# Fuzzy Inference System for Cyber Security Job Application Decision-Making

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***Abstract* — Fuzzy Logic is becoming increasingly popular and used in many applications today, this is mainly due to its ability to represent vague and imprecise information to arrive at decisions, in uncertain situations, using mathematics. Numerous fields have successfully adopted fuzzy logic including robotics, engineering, industrial automation, cyber security, etc. This paper presents the design and development of a Fuzzy Inference Systems (FIS) to provide advice and assist in the decision-making process for job application into the cyber security industry. Throughout the paper we aim to present the process of job application selection and highlight key factors that contribute to the decision-making when accepting or rejecting a candidate., as well as the system development lifecycle, the rationale, and testing the impact of different membership functions and defuzzification techniques.**

***Keywords* — *Fuzzy Logic, FIS, Cyber Security, Fuzzy Rules, Decision-Making.***

## I. Introduction

Cyber Security is a continuously developing and changing industry, with the advancement of technology and the increasing threat landscape caused by cyber criminals and cyber-attacks, there is a clear need for professionals within the field. According to a workforce study [1] in 2018 there was an estimated global cybersecurity workforce shortfall of approximative three million, a consequent study [2] in 2019 showed that number further increasing to four million. While the gap narrowed in 2020, there is still a significant shortfall of workforce within the field, around three million globally [3]. Cyber security is a complex field and has been characterized as “multidisciplinary” [4], as it compromises both the technical and business matters and concerns faced by enterprises today [5]. This increases the level of difficulty of selecting and recruiting appropriate candidates that understand both technical and business dimensions of the field, and in addition to technical competency, there is a need for cybersecurity professionals to possess leadership skills for managing security policies, as well as managerial and communications skills [6].

Due to the complexity of the process and the certain level of uncertainty involved in the decision-making regarding the job application of candidates, we believe that fuzzy logic can be successfully applied in order to assist recruiters in selecting the most appropriate candidates. Fuzzy Logic was first introduced by professor Lotfi A. Zadeh in 1965 [7] and, according to [9] “can deal with information arising from computational perception and cognition, that is, uncertain, imprecise, vague, partially true, or without sharp boundaries”, as well as “allows for the inclusion of vague human assessments in computing problems”, which makes it especially appropriate and beneficial for the purpose of our work. Furthermore, fuzzy logic provides, according to [8] “a different way to approach a control or classification problem”, this is because, as a “multivalve logic” it allows for intermediate values to be defined between conventional evaluations (true/false, yes/no, high/low, etc).

## II. System Development

### A. Methodology

Because of the wide range of jobs and different fields present in cybersecurity (e.g. penetration testing, forensics, cyber threat, etc.), we will approach the design of the system and its parameters from the perspective of a company searching for an entry-level to mid-level security analyst for the SOC (Security Operations Center). Once the system is successfully developed and tested, future modifications will allow for the adoption of the system in other parts of the industry, if needed parameters could be changed to provide advice for job applications within other roles.

Our system will look at the decision-making process regarding job application for our security analyst role, when designing the system we will be looking at the recruitment criteria for similar roles, and research how major cyber security companies approach the process of selecting and accepting candidates for a role.

### B. Initial Design

In order to highlight the key factors we need to consider during the decision-making process, we used a range of job criteria presented in the entry requirements of cyber security related companies such as Deloitte [10], Roke [11], Egress [12] and IBM [13]. The following list of key factors was created:

| |
|---|
| - *Education* |
| - *Professional Qualifications* |
| - *Experience* |
| - *Skills* |
| - *Personality* |
| - *Interview* |

The range of factors presented above can be further expanded, as presented in [14], with the *Personality* category exploring the *interest on the field, curiosity, projects,* the *Education* category can include *degree and degree classification, results*, the *Skills* section can regard *soft and technical skills, leadership abilities, analytical skills and communication skills.*

The table of key factors presented above will be used as our set of inputs for the system, in order to create our fuzzy sets we need to identify the minimum and maximum values for each of our inputs.

According to [8] "a fuzzy set is defined by a function that maps objects in a domain of concern to the membership value in the set". During the modelling of our membership functions we will identify our input values which will create the universe of disclosure for individual inputs.

Our next step is modelling our linguistic terms, selecting the membership functions (MFs) we will be using is an important part of the system design as "they play a vital role in the overall performance of fuzzy representation" [15]. Membership functions can have different shapes, some of our options are *Triangular, Trapezoidal, Gaussian, etc.*, while the shape may be important when dealing with particular problems, since it can have an effect on the system, according to [15] we have control over the choice of MFs and "can be of any shape and form as long as it maps the given data with desirable degree of memberships". Furthermore, the only real condition imposed is that MFs need to vary between 0 and 1.

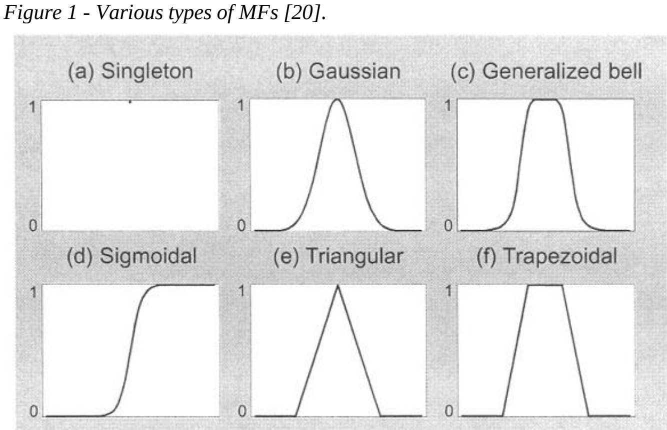
Before choosing our MF's shapes we will analyse the benefits of each individual MFs:

- *Triangular:* one of the most popular MF, and most used in practice due to its simplicity, formed using straight lines triangular shapes represent fuzzy numbers [15].
- *Trapezoid:* simplest shapes to implement, they represent fuzzy intervals [15].
- *Gaussian:* also a popular MF, those are formed by curves and provide smoothness, concise notation, and are nonzero at all points [15].

While other shapes exist such as *Bell-Shape*, they have a higher level of complexity, for our purposes we will only consider the functions mentioned above only.

After consulting the guidance and the literature [16], [17], we decided to use a combination of the *Triangular, Trapezoidal and Gaussian*, with *Trapezoidal* being predominant. While it was demonstrated in [18] that the *Triangular MF* has a better overall performance than *Gaussian*, and all other MFs, for the purpose of our work we choose the *Trapezoidal MF* as our main shape as it provides with a simple implementation and "can better capture the vagueness of linguistic assessments" [19].

