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Research paper



Dyslexia Risk Screening System based Fuzzy Logic

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Abstract

It is estimated that more than 314, 000 of Malaysian young children are dyslexic, which means having difficulty particularly in reading and spelling. Manual dyslexia screening test ages 6 to 10 years old (in Bahasa Malaysia) produced by Persatuan Dyslexia Malaysia contains 10 sets of tests including reading, rapid naming and pseudowords. However, confirmation of dyslexic status takes several days as the test scores are manually calculated. Therefore, a rapid computerized dyslexia risk screening tool based fuzzy logic has been proposed here. Using the scores obtain from four main tests namely as rapid naming, one-minute reading, two-minute spelling and pseudowords, the fuzzy system is able to determine dyslexic condition instantly. The main fuzzy inputs using pre-existed scores of 17 dyslexia subjects (3 girls and 14 boys) resulted promising system's accuracy (94.1 %) when classifying dyslexic risk in young children. In the future, this research will include non-dyslexia as well as other learning disability subjects for accuracy clarification towards non-dyslexia classification.

Keywords: *Dyslexia; Dyslexia Classification; Dyslexia Screening; Fuzzy Logic; Matlab.*

1. Introduction

Dyslexia is defined as a type of learning disability caused by neurological in the brain. Individuals who suffer from this will have difficulty in the aspects of reading, writing and spelling as they are unable to understand and interpret the content compared to normal people thus leading deficient in study performance [1],[2],[3]. According to the population across the world, approximately 3 to 12 % of children are dyslexic or in other words, 1 in 10 children has high chance to be dyslexic [4]. Based on the report, it is approximated that more than 314,000 Malaysian children are dyslexic but due to poor early screening technique, proper remedial program can only reach out to certain children population [5].

Dyslexia can be further categorized into several types of learning disorders namely as dysgraphia, dyscalculia and language [6]. Besides that, other categories related to dyslexia are Phonological Dyslexia, Surface Dyslexia, Visual Dyslexia, Double Deficit Dyslexia, Surface Dyslexia and Rapid Naming Deficit [6], [7]. The characteristics for each type of dyslexia are shown in Table 1.

Fuzzy Logic has been widely used in designing and implementation of engineering work. For example, it was applied in modelling a temperature control for thermostatic appliance in refrigerator. The study had successfully proven that the modelling technique can be greatly used in the enhancing the performance of evaporative condensers by executing alteration with the aid of Fuzzy Logic controller [8]. Besides that, it is also employed in medical diagnosis system to identify and classify the diseases. In India, it has been constantly used to design medical diagnosis work such as tuberculosis and typhoid fever to obtain a better outcome of diagnosis and reliable treatment scheme as the local often face with the insufficiency of doctors to diagnose, the occurrence of misdiagnosis, the poverty thus causing the rate of death to increase [9].

Table 1: The characteristics of each type of dyslexia learning disabilities [6],[7]

Types of Dyslexia	Characteristics
Dysgraphia	Difficulty in writing
Dyscalculia	Difficulty in calculation
Language	Difficulty in receptive (listening) and expressive (talking)
Phonological	Difficulty in making the sounds properly
Visual	Reading and writing are the issues as the words seem to be floating when they try to read and write
Rapid Naming	Unable to name the letters of numbers in rapid time
Double Deficit	A combination of phonological and rapid naming
Surface	Cannot recognize the whole words

Currently, Persatuan Dyslexia Malaysia has published a standardized screening instrument which is known as Ujian Pengesanan Awal Disleksia Malaysia to identify dyslexia among children [10]. This manual screening book is mainly focusing on identifying dyslexia in children age from 6 to10 years old through ten basic assessment tests. There is a need to develop a computer-based dyslexia screening system because longer time is required to obtain dyslexic result as the calculations are done manually and hence delay dyslexic risk confirmation.

