<u>RESEARCH RECOMMENDER</u>

CO542 - Artificial Neural Networks and Fuzzy Systems
Mid Examination

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1. Introduction

The final year research project is a crucial point in a student's academic career. A student should choose a research area based on their interests and skills. If they only focused on a narrow domain of research topics, they cannot make an educated decision on a research topic and might lead to unforeseen difficulties. Also the research topic should be able to satisfy criteria such as stakeholder preference, capacity, expertise area and motivation. If a student chooses to do a project that does not match his skills and preferences, the student might not perform well on the project and it will have a negative impact on him. Also the chance of another student to do that research more efficiently is lost. Even the lecturer who's guiding the research will face difficulties. Both the parties will waste time, labour and funds. Therefore to achieve the best ex[irience for students, academic staff and any interested parties, it is vital for students to accurately select a research area that they are truly interested in.

However, selecting a single research area using crisp logic is an almost impossible task to perform. Various students have different interests, skills levels and expectations at different levels. Rarely 2 or more students have the same preferences. Also researches might have various fields and requirements. Hence considering all these conditions, it is impossible to design a system which accurately gives recommendations using crisp logic. Therefore to achieve the best experience for all interested parties, a solution using fuzzy logic is introduced in this project. Using fuzzy logic we were able to consider the various preferences and preferences levels the students have. Also we give a chance to users of our system to select the research areas they are interested in or currently available beforehand so that users will only see the recommendations for the research projects that are currently being offered by the department.

So this fuzzy system will offer better recommendations to the students based on their preferences and skill levels so they will be able to do their research more efficiently and will be able to achieve satisfactory results to the other involved parties such as supervisors and industry. Also this will improve the academic progress of the students as well. This can be used with both undergraduate and postgraduate students as well. As a result the Computer Engineering Department will be able to conduct research in a more effective manner. Department will be able to progress at a much faster rate on the research areas than before using this system.

These are the reasons why we developed this research recommender application for final year students in the Department of Computer Engineering, Faculty of Engineering, University of Peradeniya.

2. Related Work

There are many implementations of recommendation systems. career recommendation systems [2], [3]. We inspected the fuzzification and defuzzification functions in each system and also, how to choose a proper membership function. The triangular and trapezoidal functions were chosen in those systems with knowledge of domain experts. However, [1] states that 'there are two approaches to determining a membership function. The first approach is to use the knowledge of human experts, that is, ask the domain experts to specify the membership functions. Because fuzzy sets are often used to formulate human knowledge, the membership functions represent a part of human knowledge. Usually, this approach can only give a rough formula of the membership function; fine-tuning is required.'. We used gaussian membership functions because the slope is non linear and slight variations around the mean does not change the fuzzy values drastically. This coincides with our expectations of the model.

3. Methodology

3.1. Inputs and Outputs to the Fuzzy Inference System

The inputs to the fuzzy inference system are the interests of a student. A student can rate their interests from 0 to 5 where 0 having the least interest and 5 having the most interest, and can be given as an input to the system. Note that the research areas taken as inputs from the student are not used by the fuzzy inference system. Research areas are used to filter the outputs obtained from the fuzzy inference system when displaying in the graphical user interface. By default all the research areas are displayed.

Following are interests which are given as inputs to the fuzzy inference system,

- Security
- Networking
- Embedded systems
- Low level programming
- Computer architecture
- Machine learning
- High level programming
- Image processing
- Signal processing
- Devops

Following are the research areas given as outputs by the fuzzy inference system,

- Computer Networking and Wireless Communication
- Secure microkernels for embedded systems
- Architectural support for Reliability and Security
- Machine Learning and Big Data
- IoT
- Heterogeneous Pipelines in Embedded Processors
- Image Processing
- Cloud computing

FIGURE 1: Fuzzy Inference System

3.2. Fuzzification

Fuzzification is the first step in the fuzzy inference system. The degree to which the crisp input value belongs in the fuzzy set is determined in this step. In simple words, fuzzification maps the crisp values to fuzzy values by using membership functions.

In the process of fuzzification, interests are given a degree and a linguistic variable by using the interest value and the membership function. For this process gaussian membership functions were used and they were selected by considering the research work done by the other researchers. Parameter values were selected by trial and error method. Each team member conducted tests for various parameter values and the best values were selected.