*Figure 1 - Various types of MFs [20].*



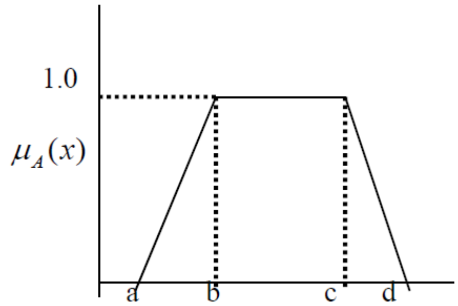

**Trapezoidal membership function:**

*Trapezoid (x; a, b, c, d) =*

- *0 if x <= a,*
- *(x-a)/ (b-a) if a <= x <=b,*
- *1 if b <= x <= c,*
- *(d-x)/ (d-c) 0 if c <= x <= d,*
- *0, if d <= x.*

$$\mu_{\text{trapezoid}} = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

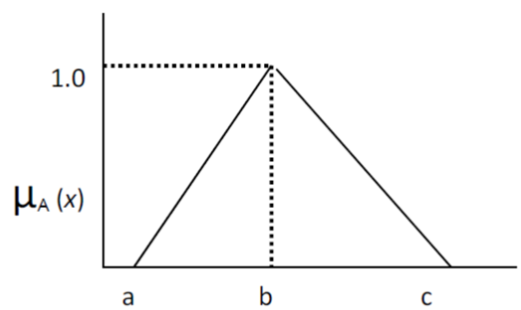
*Figure 2 - Trapezoidal MF [20].*




**Triangular Membership function:**

$$\mu_A(x) = \begin{cases} 0 & if\ x \le a \\ \dfrac{x-a}{b-a} & if\ a \le x \le b \\ \dfrac{c-x}{c-b} & if\ b \le x \le c \\ 0 & if\ x \ge c \end{cases}$$

*Figure 3 - Triangular MF [20].*

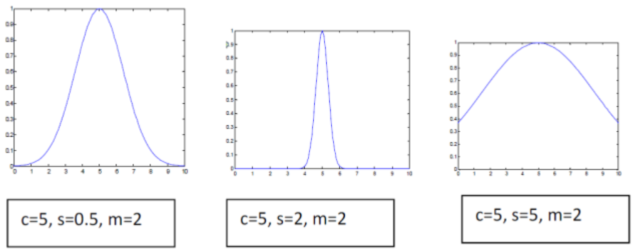



**Gaussian membership function:**

$$\mu_A(x, c, s, m) = \exp\left[-\frac{1}{2}\left|\frac{x-c}{s}\right|^m\right]$$

The formula above is the representation of the Gaussian MF as *Gaussian (x; c, s), where c = mean* and *s = standard deviation*, as presented in [2].

*Figure 4 - Shapes of Gaussian MF with different s and m values [20].*




## III. System Inputs

### *A. Education*

One of the major criteria for accepting candidates is education, according to [4] cyber security is a "immature" and not yet a fully defined discipline, he further states that "there is need for a whole variety of academic degree programs in cybersecurity from the technical aspects through to courses based on psychology, psychiatry, criminal justice, business" [4]. A similar view is presented in [5] who believes "the industry depends heavily on the higher education system for qualified employees".

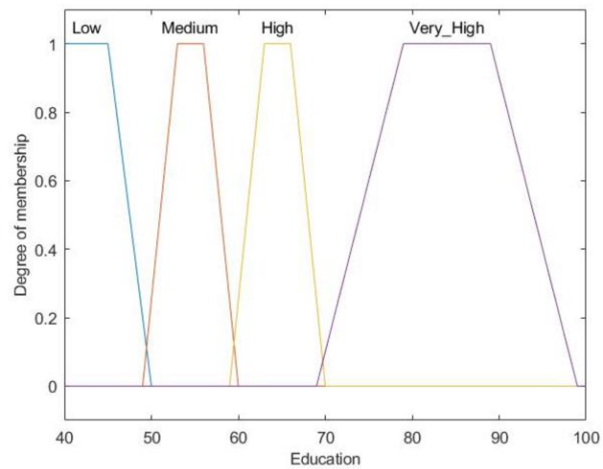
When looking at various opportunities in the field we observed the majority of companies looking in particular for undergraduates, with few exceptions asking for a postgraduate degree. For that reason, we will design our education input to be focusing on undergraduate education. The education membership function will be based on the UK Degree classification for bachelors with a Universe of Disclosure of 40 to 100, which represent the mark students can obtain with a threshold of 40% that represents the minimum grade for passing and obtaining a honours degree [21]. We provide a table explaining the degree classification and the exact grade range assigned to it, this is the official degree classification obtained from De Montfort University (DMU), Leicester:

| ***Degree Classification*** | ***Mark Range*** |
|---|---|
| ***1$^{st}$*** | *69.5%+* |
| ***2:1*** | *59.5%-69.49%* |
| ***2:2*** | *49.5%-59.49%* |
| ***3$^{rd}$*** | *39.5%-49.49%* |
| ***Pass*** | *39.49%+* |

The universe of disclosure will be 40 to 100 to allow for applicants with a lower mark to be considered, the only condition is that the mark needs to be a pass. This is mainly to help consider candidates with lower education but higher experience. When consulting organization's requirements regarding education we noticed companies normally looking for candidates with a degree classification of 2:2 to 1$^{st}$.

| **Linguistic Term** | **Values [a, b, c, d]** |
|---|---|
| Low | [0 40 45 50] |
| Medium | [49 53 56 60] |
| High | [59 63 66 70] |
| Very High | [69 79 89 100] |

*Figure 5 - Education MF Input.*




When researching our inputs, we found a lot of the recruitment criteria to be company or recruiter specific. In order to find a consensus for our MFs and values, we made a decision to contact a field professional recruiter to aid us in selecting the appropriate parameters. The interview was conducted online on 18$^{th}$ of January 2021, with a follow up on 21$^{st}$ of January 2021 for a final review of the system.

The recruiter agreed with our parameters for the Education input and further confirmed that companies will be more likely to consider candidates with 2:2 and above when looking at the education section.

We were also advised to adjust our initial list of key factors by combining some of our inputs and adding new variables. Our updated list of inputs is:

| |
|---|
| - *Education* |
| - *Skills* |
| - *Experience* |
| - *CV & Cover Letter* |
| - *Interview* |

- The *Skills* section may include soft and technical skills, communication and writing skills, etc.
- *Experience* has now been expanded to include volunteering, projects, qualifications to match any possible scenario.
- An important section we initially overlooked, *CV and Cover Letter*, was now added.
- And the candidate's interest and personality has now been integrated into the *Interview*, this is because that is where the recruiters are best able to determine such factors.

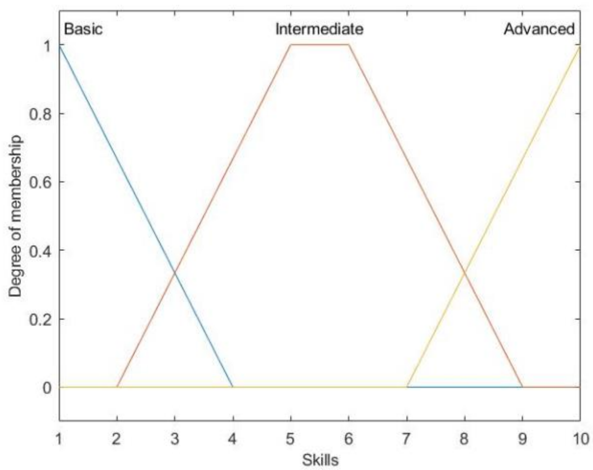
### *B. Skills*

Throughout our research we found the skills section, while an important factor in considering applicants, to be highly varying among different companies and for different job positions. Skills can include academic skills, soft skills, or specific technical skills.

Because it is a very fuzzy input with no clear universe of disclosure, we based our parameters on the expert's advice. It was agreed that the best implementation will be rating the skills level on a scale of 1 to 10, this is justified as an applicant will always have a certain level of skills and never be 0.

| **Linguistic Term** | **Values [a, b, c, d]** |
|---|---|
| Basic | [0 1 4] |
| Intermediate | [2 5 6 9] |
| Advanced | [7 10 11] |

*Figure 6 - Skills MF Input.*




As shown in **Figure 6** for this input we used a combination of triangular shape with trapezoidal shape to better represent the fuzzy input and different levels implemented.