Based on the limitation of conventional method, this research is aimed to design a computerized rapid screening tool by applying Fuzzy Logic in MATLAB software. The result whether or not the child is having dyslexia can be obtained instantaneously. Also, the

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system is able to show whether the child is having “High Risk” or “Low Risk” of dyslexia. The objectives of this research are first to acquire and identify suitable tests that can be used to determine dyslexia condition, secondly is to define the inputs, rules and output (“High Risk” and “Low Risk”) of Fuzzy Logic based on the tests scores and thirdly, to design a screening tool software by using Fuzzy Logic Toolbox in Matlab software.

In order to fulfill the objectives of the research, several limitations have been encountered for instance; difficulty to obtain the Malaysia version of standardized instrument for dyslexia screening as well as to recruit dyslexia subjects for data collection purpose. To tackle these problems, collaboration with En Saifuddin Mohtaram, one of the authors of Ujian Pengesanan Awal Disleksia Malaysia manual screening book had been initiated. Based on direct consultation with him, four out of ten tests as provided in the screening manual are sufficiently enough to be used as the input for dyslexic risk identification whereas the developed system will be evaluated using pre-existing collected data (dyslexic children) as supplied by Encik Saifuddin Mohtaram. The list of the selected tests to be assessed as well as corresponding categories (based on age) is presented in Table 2.

Table 2: Lists of tests and total scores associated with categories (based on age) for screening assessment [10]

Types of test	Categories (years old)	Total Scores
Test 1: Rapid naming	6, 7 to 8 and 9 to 10	56
Test 3: One-minute reading	6	32
	7 to 8	50
	9 to 10	75
Test 5:Two-minute spelling	6, 7 to 8 and 9 to 10	12
Test 7: Pseudowords	6	5
	7 to 8	10
	9 to 10	15

2. Fuzzy Interface System

Figure 1 shows the basic block diagram of Fuzzy Logic that includes combination of fuzzification, interface unit and defuzzification before the output can be produced in linguistic term. Fuzzy Logic is widely used in medical diagnostic systems to solve medical examination problem.

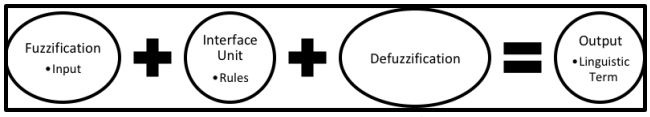

Fig. 1: Block diagram of Fuzzy Logic

To scheme a Fuzzy Diagnosis System, a Graphical User Interface (GUI) called Fuzzy Interface System (FIS) is utilized to make a decision using graphical tools or command-line functions. Figure 2 illustrates the flowchart of the FIS. It consists of FIS Editor, Membership Function Editor, Rule Editor, Rule Viewer and Surface Viewer. FIS Editor functions to display every input variable and output variable whereas Membership Function Editor defines the shapes of all the membership functions associated with each variable. Meanwhile, the behaviour of the system is defined by the operational rules created in Rule Editor whereas Rule Viewer and Surface Viewer are the read-only tools that can be used for data evaluation.

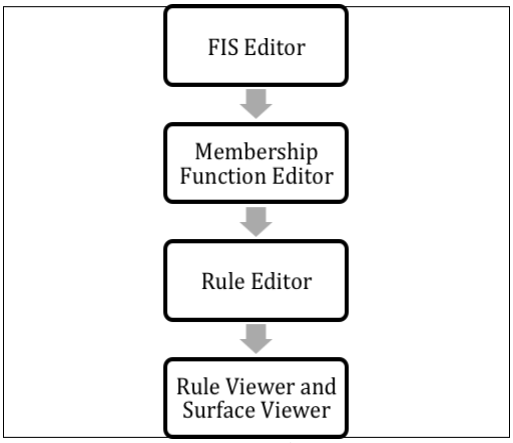

Fig. 2: FIS flowchart

3. Development of Dyslexia Risk Screening System

As shown in Figure 3, the process begins with the insertion of input into the system, which are the resulted scores of each test that is being assessed. Then, the inputs will be analyzed according to the conditions as set by the manual assessment. For instance, for scores obtain below 28 in Test 1 for 6 year-old category is considered as dyslexic whereas for 7 to 8 and 9 to 10 year-old categories, the scores should be below 35 and 39, respectively. The final stage will be the output in the form of defuzzification value that indicates the level of dyslexia risk. Further description on fuzzy output will be discussed in section 3.2.