Each interest has 3 membership functions to determine the membership degree and linguistic variable. Following figure shows the 3 membership functions of an interest.

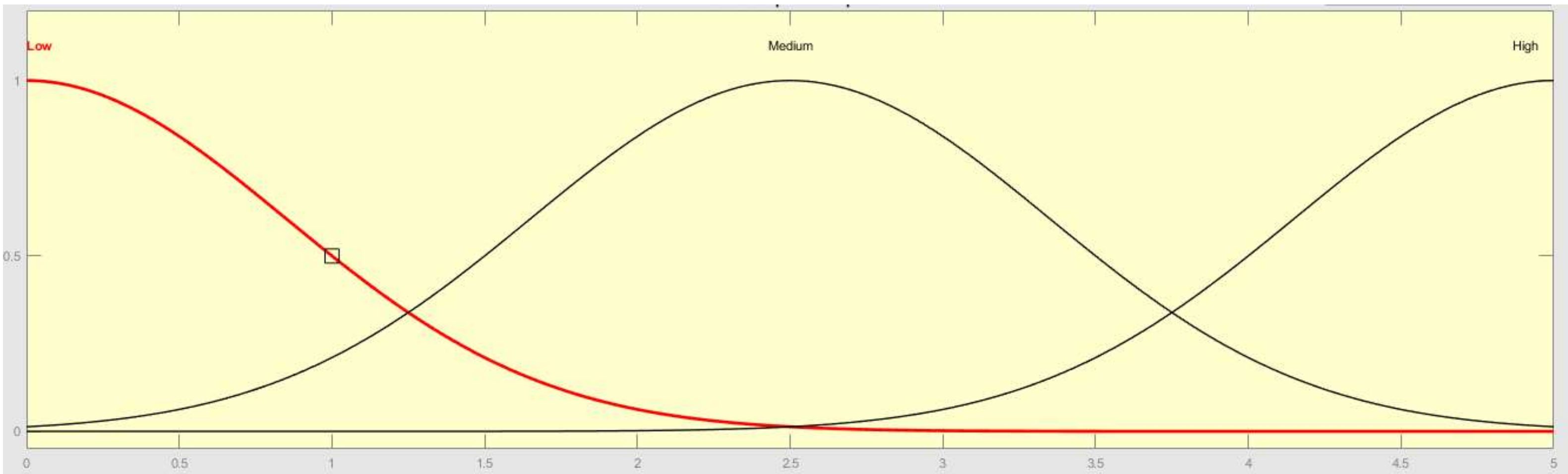

FIGURE 2: Input Membership Functions of an Interest

An interest can be mapped to following 3 fuzzy values depending on the rating.

- Low
- Medium
- High

Membership functions of Input Variables	Low {variance, mean}	Medium {variance, mean}	High {variance, mean}
	{0.8, 0}	{0.8, 2.5}	{0.8, 5}
Membership functions of Output Variables	Not Recommended {variance, mean}	Recommended {variance, mean}	Highly Recommended {variance, mean}
	{1.5, 0}	{1.5, 5}	{1.5, 10}

TABLE 1: Gaussian Membership Function Parameters for Input and Output Variables

3.3. Rule Evaluation

Rule evaluation is the step after fuzzification. In this step, the obtained fuzzy values from the fuzzification are applied to the rule base to determine the output fuzzy value. When developing the rule base, assumptions were used to determine the relation between research area and the interests and they are shown in the following table.

Research Area	**Interests related to specific research area**
Computer Networking and Wireless Communication	Security, Networking
Secure microkernels for embedded systems	Embedded system, Low level programming, Computer architecture, Security
Architectural support for Reliability and Security	Computer architecture, Low level programming, Security
Machine Learning and Big Data	High level programming, Machine learning
IoT	Embedded system, Security, Networking
Heterogeneous Pipelines in Embedded Processors	Embedded system, Low level programming, Computer architecture
Image Processing	Image Processing, Signal Processing, High level programming
Cloud computing	Security, Networking, Devops

TABLE 2 : Relation between Research Area and Interests

Each research area has 3 membership functions named Not Recommended, Recommended, Highly Recommended. They are also gaussian membership functions. Following figure shows the 3 membership functions in a research area.

