Fuzzy Logic System Implementation with Mamdani Method in Computer-Based Intelligence Quotient Test to Determining the Type of Intelligence Dimension

G N Putri¹, B Dirgantoro¹, P Aulia², and C Setianingsih¹

¹ Department of Computer Engineering, Faculty of Electrical Engineering, Telkom University, Bandung, Indonesia
² Department of Business Administration Faculty Communication and Business, Telkom University, Bandung, Indonesia

Abstract. A person of a thing can cultivate intelligence in areas of interest, sometimes many people complain because the results of their intelligence quotient test (IQ) show unsatisfactory results. Because they are still looking only lies in those abilities. Intelligence quotient tests are used to explore knowledge about certain individual skills and intelligence. To determine someone's intelligence, it takes a long time to analyze and get the test output from calculations by certain methods manually. The determination of a person's dimension intelligence can be done by certain method, this research is one way to make a fuzzy model for the type of intelligence dimension support system based on standardization in psychology The result of this research is expected to explain how to modeling the fuzzy logic system with Mamdani method in a support system to determine the types of intelligence dimensions, namely the festigung / exact or flexibilitat / non-exact.

1. Introduction

The growth in the usability of a computer is getting higher along with the development of scientific needs. The computerized testing system has the potential to become a practical and cost-effective tool. It can be realized, if the correct consideration is made for designing and implementation of a testing system and if the professional standards are held by the services providers and test users [1]. The computers can be used for administrative issues, scoring and interpretation of the test, or to make a new task and measuring abilities that traditional procedures cannot do.

Intelligence quotient test is a test that reveals intelligence to determine the extent to which a person's general ability to predict what kind of education or training can be given to him/her. Intelligence is designed for learning under test conditions about someone's success in adapting to certain situations. A large number of a different method intended to measure the most famous intelligence, one of which is an intelligence quotient test (IQ). Artificial intelligence methods have a lot of usabilities that are needed in many fields. Soft computing technology is a field of interdisciplinary research studies in computing and artificial intelligence. Several techniques in soft computing have been developed because they have advantages in solving problems that contain uncertainty, inaccuracy and partial truth. Fuzzy logic widely used in various problem fields, such as process control, classification and pattern matching, operations management and decision making, economic research and so on. The method used in making conclusions must consider alternatives that support the success of conclusions to produce optimal decisions.
2. Method

2.1. Computer-Based Psychological Test

Psychologically, the administration of computer-based tests produced a test score that corresponds to the actual abilities of each test taker. This is because not all of the test items are given, so it can avoid the exhaustion that appears when the test was taken. Generally, only a small percentage have become inconsistent-results in some research, research has shown that conventional and computer-based facilities are equivalent (Schulenberg & Yutrzenka 20014).

![Figure 1. Context Diagram of System](image)

Figure 1 shows the overall system flow of the intelligence test process. In the first step, users register by filling in their data, then users can immediately do the test. The results will automatically come out when the user completes the test.

2.2. Intelligence Quotient Test

Based on experience, there are no clear indicators and measuring tools to measure or assess the intelligence of every individual, except for intellectual intelligence or IQ, in this context known as a test commonly called a psychological test. The value of intelligence is often associated with age and produces IQ to find out how the relative position of the person concerned with people of the same age [2]. The intelligence quotient test consists of nine subtests total of 176 question items. Each subtest has an aspect value that represents the subtest.