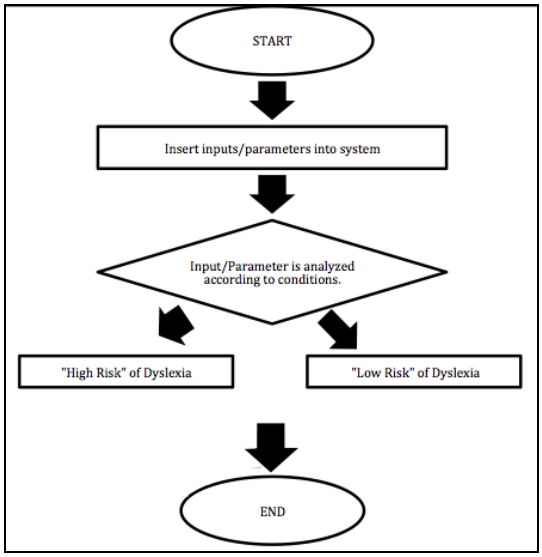

Fig. 3: Operation flowchart of the risk assessment tool

3.1. Fuzzy Logic Representation

Fuzzy Logic is a rule base identification and tuning toolbox where IF-THEN rules are being applied to create the output of the system. The rule-based system allows the analysis of various combinations of operators to take place. In this stage, the rules are created according to all possible outcomes by choosing any of the membership functions and establishing the relationship with connection “or” or “and” then finalizing the rule statements with result output to link and generate the rule statement based on level of risk for dyslexia as basis. Table 3 illustrates part of the 30 operational rules statements defining risk assessment based on four main tests.

Table 3: Part of the 30 operational rules statements. Noted that D is for Dyslexia whereas N is Normal.

Rules	Input Variables				Output Variables
	Test 1	Test 3	Test 5	Test 7	
1	D	D	D	D	High Risk
2	D	D	D	N	High Risk
3	D	D	N	D	High Risk
4	D	N	D	D	High Risk
5	N	D	D	D	High Risk
6	D	D	N	N	Low Risk

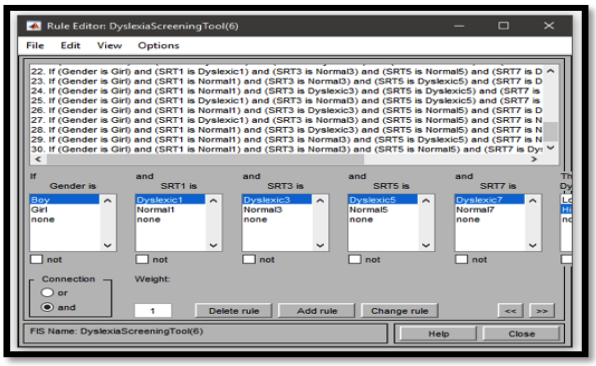

Fig. 4: Rule Editor to create rule statements

3.2. Fuzzy Logic Output

As illustrated in Table 4, the Fuzzy Logic system is set to give two possible outcomes namely as "High Risk" and "Low Risk" based on the range of number of tests found to be dyslexic. For example, if scores in 3 to 4 tests are below cut-off marks, the defuzzification value will show between 3 to 4 indicating High Risk. Likewise, if only 1 to 2 tests scores below cut-off marks, the defuzzification value will show between 1 and 2 implying Low Risk. Meanwhile, Figure 5 displays the output membership function and it can be seen clearly the type of membership function graph used is trapezoidal.