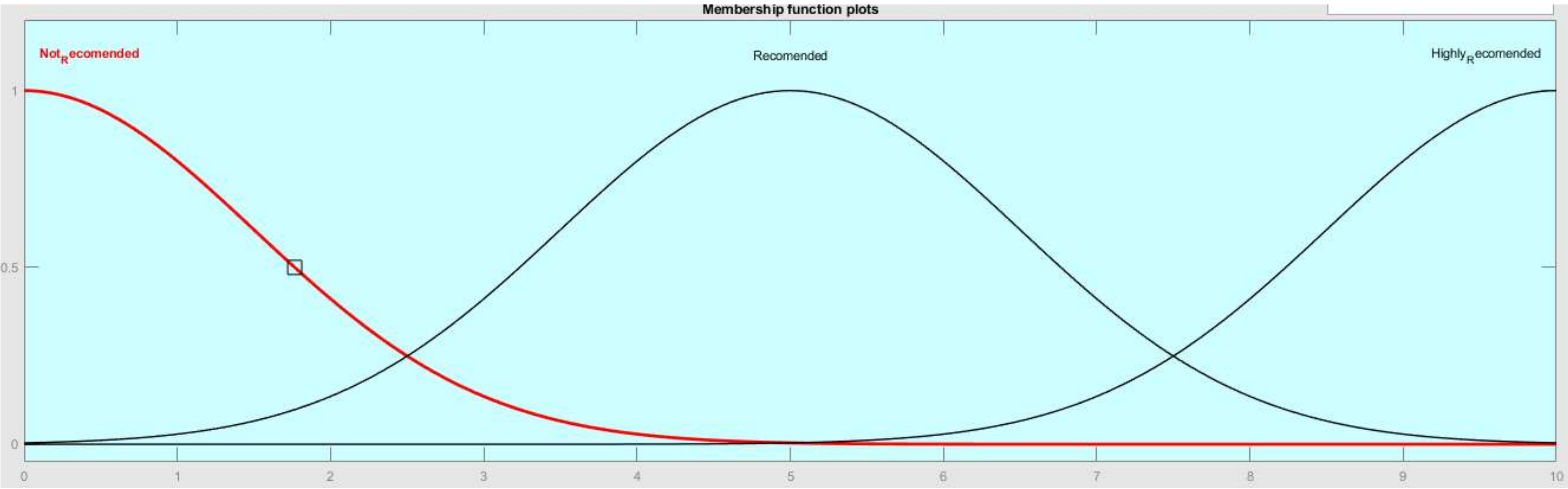

FIGURE 3: Output Membership Functions of a Research Area

Rule base developed are as follows.

1. Low(Security)^Low(Networking) ⇒ Not Recommended(Computer Networking and Wireless Communication)
2. Medium(Security)^High(Networking) ⇒ Recommended(Computer Networking and Wireless Communication)
3. High(Security)^High(Networking) ⇒ Highly Recommended(Computer Networking and Wireless Communication)

4. Low(Embedded system)^Low(low level programming)^Low(computer architecture)^Low(security) ⇒ Not Recommended(Secure microkernels for embedded systems)
5. High(Embedded system)^High(low level programming)^Medium(computer architecture)^Medium(security) ⇒ Recommended(Secure microkernels for embedded systems)
6. High(Embedded system)^High(low level programming)^High(computer architecture)^High(security) ⇒ Highly Recommended(Secure microkernels for embedded systems)

7. Low(computer architecture)^Low(low level programming)^Low(security) ⇒ Not Recommended(Architectural support for Reliability and Security)
8. High(computer architecture)^High(low level programming)^Medium(security) ⇒ Recommended(Architectural support for Reliability and Security)
9. High(high level programming)^High(machine learning) ⇒ Highly Recommended(Architectural support for Reliability and Security)

10. .Low(computer architecture)^Low(low level programming)^Low(security) ⇒ Not Recommended(Machine Learning and Big Data)
11. Medium(computer architecture)^High(low level programming)^Medium(security) ⇒ Recommended(Machine Learning and Big Data)
12. High(computer architecture)^Low(low level programming)^Low(security) ⇒ Highly Recommended(Machine Learning and Big Data)

