Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Combination Multilayer Fuzzy Inference System with K-means for Classification of Dental Diseases

Randy Prandana[1], Herman Mawengkang[2,*], Saib Suwilo[2]

[1]Fakultas Ilmu Komputer dan Teknologi Informasi, Program Studi Magister Teknik Informatika, Universitas Sumatera Utara, Medan, Indonesia
[2]Fakultas Matematika dan Ilmu Pengetahuan Alam, Program Studi Matematika, Universitas Sumatera Utara, Medan, Indonesia
Email: [1]randy@shaff.id, [2,*]hmawengkang@yahoo.co.id, [3]saib@usu.ac.id
Correspondence Author Email: hmawengkang@yahoo.co.id
Submitted: **06/08/2024**; Accepted: **09/09/2024**; Published**: 30/09/2024**

Abstract−This study was conducted to solve the problem of classifying dental diseases such as pulpitis, gingivitis, periodontitis and advanced periodontitis. The method in this study uses a combination of algorithms with a multilayer system where in the first layer a fuzzy inference will be carried out whether a patient is suffering from pulpitis. Early symptoms of pulpitis are characterized by pain with varying levels. Meanwhile, in the second layer a fuzzy inference process will also be carried out to identify other types of dental diseases, but in this second layer the centroid value calculation process is carried out using the K-means algorithm for all input variables. Then the inference process will run to determine the type of disease suffered by the patient following the fuzzy set of other types of diseases. This study is expected to contribute to helping the initial screening process for dental diseases so that it is easier for dentists to carry out further examinations. The results of this study have been proven to be able to help doctors in conducting initial screening to determine dental disease. In this study, the multilayer system is intended to differentiate the results of dental disease classification because pulpitis does not have a relationship between input variables and other types of dental disease. Meanwhile, the use of the fuzzy inference system method in this study showed good results because the FIS method can map the level of pain suffered by a patient with mild, moderate and severe levels into a numeric value that can be classified where the level of pain is a feeling that cannot be calculated, by using the fuzzy method, the linguistic value can be defined into a conclusion. Grouping input values by finding the means value in the second layer and combined with the fuzzy method has been proven to provide good results for determining the type of dental disease.

Keywords: Classification, Fuzzy Inference System, Multilayer, K-Means, Dental Diseases

1. INTRODUCTION

In the field of oral health, errors often occur during the initial screening of patients [1], [2]. This error occurs because a patient who cannot describe well about the pain he is suffering causes a doctor's mistake in performing anesthesia to endanger the patient [3]. For this reason, a numerical system is needed that can map and calculate several attributes felt by a dental patient to produce a conclusion about the disease suffered so that it makes it easier for a doctor to take further action against the patient [4].

One method that is widely used in expert systems such as in the case of initial screening of disease symptoms experienced by patients is to use fuzzy methods [5], [6], [7]. The fuzzy method is an algorithm that can perform calculations on linguistic data that has no certainty into a numerical series that can be calculated so that the data can be classified into new data [8], [9], [10]. The ability of the fuzzy method to classify linguistic variables based on their increments is what makes the reason for some researchers to apply this method in the health sector, especially to conduct initial screening to find out the symptoms experienced by a patient.

The fuzzy inference system (FIS) method can be used to draw conclusions based on a set of fuzzy rules [11], [12], [13]. The intended fuzzy rules are FIS input and FIS output [14], [15]. In the case of initial screening of dental patients, FIS input can be made by dividing several parts of the pain group into 3 conditions, where the intended conditions are for the level of pain with mild, moderate to severe pain levels, the assessment of the level of pain can be given by subjective assessment by a patient based on a range of values that have been mapped to the fuzzy method following several attributes that will be classified to produce a conclusion on the type of disease suffered.

In its application, the FIS method has weaknesses such as not being able to recognize a problem that has not previously been taught in the knowlage base of the system being built. This weakness makes a system that uses the FIS method must have a lot of training data so that the system has a high level of accuracy in making conclusions about the type of disease suffered by a patient. The amount of training data needed has a negative impact on the computational process because the more rule bases used, the more calculations will be processed until it takes a very long time and high memory capacity in one time processing data to produce a conclusion [16], [17], [18], [19].

The development of fuzzy inference systems can be seen from research conducted by [20] on fuzzy inference systems using multilayer. In this study, the multilayer system is divided into two layers where in the first layer all input data will be processed to identify whether the input characteristics entered into the system that has been created are the characteristics of a person who has the potential to develop kidney cancer, if the results of fuzzy inference in the first layer show that a patient has the potential to develop kidney cancer, the system will continue to perform calculations on layer two to classify the stage level of kidney cancer received. Broadly speaking, this system saves computing time in the identification process, the system will stop working if the layer 1 fuzzy inference calculation does not show a sign of a patient who has the potential for kidney cancer. The multilayer system in this study saves a lot of time to perform classification and immediately stops performing calculations if the statement in layer 1 is not

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

fulfilled, but the fuzzy inference system used in this study still uses traditional fuzzy inference methods without any modification or additional complexity so that there is still a high chance that the system will make mistakes when classifying if the test data is data that has not previously been recognized by the test data due to the If-Then fuzzy rule base which can only conclude a problem if the if statement is fulfilled.