Table 4: Output range of fuzzy sets that represented dyslexia

Defuzzification Value	Fuzzy Output
3 to 4	High Risk
1 to 2	Low Risk

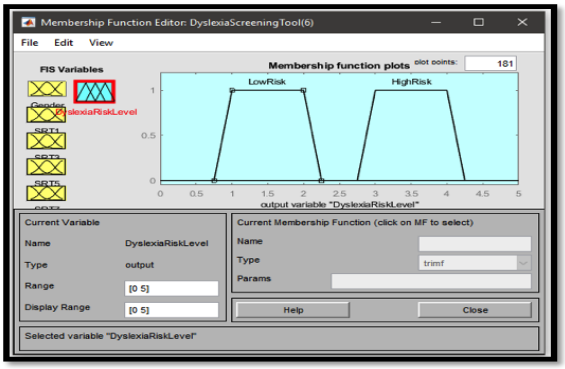

Fig. 5: Output membership function for level of risk assessment

3.3. Rule Viewer

The Rule Viewer as displayed in Figure 6 is a roadmap of the whole fuzzy inference system based on the rules creation. The whole plot displays the aggregation of output with the combination of rules made. The first five columns of plots are the input variables whereas the last column of plots displays the corresponding output shape. Labeled, as "Insert Data for Testing" is the place where the pre-existed input data will be inserted for evaluation. Finally, the last row in the last column that has red line will show defuzzified value.

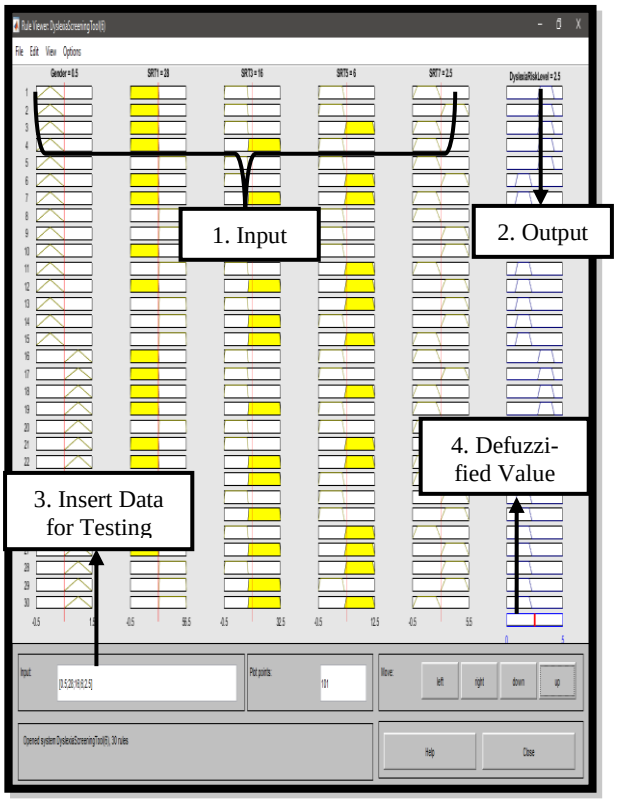

Fig. 6: Rule Viewer

4. Results and Discussion

This section provides evaluation and discussion of the developed system using pre-existed data as provided by En. Saifuddin Mohtaram. The pre-existed data is the resulted scores collected from 17 dyslexia subjects (3 girls and 14 boys) in four main tests including their dyslexia status. Altogether, there were 68 scores used as testing samples accumulated from four tests (17 scores in each test) based on Ujian Pengesanan Awal Disleksia Malaysia manual book.