13. Low(Embedded system)^Low(security)^Low(Networking) ⇒ Not Recommended(IoT)
14. High(Embedded system)^Medium(security)^Medium(Networking) ⇒ Recommended(IoT)
15. High(Embedded system)^High(security)^High(Networking) ⇒ Highly Recommended(IoT)

16. Low(Embedded system)^Low(low level programming)^Low(computer architecture) ⇒ Not Recommended(Heterogeneous Pipelines in Embedded Processors)
17. High(Embedded system)^Medium(low level programming)^High(computer architecture) ⇒ Recommended(Heterogeneous Pipelines in Embedded Processors)
18. High(Embedded system)^High(low level programming)^High(computer architecture) ⇒ Highly Recommended(Heterogeneous Pipelines in Embedded Processors)

19. Low(Image Processing)^Low(Signal Processing)^Low(high level programming) ⇒ Not Recommended(Image Processing)
20. High(Image Processing)^Medium(Signal Processing)^High(high level programming) ⇒ Recommended(Image Processing)
21. High(Image Processing)^High(Signal Processing)^High(high level programming) ⇒ Highly Recommended(Image Processing)

22. Low(Security)^Low(Networking)^Low(Devops) ⇒ Not Recommended(Cloud computing)
23. Medium(Security)^Medium(Networking)^High(Devops) ⇒ Recommended(Cloud computing)
24. High(Security)^High(Networking)^High(Devops) ⇒ Highly Recommended(Cloud computing)

Computer Networking and Wireless Communication		**Security**	**Networking**		
	Not Recommend	Low	Low		
	Recommend	Medium	High		
	Highly Recommend	High	High		
Secure microkernels for embedded systems		**Embedded system**	**Low level programming**	**Computer Architecture**	**Security**
	Not Recommend	Low	Low	Low	Low
	Recommend	High	High	Medium	Medium
	Highly Recommend	High	High	High	High
Architectural support for Reliability and Security		**computer architecture**	**Low level programming**	**Security**	
	Not Recommend	Low	Low	Low	
	Recommend	High	High	Medium	
	Highly Recommend	High	High	High	
Machine Learning and Big Data		**High level programming**	**Machine learning**		
	Not Recommend	Low	Low		
	Recommend	Medium	Medium		
	Highly Recommend	High	High		
IoT		**Embedded system**	**Security**	**Networking**	
	Not Recommend	Low	Low	Low	
	Recommend	High	Medium	Medium	
	Highly Recommend	High	High	High	
Heterogeneous Pipelines in Embedded Processors		**Embedded system**	**low level programming**	**computer architecture**	
	Not Recommend	Low	Low	Low	
	Recommend	High	Medium	High	
	Highly Recommend	High	High	High	
Image Processing		**Image Processing**	**Signal Processing**	**high level programming**	
	Not Recommend	Low	Low	Low	
	Recommend	High	Medium	High	
	Highly Recommend	High	High	High	
Cloud computing		**Security**	**Networking**	**Devops**	
	Not Recommend	Low	Low	Low	
	Recommend	Medium	Medium	High	
	Highly Recommend	High	High	High	

TABLE 3 : Rule Base in a Tabulated Representation

The Mamdani Model was used with Max-Min composition to evaluate the rules to obtain the fuzzy outputs.

3.4. Defuzzification

Defuzzification is the last step in the fuzzy inference system. In this step, the fuzzy output obtained from the rule evaluation step is mapped to a crisp output value. Out of the fuzzification methods, the mean of the maxima method was used to defuzzify.

Mean of the maxima = (Start of maximum + Last of maximum)/2

3.5. Methodology Explained using an Example

To explain the methodology using an example, consider the following ratings for interests.

Security ⇒ 4
Networking ⇒ 5
Embedded systems ⇒ 0
Low level programming ⇒ 0
Computer architecture ⇒ 0
Machine learning ⇒ 0
High level programming ⇒ 0
Image processing ⇒ 0
Signal processing ⇒ 0
Devops ⇒ 0

First step is fuzzification to obtain the fuzzy values.