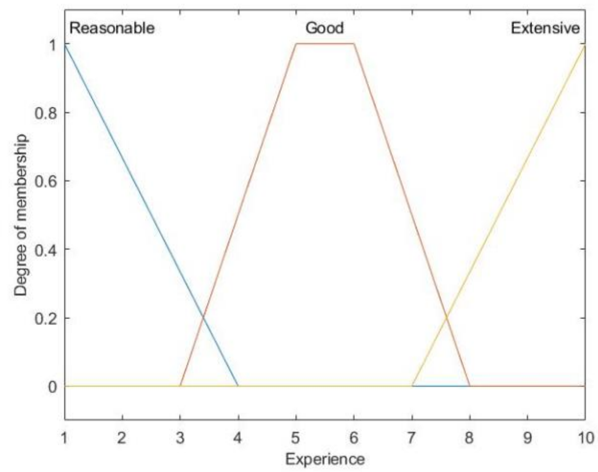
## *C. Experience*

Similar to our previous input, the experience section brings a similar level of fuzziness with no clear universe of disclosure. Companies regard experience depending on the candidate's history and abilities. For one, we could look at experience as the number of years worked for one or more companies, while this is alright for candidates with a history of employment it is not applicable for individuals starting their career with no previous employment. For those candidates, experience could mean volunteering, academic and non-academic projects, qualifications, etc. This will allow applicants to have a fair chance when being assessed by the system.

When modelling our input, we took a similar approach as the previous MF with a scale of 1 to 10 representing in this occasion the number of years. For our purpose we are assuming that candidates will, at a minimum, have a year of "experience" which could be a year undertaking projects in university, working for a company, undertaking volunteering, etc., this is will be a minimum requirement for applying in such a position for most companies.

| **Linguistic Term** | **Values [a, b, c, d]** |
|---|---|
| Reasonable | [0 1 4] |
| Good | [3 5 6 8] |
| Extensive | [7 10 11] |

*Figure 7 - Experience MF Input.*



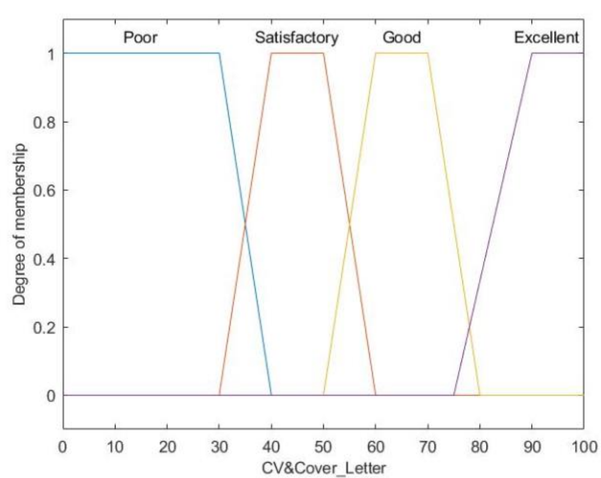

Same combination of triangular and trapezoidal shapes was used for this input.

## *D. CV, Cover Letter, and Interview*

In regards to the job application and recruitment process, the CV, Cover Letter, and Interview are considered to be vital components. After consulting with our recruitment expert, it became clear that those inputs should have the same universe of disclosure of 0 to 100, this is so that we can easily assign different levels and assess candidates.

| **Linguistic Term** | **Values [a, b, c, d]** |
|---|---|
| Poor | [0 0 30 40] |
| Satisfactory | [30 40 50 60] |
| Good | [50 60 70 80] |
| Excellent | [75 90 100 110] |

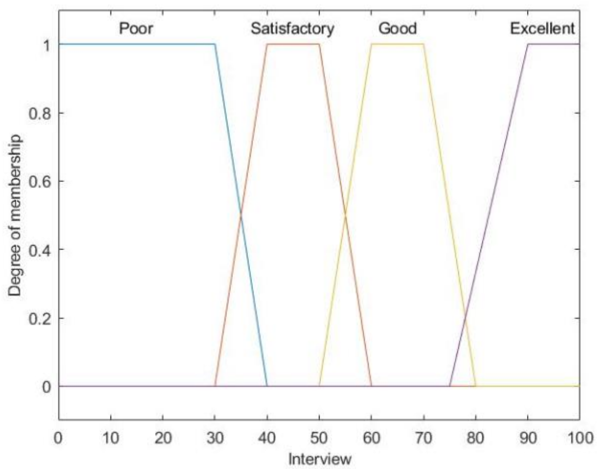
*Figure 8 - CV and Cover Letter MF Input.*




The CV and Cover Letter are, according to our expert, an evaluation of the candidate from both a professional and personal perspective. A good CV and Cover Letter is a person's extension and for that reason it needs to present the candidate's qualities and abilities.

A bad interview can often attract rejection, and, to make sure applicants have a fair chance, our system will allow for a second interview if certain conditions are met, to ensure a fair process.

*Figure 9 - Interview MF Input.*



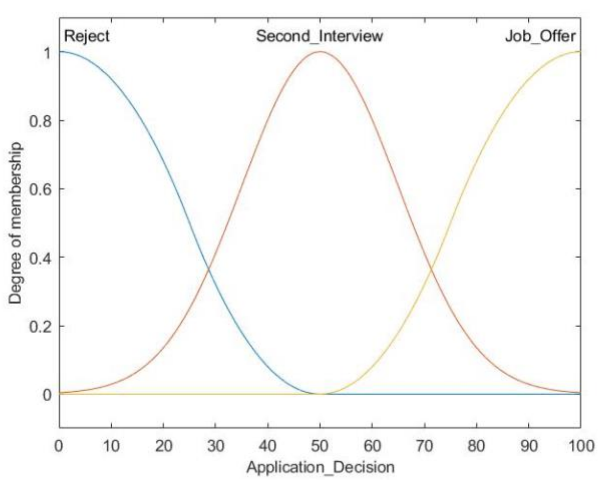

To avoid overlapping, both inputs use the same values, this is due to their similar levels of assessments that we can attribute to the two components of the recruitment process.

### *E. System Output*

Initially our decision output was designed with two membership functions, *'reject' and 'offer'*, which is the usual outcome of a job application. For our system we wanted to properly assess candidates and ensure they receive a fair and complete evaluation, as well as opportunity, if in doubt about an applicant, to invite him for a second interview. Our final version of the MFs for the output is:

| **Linguistic Term** | **Values [a, b]** |
|---|---|
| Reject | [0 50] |
| Second Interview | [15 50] |
| Job Offer | [50 100] |

*Figure 10 - Decision MF Output.*




We designed the membership functions of the output as a Gaussian MF's in order to output a fuzzy response instead of a crisp value, this is mainly because the decision is complex and is dependent on several factors, a certain level of uncertainty will always be present. The performance will be determined later, as well as the suitability of the universe of disclosure (0 to 100).

## IV. System Design and Rules

Our initial design (Appendix IX.A) of the system should map the approach taken by recruiters during the decision-making of a job application, as well as relate our chosen MFs with the defined scales of measurement. While we were careful in considering our MFs and inputs, testing will be used to ensure their validity. Due to the large number of factors that need considering when making decisions regarding job applications, there is a risk of overlapping and the system becoming overly complex, for that reason we took steps to ensure the design remains balanced. Several inputs were combined, and key factors were integrated into one input rather than creating multiple, this should ensure a better overall performance and will be tested later on.

