where all the values for the input indicators have been filled in, and a user was selected. The minimal values for the four defining features of the teacher suitable for every stage of the academic process are set by the developer, such as: Teaching skills 70, Implication 70, Research skills 30, Knowledge transfer 30, corresponding to 1\(^{st}\) and 2\(^{nd}\) year. From the *Evaluation criteria* panel (Fig. 6), the user chooses one of the three available stages *(1\(^{st}\) and 2\(^{nd}\) year, 3\(^{rd}\) and 4\(^{th}\) year, Master)*, which are then loaded into the *Minimal requirements* panel and simultaneously compared to the computed values. The words
displayed next to each value (Fig. 6) carry both intrinsic and visual information – OK displayed in green means the value is good, NOT OK displayed in red shows the value is too small.

Finally, the entire information about the evaluation process is summarized in a message that is displayed in the interface’s Explanations (see Fig. 7) and can be sent by email, to the previously selected email address.

<table>
<thead>
<tr>
<th>Chose name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor 1 – less professor</td>
</tr>
</tbody>
</table>

| Teaching Methods | 3 | 0–10 points |
| Explantions      | 5 | 0–10 points |
| Student Interaction | 2 | 0–10 points |
| Evaluation       | 5 | 0–10 points |
| Exam Duties      | 5 | 0–10 points |

**Fuzzy module for Teaching Activities**

**Fuzzy module for Research**

| Conference Papers | 6 |
| Journal Papers    | 10 |
| Books             | 2 |
| PhD Students      | 1 |

**Minimal requirements**

- **Teaching Skills**: 70, Not OK
- **Implication**: 70, Not OK
- **Research Skills**: 30, OK
- **Knowledge Transfer**: 30, OK

**Evaluation criteria**

- 1st and 2nd year (Bachelor, introductory)
- 3rd and 4th year (Bachelor, specialization)
- Master

**Evaluate!**

For “Teaching to 1st and 2nd year students”, your results show that you should increase your:

- Teaching Skills by 20.00 points
- Implication by 20.22 points

Send email!

**Figure 5.** The Data input section of the user interface.

**Figure 6.** Choosing the evaluation criteria; minimal requirements and result of comparison with computed values.

**Figure 7.** Summary of the evaluation process, displayed as message in the Explanations panel.

To furthermore exemplify the use of the developed system, an artificial data batch corresponding to 3 professors was produced – Table 1. The minimal requirements for all three considered stages are listed in Table 2. The resulting output values for the four features (Teaching skills, Implication, Research skills, and Knowledge transfer) together with the conclusions (OK, NotOK) are found in Table 3. Professor 1 is most likely to be assigned to teaching 3rd and 4th year students (most OKs per that column), while Professor 2 will probably deal with freshmen, but can also have fruitful interactions with 3rd and 4th year students. Professor 3, with his high values for the 4 indicators of research activities is best suited for teaching to 3rd and 4th year or master students. Based on the results of this evaluation, should Professors 1 and 3 want to teach freshman years, the system clearly shows they need to up their teaching skills and implication. Same goes for Professor 2, but this time on the research activities, where his low values make him non-eligible for teaching to master students.
Table 1. Input data for system testing.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Prof1</th>
<th>Prof2</th>
<th>Prof3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching methods</td>
<td>3</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Explanations</td>
<td>5</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Student interaction</td>
<td>3</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Evaluation</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Exam duties</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conference papers</td>
<td>6</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Journal papers</td>
<td>10</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Books</td>
<td>2</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>PhD students</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 2. Minimal requirements.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Minimal requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,2</td>
</tr>
<tr>
<td>Teaching Skills</td>
<td>70</td>
</tr>
<tr>
<td>Implication</td>
<td>70</td>
</tr>
<tr>
<td>Research Skills</td>
<td>30</td>
</tr>
<tr>
<td>Knowledge Transfer</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 3. Output values and conclusions.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Prof1</th>
<th>Prof2</th>
<th>Prof3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Out</td>
<td>1,2</td>
<td>3,4</td>
</tr>
<tr>
<td>Teaching Skills</td>
<td>50</td>
<td>NotOK</td>
<td>OK</td>
</tr>
<tr>
<td>Implication</td>
<td>50</td>
<td>NotOK</td>
<td>OK</td>
</tr>
<tr>
<td>Research Skills</td>
<td>56</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>Knowledge Transfer</td>
<td>44</td>
<td>OK</td>
<td>NotOK</td>
</tr>
</tbody>
</table>

Conclusions

The continuous performance evaluation of the academic staff greatly impacts the trajectory of teaching and research activities of the professors, as well as the students’ evolution. The majority of performance indicators are qualitative, but conventional evaluations tools often rely on making computations between crisp values. This paper proposes a fuzzy logic based expert system which helps the members of the academic body perform their own evaluation of teaching and research activities, in order to match them to minimal requirements for each study cycle (introductory, specialization, master).

The entire system is accessible to the user by means of an interactive and intuitive interface. Developer mode can be employed, in order to adjust the minimal requirements for each educational stage. Input values for five indicators of teaching activities and four indicators of research activities are used to compute a set of features, describing the current level of the user. The obtained values are compared to minimal requirements, and additional explanations about which aspects still need improvement are provided.

The system can be used for self-progress monitoring activities, as well as a tool in periodic evaluations requested by the university. Further developments of the tool include integrating the system into an online platform, adding multi-user facilities and optimizing it for mobile use.

Acknowledgement

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Reference