- Obtaining fuzzy values for Security = 4

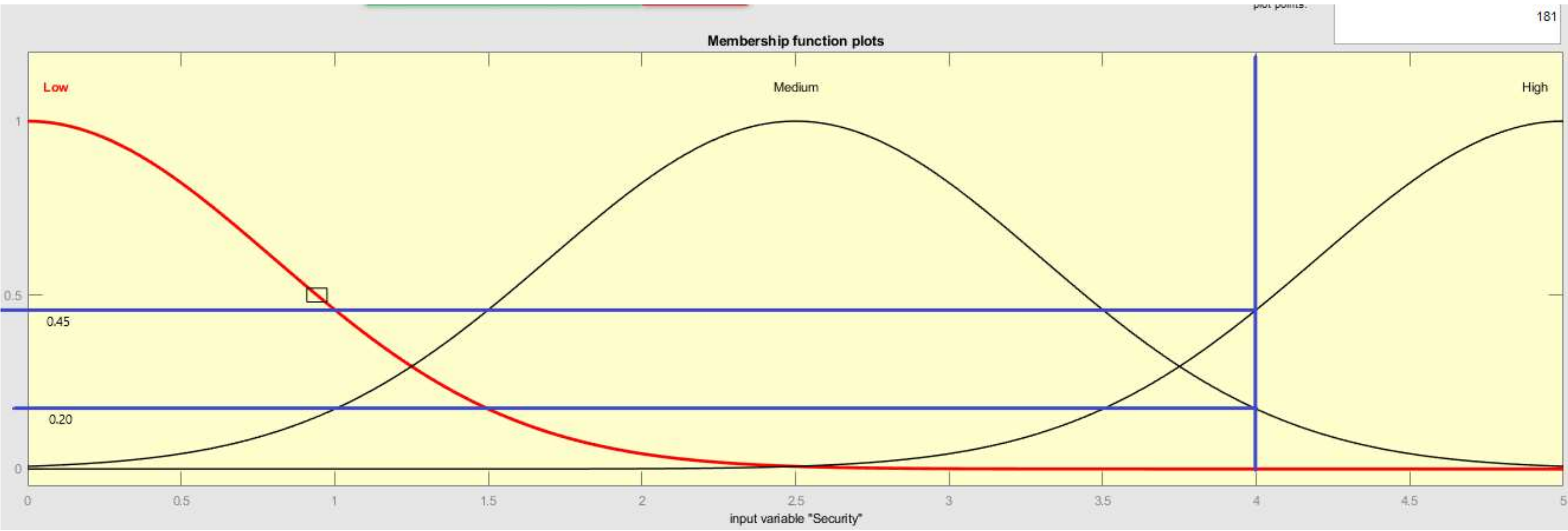

FIGURE 4:Obtaining the Fuzzy for Security = 4

From the above figure it is clear that the fuzzy values for Security = 4 are as follows.

Security = 4 ⇒ Medium = 0.2, High = 0.45

- Obtaining fuzzy values for Networking = 5

From the above figure it is clear that the fuzzy values for Networking = 5 are as follows.
Networking = 5 ⇒ High = 1