A vital part when designing our system was creating the rules, which are "are a collection of linguistic statements that describe how the FIS should make a decision regarding classifying an input or controlling an output" [25]. According to [26] "fuzzy system theory provides a powerful tool for system simulation and uncertainty quantification" but its limited in the context of a fuzzy system expressed as a rule-based, "it grows exceedingly large in terms of number of rules" [26].

A method for rule reduction is presented in [26], IRC (Intersection Rule Configuration) which "maps the intersection of antecedents fuzzy sets to output consequent fuzzy sets" this is usually the exhaustive search of solutions using all possible combinations of rules to determine the output. Unfortunately, it is not efficient due to high computational time and results:

$$R = l^n \qquad or \qquad R = l_i l_{i+1} \ldots$$

Where $R$ is the number of rules, $l$ is the number of linguistic labels, and $n$ is the number of inputs variables. A way of determining the number of possible combinations for our rules is by using the formula below:

$$I_{1n} * I_{2n} * I_{3n} * I_{4n} * I_{5n} = R$$

$R$ is the number of rules possible, $I$ the input and $n$ the number of membership functions, this is normally referred to as a complete FIS and for our system has a total number of combinations of 576 combinations.

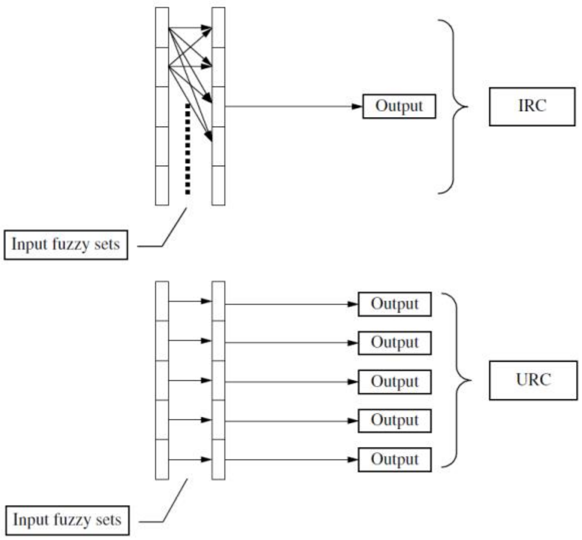
Another method we considered for rule reduction is the URC (Union Rule Configuration), which transforms the IRC to a system of single antecedent rules using a union operator, compared to the IRC which uses an intersection operator [26].

*Figure 11 - IRC-URC Equivalence [26].*

| (*p* and *q*) then *r* | IRC |
|---|---|
| not (p and q) or r | Classical implication |
| not p or not q or r | De Morgan's principle |
| not p or not q or (r or r) | Idempotency |
| (not p or r) or (not q or r) | Commutativity |
| (*p* then *r*) or (*q* then *r*) | Classical implication, URC |

The table shown above will be used to determine the best combination when deciding the appropriate rules. Furthermore, [26] presented the following benefits of using URC method, such as fast computation, simple to construct, and the solution being often equivalent to the IRC. In the IRC approach intersection of the input values is elated with output and is achieved using the "and" operator, in contrast in URC this is achieved with the "or" operator [26].

*Figure 12 - IRC - URC Input - Output Relations [26].*




An IRC rule will become from the format *If (A and B) then C* structured as *If (A then C) or If (B then C).*

When developing our rules, we looked at different scenarios that could arise during the recruitment process, several combinations were attempted before finding our initial rule list. After careful consideration, the output of our system will follow the scenarios presented below:

- *Candidates with extensive experience and a good outcome interview will receive a job offer, while applicants with extensive experience but a bad interview outcome will be invited for a second interview.*
- *Candidates with good experience can also receive a job offer as long as the level of skills is not basic, the CV and cover letter is not poor, and this depends on the interview outcome, with poor and satisfactory interviews being invited for a second interview and good and excellent being awarded a job offer.*
- *Candidates with lowest levels in all inputs, as well as candidates with no experience and skills will be rejected.*
- *Other combinations of rules concerning education will receive either a second interview as long as the skills and experience is not low, or a job offer for higher levels of education, skills/experience.*

In order to properly assess candidates and cover various scenarios a combination of the "and" and "not" operators were used. The full list of initial rules is available in Appendix IX.C.

## V. TESTING

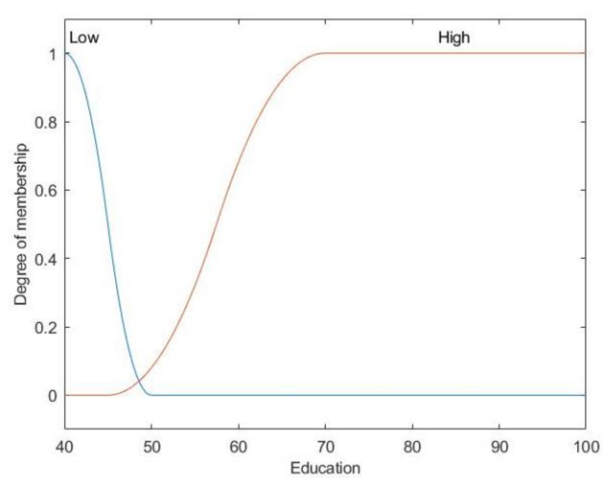
When initial testing of the system and the rules was undertaken, we observed several flaws with the decision-making of the system in certain scenarios, as presented in Appendix IX.D. The testing highlighted the need of changing some of our membership functions and change a part of our rules to ensure the system is accurate. It became clear a new version of the initial system was needed, for that reason the following changes were made, and will be tested with the initial system to determine if any improvement has been made:

- *The Education MF has been modified from the original 4 MFs to 2 MFs, this mainly because the high amount of MFs were not of use on this input. When companies are looking for education their criteria is a degree above 2:2, for that reason the input has been changed as shown below.*

| **Linguistic Term** | **Values [a, b]** |
|---|---|
| Low | [40 50] |
| High | [45 70] |

- *With the change of our input, the new membership functions used were the Z-Shaped and S-Shaped to match our new values. It should be noted that we have lowered the value to 70 as that is the threshold for obtaining a 1$^{st}$ class degree in UK.*

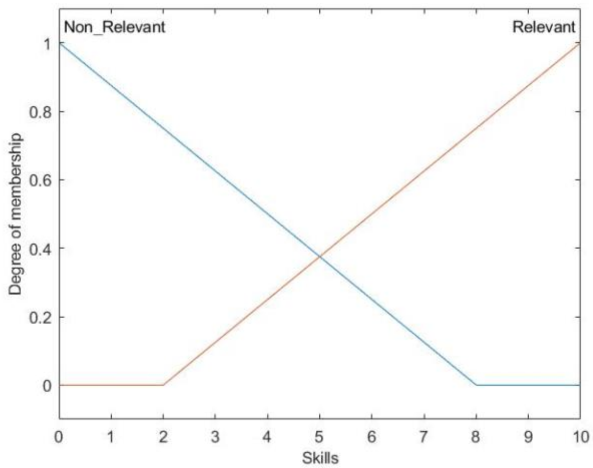
*Figure 13 - Redesigned Education Input.*



- *The Skills Input has been changed next in order to provide a simpler and more realistic assessment, as shown in our testing that the initial design need simplifying.*

| Linguistic Term | Values [a, b, c] |
|---|---|
| Non-Relevant | [-1 0 8] |
| Relevant | [2 10 11] |