| Sub Test               | Description                                                                 | Aspect Value                                                                 |
|-----------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| SE (satzerganzung)    | Complete the sentence                                                        | Measuring decision formation, make use of past experiences (think independently), practical concrete thinking |
| WA (wortauswahl)      | Synonym                                                                     | Intellectual, ability to appreciate language problems, think inductively by using language, intuition component |
| AN (analogien)        | Verbal analogy                                                              | Ability to combine, the flexibility of thinking, think logically (use thought as a basis for thinking), doesn't like completion approx. |
| GE (gemeninsamkeiten) | Same nature                                                                 | Abstraction ability (formation of understanding), ability to express/understand in language, form an understanding / look for the main problem |
| ME (merkaufgaben)     | Memory                                                                       | Measuring memory and long-lasting can see a fixed concentration and a sign of endurance |
| RA (rechenaufgaben)   | Calculate                                                                    | Practical inductive thinking counts, ability to count, using numbers is practically a matter of calculation |
| ZR (zahlennrlihen)    | Series of numbers                                                           | There are rhythmic moments, think inductive theoretical numbers, theoretical use of numbers |
| FA (figurenauswahl)   | Choose image                                                                 | Ability to imagine, constructing (synthesis and analysis), rich of responses |
| WU (wurfalaufgaben)   | Cube                                                                         | Space capability of three dimensions can be accompanied by analytical moments |
2.3. Interpretation Intelligence Quotient Test
Interpretation of intelligence quotient test results does not have standard rules. Noteworthy are the possibilities that are reflected through the results of the test because this possibility has been proven validity thorough research on many people. From the execution of intelligence quotient test, determination of the intelligence dimension can be getting from the interpretation of this test, respondent has expertise in the field of festigung/exact (Fes) or flexibilitat/non-exact (Flex). There is the difference between the festigung (Fes) and flexibilitat (Flex) that is the dimension level of the intelligence. Exact science can be interpreted as the studies of certain identical things by studying the calculation of numbers. While, non-exact science is the study of existing theories, when the new theories appear, the old theories can no longer be used. The exact science is identical with the formula and calculation of numerical calculation, while the non-exact is tending to various theories and there are no numerical calculations in them.

Figure 2 showing the flowchart of the results of an intelligence quotient test in this way. The way to determine the level of intelligence dimension of Festigung and Flexibilitat is to use the fuzzy logic system with the Mamdani method, where the input required is to use test scores from the GE, RA, AN and ZR subtest only. The input parameters used are adjusted to the standardization of the intelligence quotient test.

2.4. Classification Intelligence Quotient
Although it is difficult to define, indeed it does not seem to have a formal definition. However, at least there is one of a precise definition of intelligence that is the capacity to learn and understand something. Scores from the standard intelligence tests (IQ scores) are often used to determine a person's intelligence quotient. Table 2 is a classification of IQ value based on intelligence quotient standardization in 1937.

| Classification           | IQ       |
|--------------------------|----------|
| Very Superior            | >140     |
| Superior                 | 120 – 139|
| Bright Normal            | 110 – 119|
| Average                  | 90 – 109 |
| Dull Normal              | 80 – 89  |
| Borderline-Defective     | 70 – 79  |

2.5. Fuzzy Logic System
The experience of solving various problems of medical and psychological diagnosis shows that the measured parameters are often incomplete and unclear in determining the blurring boundary with a
zone of deviation the passes from a class to class. Therefore, in this condition, it makes sense to use the fuzzy logic theory to getting conclusions in determining the intelligence dimension [3]. Related to a scoring method by following what has been established in psychology, it's just that in this research more emphasized analysis that is the aspect of intelligence that tends to be owned by the respondent. The fuzzy knowledge-based system is a system that works based on fuzzy knowledge as a way of making decisions. The processes contained in the fuzzy knowledge-based system are:

- **Fuzzification**
  The process of mapping numerical values into fuzzy sets. Inputs whose truth value must be converted into fuzzy input in the form of linguistic values based on membership functions [4]. In this research, the author used the trapezoid curve representation.