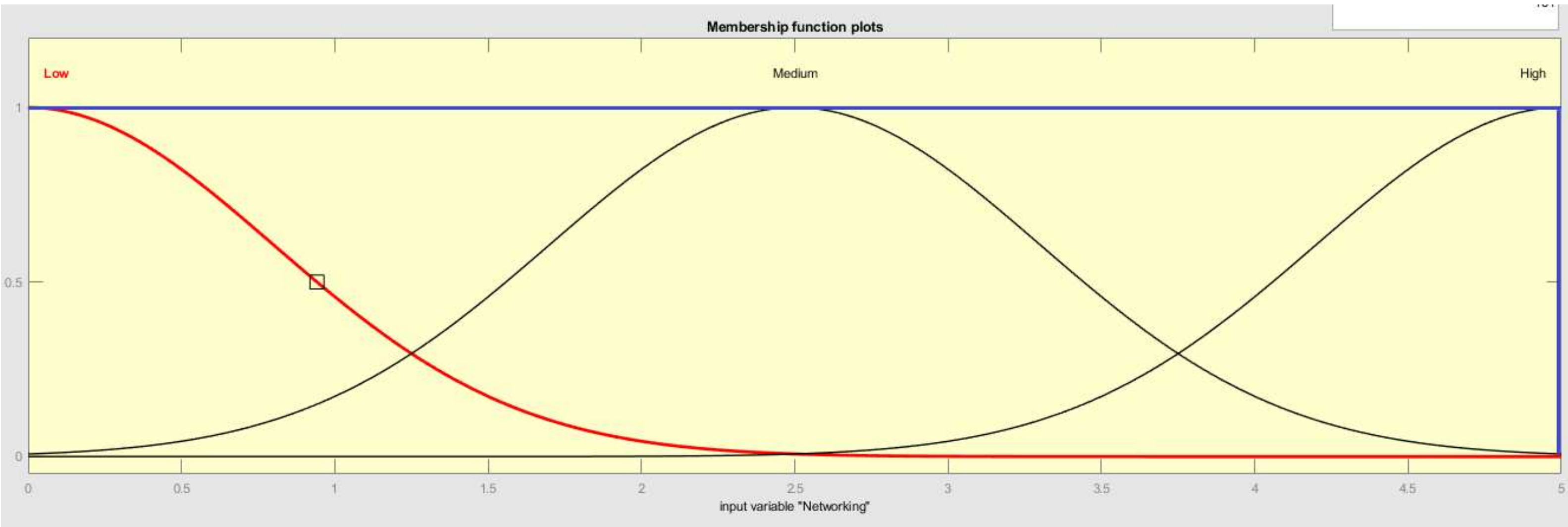

FIGURE 5:Obtaining the Fuzzy for Networking = 5

Next step is to evaluate the rules. Only Computer Networking and Wireless Communication research related rules are evaluated in this explanation.

Medium(Security)^High(Networking) ⇒ Recommended(Computer Networking and Wireless Communication)

0.2 ^ 1 ⇒ 0.2

Recommended = 0.2

High(Security)^High(Networking) ⇒ Highly Recommended(Computer Networking and Wireless Communication)

0.45 ^ 1 ⇒ 0.45

Highly Recommended = 0.45

Since the Mamdani model with Max-Min composition is used, get the union of the above two values. And the union will result as in the following figure(area with black lines).