*Figure 14 Redesigned Skills Input.*

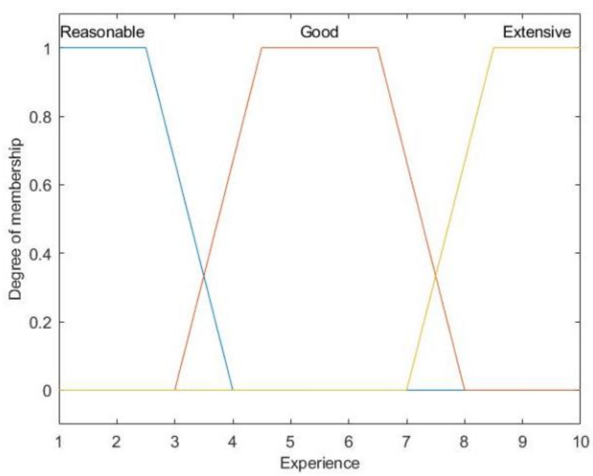



- *The new input uses now 2 triangular MFs, the change was made as companies are more likely to assess weather the candidate has the skills they are looking for, rather than the level of skills they have overall.*

- *Finally, the Experience Input has been modified by changing the initial triangular MFs to trapezoidal.*

| Linguistic Term | Values [a, b, c, d] |
|---|---|
| Reasonable | [0 0 2.5 4] |
| Good | [3 4.5 6.5 8] |
| Extensive | [7 8.5 10 11] |

*Figure 15 - Redesigned Experience Input.*




*The completed new system along with our new set of rules is available in Appendix IX.E.*

***Defuzzification Techniques***

During the testing of the initial and final system we used a number of defuzzification techniques, the system provides with a fuzzy output of *Rejecting*, *Second Interview, and Job Offering*, and there should not be any crisp value. Furthermore, the techniques mentioned previously are fully supported by Matlab include Medium value of Maximum (MoM), Largest value of Maximum (LoM), Smallest value of the Maximum (SoM), Centroid and Bisector.

When comparing the initial and final system tests done with the defuzzification techniques, the results show Mom and Lom providing a more positive result than Som, Centroid and Bisector, moreover our results show Mom has the most accurate values when compered to the other techniques.

## VI. Justification and Related Work

According to [22] “the main purpose of recruitment is to engage the best available talents from within or outside the organisation for available job positions”. With the continuously growth of the global threat landscape, the cyber security industry is in need of new “talent” that can fill the current gap in workforce. Our system aims at aiding recruiters in the process of assessing candidates by using a human-like approach during the evaluation of applicants. While our system is aimed at the cyber security field, other similar work using fuzzy logic is present in the literature. In [23] fuzzy logic is used to determine the relations between job factors and overall job satisfaction, [24] describes a personnel selection tool based on fuzzy data mining method that can assist business managers to discover eligible talent more efficiently, and [22] implemented a “fuzzy expert system (FES) tool for selection of qualified job applicants with the aim of minimising the rigour and subjectivity associated with the candidate selection process”. Systems such as the examples described above show that fuzzy logic can be successfully applied to facilitate help in tasks such recruitment, where recruiters deal with a certain amount of imprecise or uncertain situations, and human logic is needed for making an appropriate decision.

## VII. Conclusion and Limitations

The system is meant to fairly assess candidates, the selection of rules and the system itself was designed by researching the current literature, study cases, and from the experience of professionals, as well as our personal experience and judgement. The decision-making on the results of job applications remains highly situational, the system should aid in that process, but may not fully cover all possible scenarios due to high level of uncertainty.

At the moment, the final version of our system has shown increased performance and accuracy but still has shortcomings, with certain scenarios outputting unexpected results. This could be caused by a number of reasons including our rules, that may need further developing. Future work may include adding or adjusting the current rules or changing our inputs by using a wider range of membership functions.

The system provides with the decision making for job application with minor errors, the development of such a system required various aspects to be considered as well as valid membership function, appropriate rules and defuzzification techniques. This paper outlines our process of designing and developing the system as well as testing we undertook during this process.

## VIII. References

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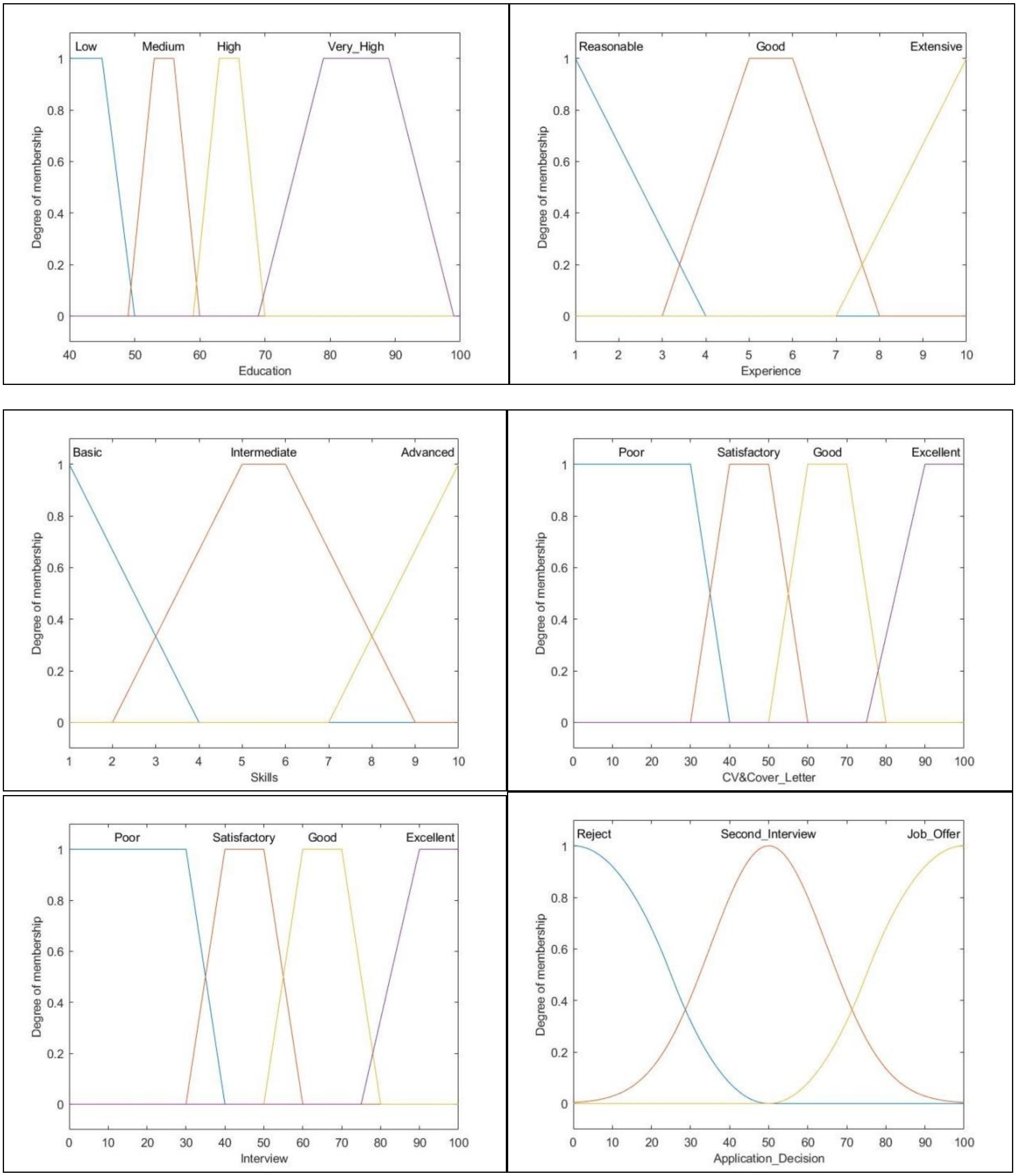
# IX. Appendix