- **Input Parameter of Sub Test GE**
  Curve representation and the membership function used are shown in figure 3 below.

\[
\mu_{\text{less (GE)}} = \begin{cases} 
1 & x \leq 80 \\
\frac{90-x}{90-80} & 80 < x < 90 \\
0 & x \geq 90
\end{cases}
\]
\[
\mu_{\text{medium (GE)}} = \begin{cases} 
1 & 90 \leq x \leq 110 \\
\frac{x-80}{90-80} & 80 < x < 90 \\
\frac{115-x}{115-110} & 110 < x < 90 \\
0 & x \geq 90
\end{cases}
\]
\[
\mu_{\text{well (GE)}} = \begin{cases} 
1 & x \geq 115 \\
\frac{x-110}{115-110} & 110 < x < 115 \\
0 & x \geq 90
\end{cases}
\]

- **Input Parameter of Sub Test RA**
  Curve representation and the membership function used are shown in figure 4 below.

\[
\mu_{\text{RA}} = \begin{cases} 
1 & x \leq 80 \\
\frac{90-x}{90-80} & 80 < x < 90 \\
0 & x \geq 90
\end{cases}
\]

\[
\mu_{\text{well (RA)}} = \begin{cases} 
1 & 90 \leq x \leq 110 \\
\frac{x-80}{90-80} & 80 < x < 90 \\
\frac{115-x}{115-110} & 110 < x < 90 \\
0 & x \geq 90
\end{cases}
\]
\[ \mu_{\text{less}}(RA) = \begin{cases} 
1 & x \leq 80 \\
\frac{90-x}{90-80} & 80 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{medium}}(RA) = \begin{cases} 
1 & 90 \leq x \leq 110 \\
\frac{x-80}{90-80} & 80 < x < 90 \\
\frac{115-x}{115-110} & 110 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{well}}(RA) = \begin{cases} 
1 & x \geq 115 \\
\frac{x-110}{115-110} & 110 < x < 115 \\
0 & x \geq 90 
\end{cases} \]

- Input Parameter of Sub Test AN

Curve representation and the membership function used are shown in figure 5 below.

![Figure 5. Curve Representation of Sub Test AN](image)

Based on figure 5 above, the fuzzy set equation from AN sub test can be shown in the equation below.

\[ \mu_{\text{less}}(AN) = \begin{cases} 
1 & x \leq 80 \\
\frac{90-x}{90-80} & 80 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{medium}}(AN) = \begin{cases} 
1 & 90 \leq x \leq 110 \\
\frac{x-80}{90-80} & 80 < x < 90 \\
\frac{115-x}{115-110} & 110 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{well}}(AN) = \begin{cases} 
1 & x \geq 115 \\
\frac{x-110}{115-110} & 110 < x < 115 \\
0 & x \geq 90 
\end{cases} \]

- Input Parameter of Sub Test ZR

Curve representation and the membership function used are shown in figure 6 below.

![Figure 6. Curve Representation of Sub Test ZR](image)
Based on figure 8 above, the fuzzy set equation from ZR sub test can be shown in the equation below.

\[ \mu_{\text{less}}(ZR) = \begin{cases} 
1 & x \leq 80 \\
\frac{90-x}{90-80} & 80 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{medium}}(ZR) = \begin{cases} 
1 & 90 \leq x \leq 110 \\
\frac{x-80}{90-80} & 80 < x < 90 \\
\frac{115-x}{115-110} & 110 < x < 90 \\
0 & x \geq 90 
\end{cases} \]

\[ \mu_{\text{well}}(ZR) = \begin{cases} 
1 & x \geq 115 \\
\frac{x-110}{115-110} & 110 < x < 115 \\
0 & x \geq 90 
\end{cases} \]

- Output of Conclusion

Curve representation and the membership function used are shown in figure 7 below.

**Figure 7. Curve Representation of Output**

Based on figure 7 above, the fuzzy set equation from output can be shown in the equation below.

\[ \mu_{\text{low}}(\text{output}) = \begin{cases} 
1 & x \leq 40 \\
\frac{60-x}{60-40} & 40 < x < 60 \\
0 & x \geq 60 
\end{cases} \]

\[ \mu_{\text{high}}(\text{output}) = \begin{cases} 
1 & x \geq 60 \\
\frac{x-40}{60-40} & 40 < x < 60 \\
0 & x \leq 40 
\end{cases} \]

- Inference

Simulates human decision making based on fuzzy concepts. In this research the author used the Mamdani model it is because resembles human intuition or feeling, the calculations are quite complex and produce a high level of accuracy. The rule base used in this fuzzy logic system is based on the analysis provided by psychologists. Table 3 below explains the example of the rule of fuzzy logic.