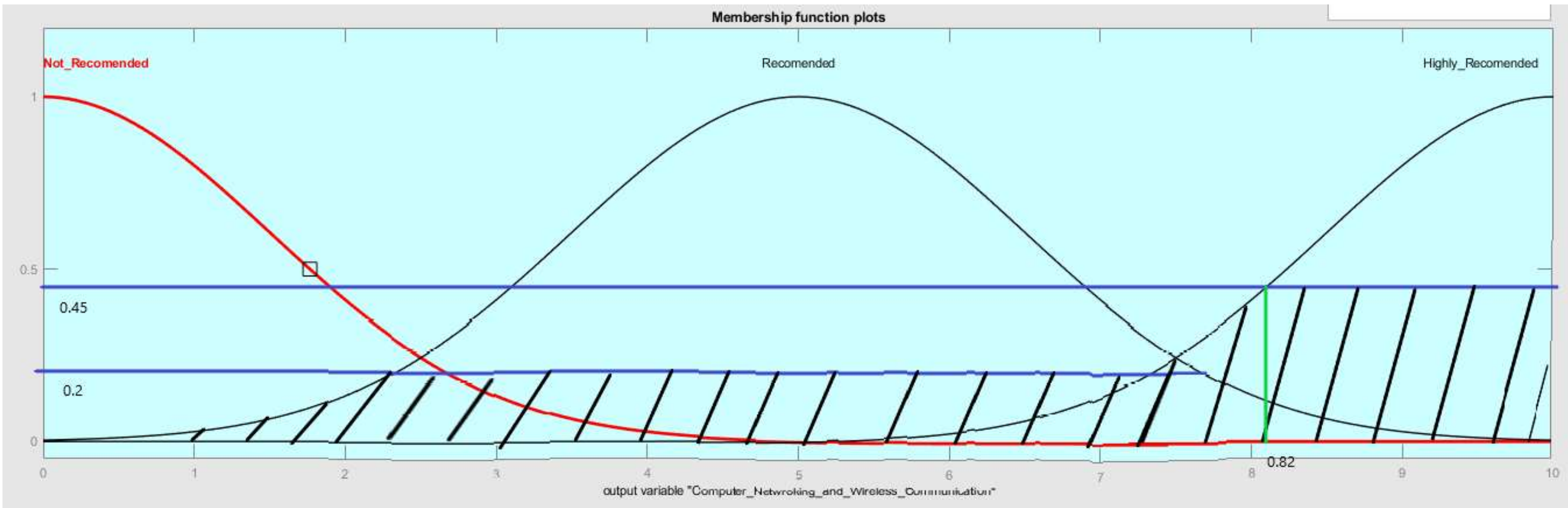

FIGURE 6:Obtaining the crisp output value

Final step is to do the defuzzification to get the crisp output. Since the mean of maxima is used as the defuzzification method, start maximum value and the last maximum value has to be obtained(marked in green vertical lines..

Start maximum value = 0.82

Last Maximum value = 10

Mean of maxima = (Start maximum value + Last maximum value) / 2
= (0.82 + 10) / 2
= 0.91
= 91%

4. Results and Discussion

Consider the results of the fuzzy system shown below,
For interests input levels:

Security : 4
Networking : 5

We get a recommendation level of 91.00% for **Computer Networking and Wireless Communication.**