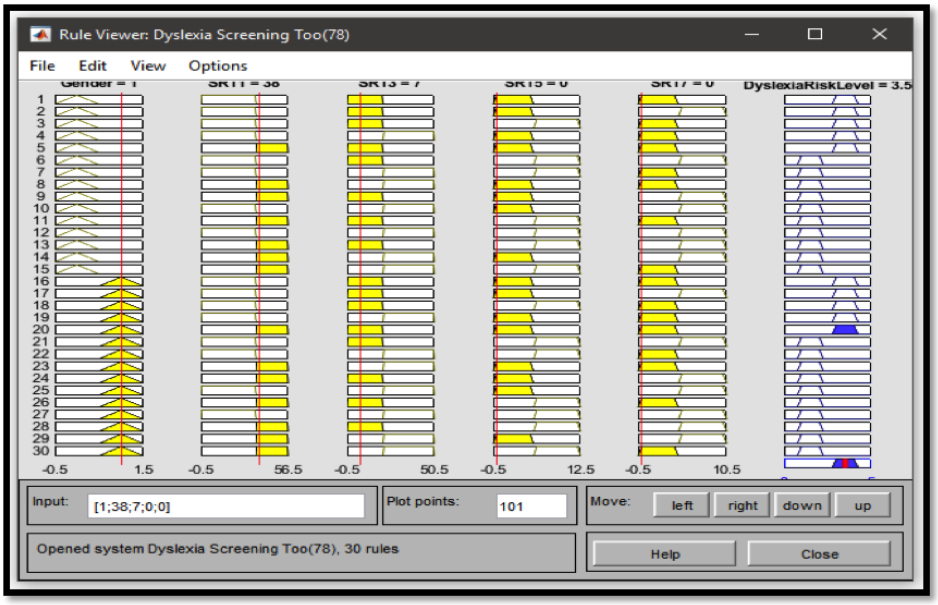

Fig. 7: Rule Viewer for 7 year-old category (Subject: Girl)

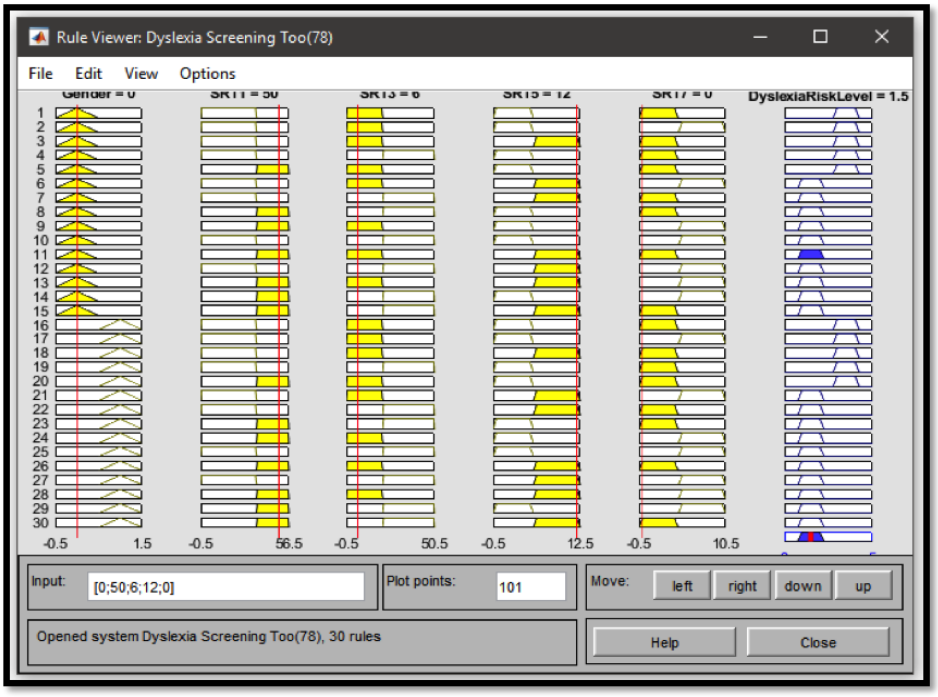

Fig. 8: Rule Viewer for 8 year-old category (Subject: Boy)

4.1. Rule Viewer Outcome

It can be seen in the Rule Viewer screenshot of Figure 7 the pre-existed inputs were 1, 38, 7, 0 and 0 corresponding to the type of subject's gender (girl) and the scores she obtained in Test 1, Test 3, Test 5 and Test 7, respectively. Meanwhile, the output appeared at the last column was Dyslexia Risk Level with defuzzification value 3.5 implying "High Risk" of having dyslexia. On the other hand, Figure 8 illustrates the example of "Low Risk" prediction for 8 years old boy with defuzzification value 1.5. In this screenshot, the scores for Test 1, Test 3, Test 5 and Test 7 were 50, 6, 12 and 0, respectively.