**Table 3. Example of The Rule of Fuzzy Logic System**

| Rule     | Condition                                      | Effect               |
|----------|------------------------------------------------|----------------------|
| Rule-1   | IF GE value is **Less** AND RA value is **Less** AND AN value is **Less** AND ZR value is **Less** | THEN Dimension level is **Low** |
| Rule-2   | IF GE value is **Less** AND RA value is **Less** AND AN value is **Less** AND ZR value is **Medium** | THEN Dimension level is **Low** |
Rule-3  IF GE value is Less AND RA value is Less AND AN value is Less AND ZR value is Well THEN Dimension level is Low

Rule-81 IF GE value is Well AND RA value is Well AND AN value is Well AND ZR value is Well THEN Dimension level is High

• Defuzzification

Getting an output value which is assertive as a final result. In the defuzzification process, three criteria must be owned, namely reasonable, simple and continuous calculation. In this research, the author uses the centroid method by taking the value of the center point ($Z^*$) from the area in the membership function.

Figure 8 explains that the first step to do is determine the membership function of the fuzzy system that was designed. After that, the process of adding all of the subtests scores required for determining the intelligence dimension. The next step is to form rules based on the principles of science from psychology obtained from psychologists. Then, the central values are obtained that determine the higher membership levels. After obtaining the central point value from the defuzzification input, then to find the intelligence dimension Festigung or Flexibilitat used a formula based on psychological standardization below.

**Figure 8. Flowchart of Determine Intelligence Dimension**

| Table 4. Psychological Standardization Formula |
|-----------------------------------------------|
| Input (weighted score) | Condition | Input (weighted score) | Output |
|------------------------|-----------|------------------------|--------|
| GE + RA                | >         | AN + ZR                | Festigung |
| AN + ZR                | >         | GE + RA                | Flexibilitat |

From table 4 above will be obtained the dimension of intelligence and the level of intelligence dimension using the fuzzy logic system with the Mamdani method.

3. Implementation

The implementation of the computer-based intelligence quotient test was carried out in several classes majoring in computer engineering at Telkom University with a total of approximately 100 respondents from 21st October 2019 to 24th October 2019. The test was carried out two times, the first is a paper-based test and the second is a computer-based test. After carrying out the test twice, the respondents will be given a questionnaire and asked to fill it out. Website appearance that has been designed is explained below.
4. Result

4.1. Questionnaire’s Data Calculation
From the questionnaire submitted to the respondent, the calculation results obtained that, 42% of respondents are agreed that the computer-based intelligence quotient test system facilitates the implementation and calculation of the test results, and 1.1% of respondent are disagree that the computer-based intelligence quotient test system facilities the implementation and calculation of the test results, 43.6% of respondents are agreed that the computer-based intelligence quotient test system provided the appropriate analysis results, 44.1% of respondents are prefer to a computer-based intelligence quotient test system than a paper-based intelligence quotient test that is carried out manually, and 9.4% of respondent are not prefer to a computer-based intelligence quotient system.

4.2. Determination of Intelligence Dimension Test Item
In this section, the fuzzy logic system with the Mamdani method is used. The fuzzy logic method is used to determining the intelligence dimension. Selection of Festigung (Fes) or Flexibilitat (Flex) dimension of intelligence on the high or low level. The results of this test were obtained from sampling from 10 respondents.
Table 5. Sampling Results of Test Item on PBT