## *A. Initial Design – Input & Membership Functions*



### B. *The Fuzzy Inference System and Membership Functions as an m-file*

```
FIS=newfis('Job Application Decision System');

FIS=addvar(FIS,'input','Education',[40 100]);
FIS=addmf(FIS,'input',1,'Low','trapmf',[0 40 45 50]);
FIS=addmf(FIS,'input',1,'Medium','trapmf',[49 53 56 60]);
FIS=addmf(FIS,'input',1,'High','trapmf',[59 63 66 70]);
FIS=addmf(FIS,'input',1,'Very_High','trapmf',[69 79 89 100]);

subplot(3,2,1);
plotmf(FIS,'input',1);
title('Education');

FIS=addvar(FIS,'input','Skills', [1 10]);
FIS=addmf(FIS,'input',2,'Basic','trimf',[0 1 4]);
FIS=addmf(FIS,'input',2,'Intermediate','trapmf',[2 5 6 9]);
FIS=addmf(FIS,'input',2,'Advanced','trimf',[7 10 11]);

subplot(3,2,2);
plotmf(FIS,'input',2);
title('Skills');

FIS=addvar(FIS,'input','Experience', [1 10]);
FIS=addmf(FIS,'input',3,'Reasonable','trimf',[0 1 4]);
FIS=addmf(FIS,'input',3,'Good','trapmf',[3 5 6 8]);
FIS=addmf(FIS,'input',3,'Extensive','trimf',[7 10 11]);

subplot(3,2,3);
plotmf(FIS,'input',3);
title('Experience');

FIS=addvar(FIS,'input','CV&Cover_Letter', [0 100]);
FIS=addmf(FIS,'input',4,'Poor','trapmf',[0 0 30 40]);
FIS=addmf(FIS,'input',4,'Satisfactory','trapmf',[30 40 50 60]);
FIS=addmf(FIS,'input',4,'Good','trapmf',[50 60 70 80]);
FIS=addmf(FIS,'input',4,'Excellent','trapmf',[75 90 100 110]);

subplot(3,2,4);
plotmf(FIS,'input',4);
title('CV&Cover_Letter');

FIS=addvar(FIS,'input','Interview', [0 100]);
FIS=addmf(FIS,'input',5,'Poor','trapmf',[0 0 30 40]);
FIS=addmf(FIS,'input',5,'Satisfactory','trapmf',[30 40 50 60]);
FIS=addmf(FIS,'input',5,'Good','trapmf',[50 60 70 80]);
FIS=addmf(FIS,'input',5,'Excellent','trapmf',[75 90 100 110]);

subplot(3,2,5);
plotmf(FIS,'input',5);
title('Interview');

FIS=addvar(FIS,'output','Application_Decision', [0 100]);
FIS=addmf(FIS,'output',1,'Reject','zmf',[0 50]);
FIS=addmf(FIS,'output',1,'Second Interview','gaussmf',[15 50]);
FIS=addmf(FIS,'output',1,'Job_Offer','smf',[50 100]);

subplot(3,2,6);
plotmf(FIS,'output',1);
title('Application_Decision');
```

## C. *Initial Rules Combinations*

*Figure 16 - Rule GUI - MATLAB.*

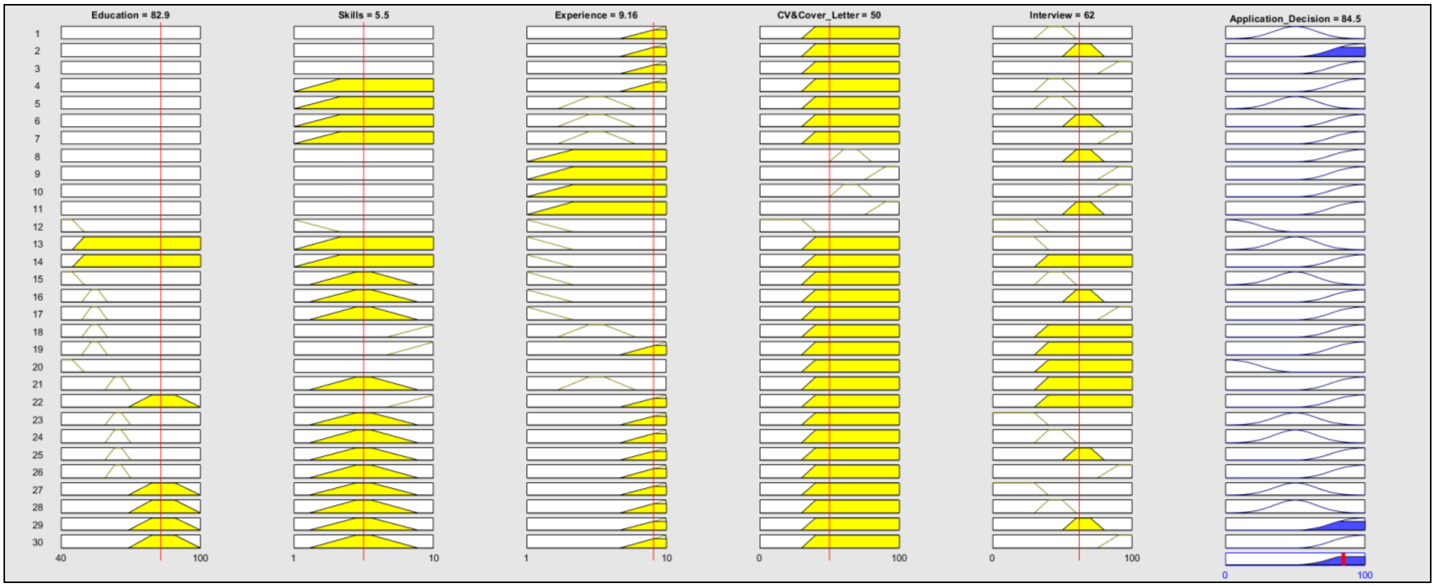



*Table 1 - Rule List.*

| |
|---|
| **'1. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1)** ' |
| **'2. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1)** ' |
| **'3. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1)** ' |
| **'4. If (Skills is not Basic) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1)** ' |
| **'5. If (Skills is not Basic) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1)** ' |
| **'6. If (Skills is not Basic) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1)** ' |
| **'7. If (Skills is not Basic) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1)** ' |
| **'8. If (Experience is not Reasonable) and (CV&Cover_Letter is Good) and (Interview is Good) then (Application_Decision is Job_Offer) (1)** ' |
| **'9. If (Experience is not Reasonable) and (CV&Cover_Letter is Excellent) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1)** ' |
| **'10. If (Experience is not Reasonable) and (CV&Cover_Letter is Good) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1)** ' |
| **'11. If (Experience is not Reasonable) and (CV&Cover_Letter is Excellent) and (Interview is Good) then (Application_Decision is Job_Offer) (1)** ' |
| **'12. If (Education is Low) and (Skills is Basic) and (Experience is Reasonable) and (CV&Cover_Letter is Poor) and (Interview is Poor) then (Application_Decision is Reject) (1)** ' |
| **'13. If (Education is not Low) and (Skills is not Basic) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1)** ' |
| **'14. If (Education is not Low) and (Skills is not Basic) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1)** ' |
| **'15. If (Education is Low) and (Skills is Intermediate) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Reject) (1)** ' |
| **'16. If (Education is Medium) and (Skills is Intermediate) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1)** ' |

| |
|---|
| **'17. If (Education is Medium) and (Skills is Intermediate) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'18. If (Education is Medium) and (Skills is Advanced) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1) '** |
| **'19. If (Education is Medium) and (Skills is Advanced) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1) '** |
| **'20. If (Education is Low) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Reject) (1) '** |
| **'21. If (Education is High) and (Skills is Intermediate) and (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1) '** |
| **'22. If (Education is Very_High) and (Skills is Advanced) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1) '** |
| **'23. If (Education is High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1) '** |
| **'24. If (Education is High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1) '** |
| **'25. If (Education is High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'26. If (Education is High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'27. If (Education is Very_High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1) '** |
| **'28. If (Education is Very_High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1)'** |
| **'29. If (Education is Very_High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'30. If (Education is Very_High) and (Skills is Intermediate) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |

**Rules as an m-file**

```
rules = [
0 0 3 -1 2, 2 (1) : 1
0 0 3 -1 3, 3 (1) : 1
0 0 3 -1 4, 3 (1) : 1
0 -1 3 -1 2, 3 (1) : 1
0 -1 2 -1 2, 2 (1) : 1
0 -1 2 -1 3, 3 (1) : 1
0 -1 2 -1 4, 3 (1) : 1
0 0 -1 3 3, 3 (1) : 1
0 0 -1 4 4, 3 (1) : 1
0 0 -1 3 4, 3 (1) : 1
0 0 -1 4 3, 3 (1) : 1
1 1 1 1 1, 1 (1) : 1
-1 -1 1 -1 1, 2 (1) : 1
-1 -1 1 -1 -1, 3 (1) : 1
1 2 1 -1 2, 2 (1) : 1
2 2 1 -1 3, 3 (1) : 1
2 2 1 -1 4, 3 (1) : 1
2 3 2 -1 -1, 3 (1) : 1
2 3 3 -1 -1, 3 (1) : 1
1 0 0 -1 -1, 1 (1) : 1
3 2 2 -1 -1, 3 (1) : 1
4 3 3 -1 -1, 3 (1) : 1
3 2 3 -1 1, 2 (1) : 1
3 2 3 -1 2, 2 (1) : 1
3 2 3 -1 3, 3 (1) : 1
3 2 3 -1 4, 3 (1) : 1
4 2 3 -1 1, 2 (1) : 1
4 2 3 -1 2, 2 (1) : 1
4 2 3 -1 3, 3 (1) : 1
4 2 3 -1 4, 3 (1) : 1
]

FIS = addrule(FIS, rules);
```

## D. ***Initial System Test***

*Table 2 - Initial Results Scenarios.*

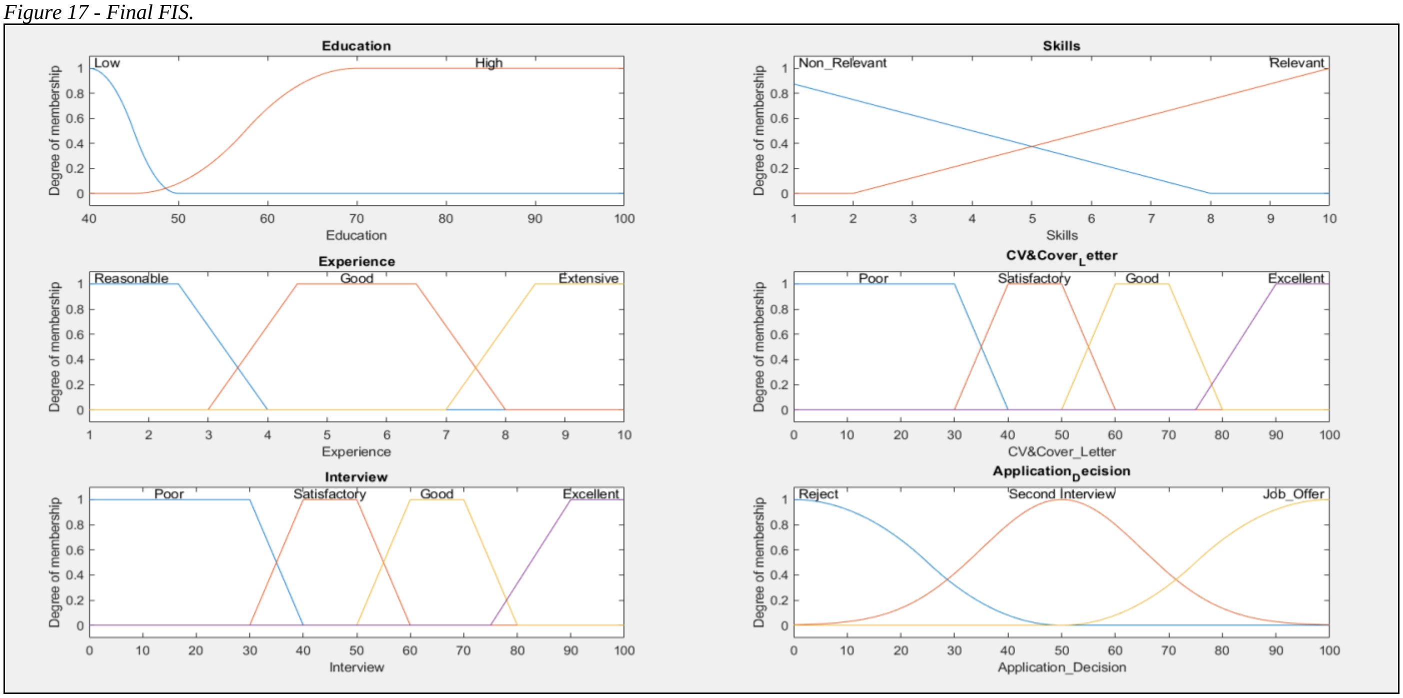
| Scenario | Result | Expected Result | Modifications |
|---|---|---|---|
| An extensive experienced candidate with a good CV and good outcome interview. | Reject | Job Offer | - *Education, Skills, and Experience Inputs have been modified and redesigned using other MFs.*<br>- *Education and Skills Inputs have been simplified to be more appropriate for realistic scenarios.*<br>- *Various rules were changed to match the new system.* |
| Candidate with a good level of experience, good skills, good CV and satisfactory interview. | Reject | Second Interview | |
| A graduate student with a 1st class bachelor's degree, with good CV, intermediate skills, but extensive experience, and an poor interview. | Second Interview | Second Interview | |
| A candidate with low education, basic skills, reasonable experience, poor CV, and poor interview outcome. | Reject | Reject | |
| A recent graduate with a 1st bachelor's degree, extensive experience, advanced skills, good CV and good interview. | Job Offer | Job Offer | |

*Table 3 - Defuzzification Initial System.*

| Input | MOM | LOM | SOM | Centroid | Bisector |
|---|---|---|---|---|---|
| [40 1 8 50 70] | 0 | 0 | 0 | 36.2 | 21 |
| [40 6 7 60 45] | 0 | 0 | 0 | 33.1 | 30 |
| [75 8 9 67 20] | 50 | 72 | 28 | 50 | 50 |
| [20 2 2 20 20] | 10 | 20 | 0 | 15.9 | 15 |
| [80 9 9 80 85] | 90 | 100 | 80 | 84.1 | 85 |