4.2. Comparison Between Actual and Predicted

The visual comparison between actual diagnose and predicted by the fuzzy system is shown in Figure 9. The original pre-existed data contained 17 subjects who were all diagnosed as having dyslexia. From the graph, it can be seen clearly that the developed system successfully predicted high risk of dyslexia in 16 out of 17 subjects with defuzzification value of 3.5. On the other hand, only one subject (the 15th subject) was predicted to be low risk (defuzzification value 1.5) though the actual diagnose was severe dyslexia. The inaccuracy obtained from this result is probably due to the fact that the 15th subject was tested and diagnosed using all ten sets of the designated tests. However, the developed fuzzy screening system only utilizes four designated tests set only. He obtained scores above threshold marks in all four selected tests but he did very poor in other six tests and hence the reason why he was diagnosed to have dyslexia.

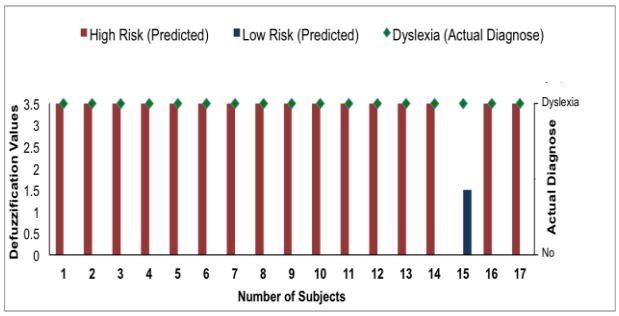

Fig 9: Comparison between actual diagnose (green diamond symbol) and predicted (column bars) by the system in 17 dyslexia subjects

4.3. Accuracy of Risk Classification

Table 5 shows the confusion matrix of risk classification as deduced from Figure 9. Using this information, the accuracy formula as appointed in (1) is used to compute the accuracy of the fuzzy system. The calculated risk classification accuracy of fuzzy system is found to be 94.1 %.

Table 5: Confusion matrix for accuracy calculation

		Predicted	
		Dyslexia (Low Risk)	Dyslexia (High Risk)
Actual	Dyslexia (Low Risk)	0	0
	Dyslexia (High Risk)	1	16

$$Accuracy = \frac{TC}{TT} \times 100\% \quad (1)$$

where TC is total number of subjects with corrected prediction whereas TT is the total number of evaluated subjects.

5. Conclusion

This research is conducted to propose an effective way to classify dyslexia risk in young children by means of fuzzy logic. The developed system is able to provide dyslexia risk information instantaneously to overcome the limitation of conventional method, which requires several days to produce result thereby, achieved the three main objectives of this study. Two main outcomes from the system were either "High Risk" or "Low Risk" depending on the defuzzification value. The original pre-existed data contained scores of Test 1, Test 3, Test 5 and Test 7 from 17 subjects who were all diagnosed as dyslexia. It was then served as the testing inputs for the fuzzy system's validation. The accuracy of the proposed system to detect dyslexia in young children was 94.1 %.

For future works, there are several recommendations that can be done. First, to improve the classification accuracy of the system, it is suggested that huge samples are required to be tested comprising subjects of dyslexia and normal subjects. Secondly, the system should also able to differentiate between dyslexia and other types of learning disabilities such as slow learners. Therefore, it is suggested that all ten tests should consider to be included in order to produce a complete and reliable screening system. And finally, it is targeted that a portable hardware device or user-friendly GUI based on the designed fuzzy system can be developed in the future.

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