| Sub Test | Id User | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----------|---------|---|---|---|---|---|---|---|---|---|----|
| 1        |         | 11| 14| 10| 11| 12| 10| 13| 9 | 10| 13 |
| 2        |         | 15| 12| 13| 15| 11| 14| 14| 14| 15|    |
| 3        |         | 19| 18| 16| 19| 17| 16| 19| 17| 18| 17 |
| 4        |         | 10| 15| 12| 15| 9 | 16| 18| 12| 7 | 12 |
| 5        |         | 19| 10| 16| 16| 11| 18| 4 | 9 | 14|    |
| 6        |         | 19| 8 | 19| 14| 4 | 9 | 14| 3 | 8 | 11 |
| 7        |         | 5 | 5 | 7 | 5 | 9 | 8 | 7 | 6 | 10| 8  |
| 8        |         | 12| 10| 15| 17| 11| 11| 10| 8 | 4 | 10 |
| 9        |         | 16| 20| 20| 19| 15| 9 | 16| 11| 16| 20 |
| IQ       |         | 139|118|142|144|112|101|143|76|94|130 |
| Level    |         | Flex|Flex|Flex|Flex|Fes|Fes|Fes|Flex|Flex|Flex |

Table 6. Sampling Results of Test Item on CBT

| Sub Test | Id User | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----------|---------|---|---|---|---|---|---|---|---|---|----|
| 1        |         | 10| 13| 13| 10| 9 | 13| 17| 10| 12| 12 |
| 2        |         | 14| 12| 16| 14| 16| 9 | 14| 13| 15| 17 |
| 3        |         | 17| 16| 16| 20| 18| 16| 19| 17| 18| 18 |
| 4        |         | 12| 14| 13| 18| 9 | 15| 20| 8 | 12| 16 |
| 5        |         | 17| 17| 17| 18| 17| 17| 18| 10| 12| 15 |
| 6        |         | 18| 8 | 17| 18| 5 | 12| 17| 10| 10| 15 |
| 7        |         | 14| 8 | 9 | 13| 11| 9 | 6 | 9 | 10| 8  |
| 8        |         | 16| 7 | 16| 15| 11| 7 | 11| 7 | 5 | 11 |
| 9        |         | 17| 17| 20| 19| 18| 0 | 18| 0 | 17| 20 |
| IQ       |         | 152|118|155|165|121|97 |165|76|116|145 |
| Level    |         | Flex|Flex|Flex|Flex|Fes|Fes|Fes|Flex|Flex|Flex |

From table 5 and table 6 above, it can be concluded that the intelligence dimension of the 10 respondent samples is the same. There is no difference in the intelligence dimension between paper-based intelligence quotient test and computer-based intelligence quotient test. The difference is in the total score per sub-test, thus producing a different IQ score. The calculation of the accuracy of the fuzzy logic system is obtained based on the following formula.

Accuracy = \( \frac{91}{100} \times 100\% = 91\% \)
The accuracy of the system is obtained from a comparison between the results of the amount of data by the following reality with the sum of all data. Mathematically can be stated with the formula above (A'yun; 2015; 51).

4.3. Psychologist Review

Based on psychologist experts, regarding this computer-based intelligence quotient test, so far there has been no use of artificial intelligence methods in the application of intelligence quotient tests. This can be a development in the field of psychological testing. Based on testing, there is no significant difference in determining the type of intelligence interpretation. According to the psychologist, the difference in the total score per sub-test between paper-based tests and computer-based tests is due to human factors. The distribution of paper-based intelligence quotient test should be done by psychologists as well, it aims to maintain the validity of a paper-based intelligence quotient test. But the difference in the number of scores is not too significant, so in this case, the fuzzy logic method can be applied to the intelligence quotient test, because the score calculation process is still valid.

5. Conclusion

From this research, it can be concluded that the computer-based intelligence quotient test is preferred over the paper-based intelligence quotient test. By utilizing the ease of managing tests and calculating the value of intelligence quotient and determination of intelligence dimension using a computer. The use of the fuzzy logic system with the Mamdani method in getting conclusions on the type of intelligence dimension can be applied to computer-based intelligence quotient tests. Differences in PBT and CBT results occur due to other factors such as human factors. The application of the fuzzy logic method to the intelligence quotient test must still consider standardizing the pattern of test items that have been determined by the original intelligence quotient test so that the test results remain valid.

6. References

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