Another study was conducted by [21] on the comparison of K-Means and Fuzzy C-Means (FCM) methods. The results of this study indicate that FCM has better performance when compared to KM in performing classification with more balanced nodes. The FCM method can be used to determine the cluster center, calculate the objective function and calculate the change of each partition matrix. Iteration stops if the conditions are met, after which the cluster center is obtained. The cluster center will be used to calculate the distance between data elements to obtain rankings. Calculation of the distance between cluster centers and ranked data elements cannot always provide the right conclusion if this method is used in several classifications in expert systems, the influence of the rule base determines what kind of method should be used to get more optimal results during the classification process [22], [23], [24].

In this study, the classification of dental diseases will be carried out using a multilayer system where the first layer will be classified using the FIS method to determine only one type of dental disease, if the dental disease with the expected target output is not found in the first layer then the second layer will be classified by applying the FIS method where the value of the membership function is obtained by applying the K-Means rule by determining the average value of the cluster of each type of dental disease in the training data. The difference between this research and previous research is that in previous studies the cluster center obtained will be used as a measure of the proximity of the distance of the data elements to the value to be tested by calculating the euclidien distance and then ranking, where the distance with the closest ranking will be classified as the expected output, but in this study the results of the cluster center in the second layer will be used for membership degrees during the fuzzification process and then fuzzy inference is carried out to determine the dental disease suffered by a patient [25], [26]. The use of the K-Means method in the FIS membership degree can simplify the input that will be classified in the fuzzy inference system [27], [28], [29].

2. RESEARCH METHODOLOGY

2.1 Research Methods

In this research, two stages of research methodology were carried out, namely by conducting literature studies and research analysis. The intended literature study is related to data collection and research material sources. Where the data intended is sourced from an expert, previous research journals, books, articles and several other references whose data is used as material for consideration in the preparation of this research.

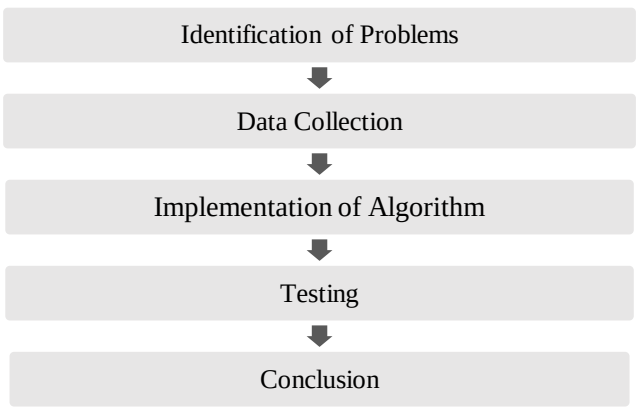
Meanwhile, the analysis stage in this research is carried out by paying attention to the input and output that will be generated from the planned algorithm, the input in this study is the level of pain felt by a patient based on several supporting attributes. The input in this study will be analyzed and compared with methods that can be used to build expert systems. The results of this study will be analyzed whether it can be used in real life and can be used as an expert system in accordance with the objectives built in this study.

2.2 Research Data

In this study, the data used is data sourced from an expert in the field of oral health and some data obtained from previous researchers' journals on the classification of dental diseases using the fuzzy infence system method.

2.3 Research Stages

The research stages are the flow of research activities that will be carried out by the author in completing this research process. The picture of the stages of this research can be seen in Figure 1 below:



Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Figure 1. Research Stages

Figure 1 above shows that the stages of this research use 5 (five) processes to get the results of this research as a whole. In the first stage, the author conducts a problem identification process, where at this stage the author analyzes the topic of the problem to be solved using the algorithm offered in this study. In the second stage, the author conducted a data collection process related to the research topic being studied using literature study techniques. The data sources used in this data collection process are the results of previous research that have been published through old national journals and international journals. In the third stage, the author implements the algorithm offered in this study in accordance with the formula that has been determined in the algorithm. In the fourth stage, the author tests the results of the algorithm implementation process that has been carried out in order to produce update information after the implementation stage of the algorithm offered in this study. Then in the last stage, the author draws conclusions as the final result of this research.

2.4 Implementation of Algorithm

This study uses 2 layers with separate FIS systems were used to identify disease. In the first layer, fuzzy inference will be carried out to detect whether a patient is suffering from pulpitis, where the initial symptoms of pulpitis are characterized by pain with varying levels. Meanwhile, in the second layer, a fuzzy inference process will also be carried out to identify other types of dental disease. Table 1 below is the expected variable output from each layer.