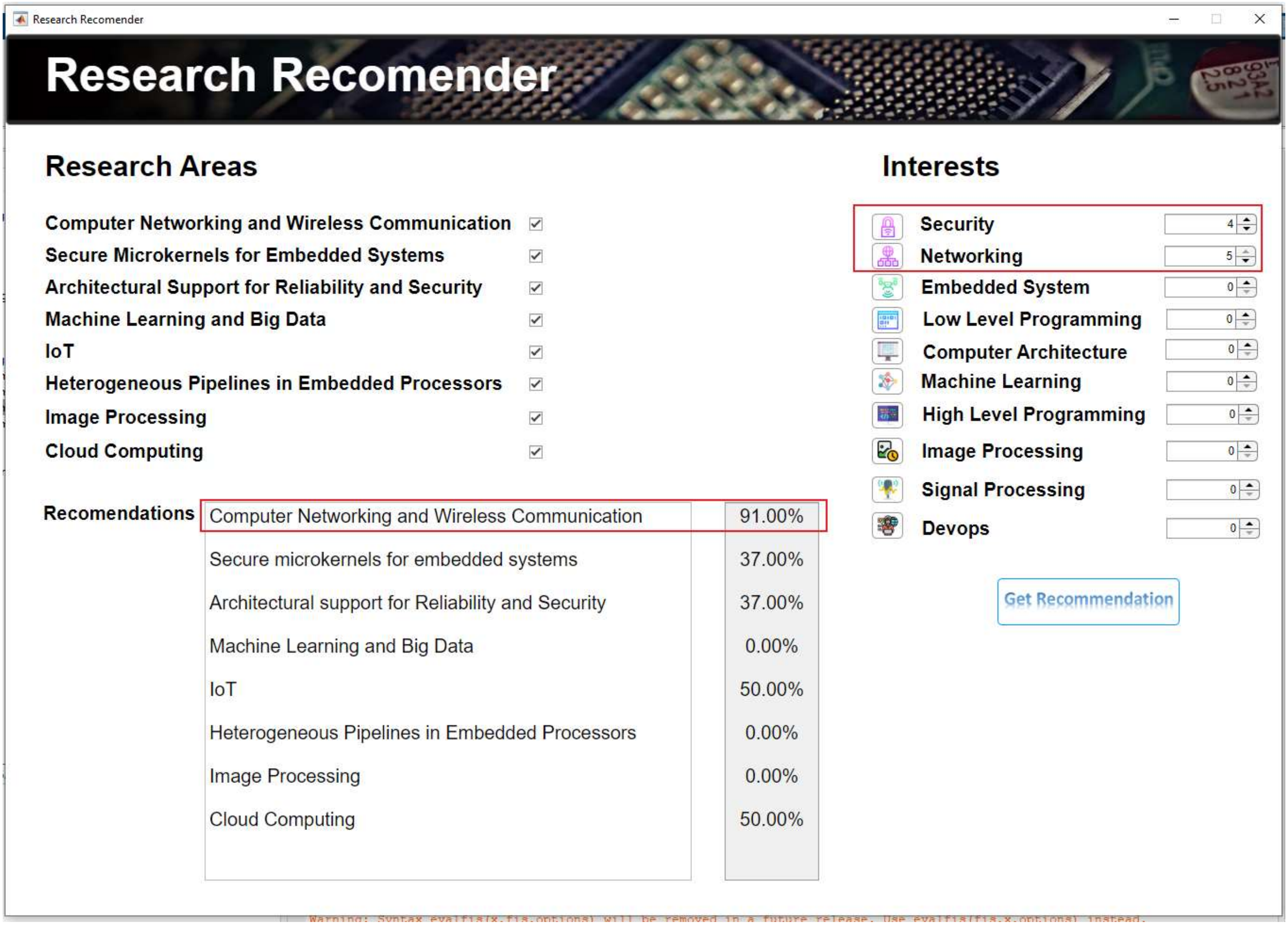

FIGURE 7:Output obtained from Implemented Fuzzy System

When comparing the results obtained in previous calculations of **Methodology Explained using an Example (3.5)**, results from our system are accurate. Membership functions and defuzzification methods used in the matlab implementation give expected results according to our rule base. Also we can observe that other research areas that get affected by high interests of Security and Networking other than Computer Networking and Wireless Communication as defined in our rule base.

We choose gaussian membership function because the slope of the function is increasing when it deviates from the mean. Also it has a low variation around the mean. We choose this function over triangular and trapezoidal membership functions because gaussian MF responds well to slight changes as well as large changes on the input with respect to other two functions.

Further improvements on our rule base, user input interest areas and levels can be conducted with collecting the feedback of the users. We will be able to fine tune the parameters.

We considered both Mamdani and Sugeno as the inference rules and then chose Mamdani in the end because Mamdani type is more efficient and accurate than Sugeno type as mentioned in the research done by Abdelwahab Hamam and Nicolas D. Georganas . Since in this implementation we need to achieve a higher accuracy on recommendations, this was the ideal choice.

We can make further improvements on our rule base, user input interest areas and levels in the future if needed as well.

Fuzzy systems focused on what a system does rather than understanding the functionality of a system. The main advantage of a fuzzy system is it is a simple, cheap solution to a complex problem. Although it is not complex, the results are often satisfactory.

Without doing a crisp logic based implementation, this fuzzy system simplifies the process of generating recommendations according to the preferences of the user. If we used crisp logic, we might have to define rules based on many scenarios and even that might not be enough. In this implementation we managed to make recommendations using only 24 rules for around 5^{10} different user preference level combinations. This is the advantage of using fuzzy logic with these types of problems.

5. Member Contributions

E/16/049 - Bandara S. D. M. V. G. H. N.

- Found related research articles and references
- Determine interests corresponding to each research area.
- Deciding the membership functions
- Testing the membership functions
- Report Writing

E/16/276 - Perera G. K. B. H.

- Designing the rule base
- Testing the membership functions
- Designing and implementing the fuzzy inference system
- Report writing
- Demonstration Video

E/16/388 - Weerasundara W. M. T. M. P. B.

- Determine interests corresponding to each research area
- Designing the rule base
- Testing the membership functions
- Designing the GUI
- Report writing

GitHub Repository

6. References

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4. Mohd Suffian Sulaiman, Amylia Ahamad Tamizi, Mohd Razzif Shamsudin, Azri Azmi, Course Recommendation System Using Fuzzy Logic Approach, Indonesian Journal of Electrical Engineering and Computer Science,Vol. 17,No. 1, January 2020
5. Abdelwahab Hamam, Nicolas D. Georganas, A Comparison of Mamdani and Sugeno Fuzzy Inference Systems for Evaluating the Quality of Experience of Hapto-Audio-Visual Applications, IEEE Xplore, Haptic Audio Visual Environments and Games,2008