## E. ***Redesigned System***

*Figure 17 - Final FIS.*



```
FIS=newfis('Job Application Decision System', 'mamdani', 'min', 'max', 'min',
'max', 'centroid');

FIS=addvar(FIS,'input','Education',[40 100]);
FIS=addmf(FIS,'input',1,'Low','zmf',[40 50]);
FIS=addmf(FIS,'input',1,'High','smf',[45 70]);


subplot(3,2,1);
plotmf(FIS,'input',1);
title('Education');

FIS=addvar(FIS,'input','Skills', [1 10]);
FIS=addmf(FIS,'input',2,'Non_Relevant','trimf',[-1 0 8]);
FIS=addmf(FIS,'input',2,'Relevant','trimf',[2 10 11]);


subplot(3,2,2);
plotmf(FIS,'input',2);
title('Skills');

FIS=addvar(FIS,'input','Experience', [1 10]);
FIS=addmf(FIS,'input',3,'Reasonable','trapmf',[0 0 2.5 4]);
FIS=addmf(FIS,'input',3,'Good','trapmf',[3 4.5 6.5 8]);
FIS=addmf(FIS,'input',3,'Extensive','trapmf',[7 8.5 10 11]);

subplot(3,2,3);
plotmf(FIS,'input',3);
title('Experience');

FIS=addvar(FIS,'input','CV&Cover_Letter', [0 100]);
FIS=addmf(FIS,'input',4,'Poor','trapmf',[0 0 30 40]);
FIS=addmf(FIS,'input',4,'Satisfactory','trapmf',[30 40 50 60]);
FIS=addmf(FIS,'input',4,'Good','trapmf',[50 60 70 80]);
FIS=addmf(FIS,'input',4,'Excellent','trapmf',[75 90 100 110]);

subplot(3,2,4);
plotmf(FIS,'input',4);
title('CV&Cover_Letter');

FIS=addvar(FIS,'input','Interview', [0 100]);
FIS=addmf(FIS,'input',5,'Poor','trapmf',[0 0 30 40]);
FIS=addmf(FIS,'input',5,'Satisfactory','trapmf',[30 40 50 60]);
FIS=addmf(FIS,'input',5,'Good','trapmf',[50 60 70 80]);
FIS=addmf(FIS,'input',5,'Excellent','trapmf',[75 90 100 110]);

subplot(3,2,5);
plotmf(FIS,'input',5);
title('Interview');

FIS=addvar(FIS,'output','Application_Decision', [0 100]);
FIS=addmf(FIS,'output',1,'Reject','zmf',[0 50]);
FIS=addmf(FIS,'output',1,'Second Interview','gaussmf',[15 50]);
FIS=addmf(FIS,'output',1,'Job_Offer','smf',[50 100]);

subplot(3,2,6);
plotmf(FIS,'output',1);
title('Application_Decision');
```

```
rules = [
0 0 3 -1 2, 2 (1) : 1
0 0 3 -1 3, 3 (1) : 1
0 0 3 -1 4, 3 (1) : 1
0 -1 3 -1 2, 3 (1) : 1
0 0 2 -1 2, 2 (1) : 1
0 0 2 -1 3, 3 (1) : 1
0 0 2 -1 4, 3 (1) : 1
0 2 1 3 3, 3 (1) : 1
0 2 1 4 4, 3 (1) : 1
0 2 1 3 4, 3 (1) : 1
0 2 1 4 3, 3 (1) : 1
1 1 1 1 1, 1 (1) : 1
-1 -1 1 -1 1, 2 (1) : 1
-1 -1 1 -1 -1, 3 (1) : 1
1 2 0 -1 -1, 1 (1) : 1
1 0 3 -1 1, 2 (1) : 1
1 0 0 1 1, 1 (1) : 1
2 2 0 -1 1, 2 (1) : 1
2 2 0 -1 2, 2 (1) : 1
2 2 0 -1 3, 3 (1) : 1
2 2 0 -1 4, 3 (1) : 1
2 0 1 -1 1, 2 (1) : 1
2 0 1 -1 2, 2 (1) : 1
2 0 1 -1 3, 3 (1) : 1
2 0 1 -1 4, 3 (1) : 1
2 0 3 -1 -1, 3 (1) : 1
]

FIS = addrule(FIS, rules);
```

*Figure 18 - New Rule List.*

| |
|---|
| **'1. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1) '** |
| **'2. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'3. If (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'4. If (Skills is not Non_Relevant) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Job_Offer) (1) '** |
| **'5. If (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1) '** |
| **'6. If (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'7. If (Experience is Good) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'8. If (Skills is Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is Good) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'9. If (Skills is Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is Excellent) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'10. If (Skills is Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is Good) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'11. If (Skills is Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is Excellent) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'12. If (Education is Low) and (Skills is Non_Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is Poor) and (Interview is Poor) then (Application_Decision is Reject) (1) '** |
| **'13. If (Education is not Low) and (Skills is not Non_Relevant) and (Experience is Reasonable) and (CV&Cover_Letter** |

| |
|---|
| **is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1)'** |
| **'14. If (Education is not Low) and (Skills is not Non_Relevant) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1) '** |
| **'15. If (Education is Low) and (Skills is Relevant) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Reject) (1) '** |
| **'16. If (Education is Low) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1) '** |
| **'17. If (Education is Low) and (CV&Cover_Letter is Poor) and (Interview is Poor) then (Application_Decision is Reject) (1)** |
| **'18. If (Education is High) and (Skills is Relevant) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1) '** |
| **'19. If (Education is High) and (Skills is Relevant) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1) '** |
| **'20. If (Education is High) and (Skills is Relevant) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'21. If (Education is High) and (Skills is Relevant) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'22. If (Education is High) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Poor) then (Application_Decision is Second_Interview) (1) '** |
| **'23. If (Education is High) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Satisfactory) then (Application_Decision is Second_Interview) (1) '** |
| **'24. If (Education is High) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Good) then (Application_Decision is Job_Offer) (1) '** |
| **'25. If (Education is High) and (Experience is Reasonable) and (CV&Cover_Letter is not Poor) and (Interview is Excellent) then (Application_Decision is Job_Offer) (1) '** |
| **'26. If (Education is High) and (Experience is Extensive) and (CV&Cover_Letter is not Poor) and (Interview is not Poor) then (Application_Decision is Job_Offer) (1)** |

| Scenario | Result | Expected Result | Modifications |
|---|---|---|---|
| An extensive experienced candidate with a good CV and good outcome interview. | Offer | Job Offer | |
| Candidate with a good level of experience, good skills, good CV and satisfactory interview. | Reject | Second Interview | |
| A graduate student with a 1st class bachelor's degree, with good CV, intermediate skills, but extensive experience, and an poor interview. | Second Interview | Second Interview | |
| A candidate with low education, basic skills, reasonable experience, poor CV, and poor interview outcome. | Reject | Reject | |
| A recent graduate with a 1st bachelor's degree, extensive experience, advanced skills, good CV and good interview. | Job Offer | Job Offer | |

| Input | MOM | LOM | SOM | Centroid | Bisector |
|---|---|---|---|---|---|
| [40 1 8 50 70] | 90 | 100 | 80 | 84.1 | 85 |
| [40 6 7 60 45] | 50 | 63 | 37 | 39.9 | 41 |
| [75 8 9 67 20] | 50 | 61 | 39 | 50 | 50 |
| [20 2 2 20 20] | 0 | 0 | 0 | 14.3 | 13 |
| [80 9 9 80 85] | 100 | 100 | 100 | 85.7 | 87 |