Table 1. Layer 1 and Layer 2 Variable Output

No	Layer	Output Variabel	Semantic Sign
1.	Layer 1	Pulpitis	Yes No
2.	Layer 2	Gingivitis	Yes No
		Periodontitis	Yes No
		Advance Periodontitis	Yes No

There are 8 input variables that will be used to carry out the classification including plaque (X1), inflamed gums (X2), pain (X3), red gums (X4), swollen gums (X5), gums that bleed easily (X6), bad breath. (X7) and Loose Teeth (X8).

The flowchart of the system that will be created is where in the first layer, 3 input attributes will be used including Plaque (X1), Inflamed Gums (X2), and Pain (X3). In the first layer, a fuzzy inference process will be carried out as to whether the existing input is included in the pulpitis disease group. If the inference results state that the symptoms experienced by the patient are included in the pulpitis disease group, the system will display that pulpitis disease has been identified. However, if the input data obtained does not identify pulpitis, the system will continue to second layer.

In second layer, additional symptom input will be entered such as, Red Gums (X4), Swollen Gums (X5), Bleeding Gums (X6), Bad Breath (X7) and Loose Teeth (X8). In the second layer, the input obtained will be calculated by an algorithm using the K-Means method to determine the centroid value of the data that has been input. Then the value will be calculated using a fuzzy inference machine to classify whether the value that has been entered is included in the type of disease, gingivitis, periodontitis or advanced periodontitis.

The flowchart of the system to be built is depicted in the image below.

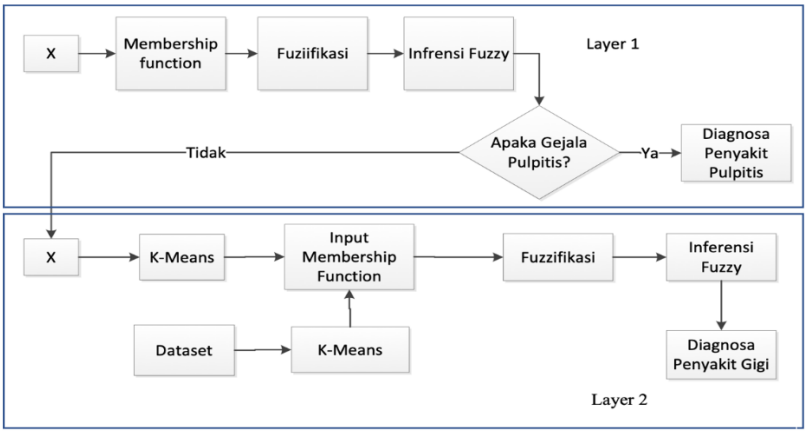


Figure 2. Algorithm Flowchart

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Each input variable has a value based on the level of pain ranging from mild, moderate and severe. These three levels of pain will be given a value so that they can be calculated systematically using fuzzy sets.

A linguistic thing such as the word "light" certainly does not have a definite mathematical value, therefore according to the fuzzy principle the value of each category will be given a value with a certain distance. In this discussion, the light category is determined with a range of values ranging from 0-30. The moderate category is at a value of 30-60, the severe category is at a value of 60-90.

After determining the distance values for each category, a fuzzy set can be depicted in the first input layer, namely the set of plaque, inflamed gums and pain layers as in the image below.

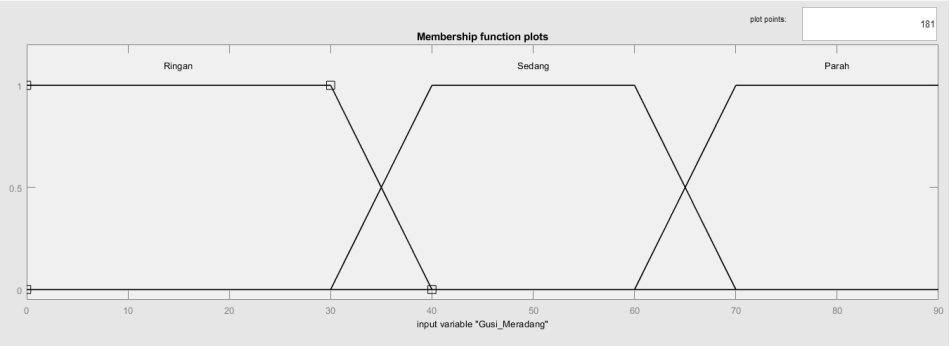


Figure 3. Set Layer 1 Inflamed Gums

Degree of membership of the Plaque Variable Set:

$$\mu\, Ringan\,(x) = \begin{cases} 1; x \le 30 \\ \dfrac{40 - x}{40 - 38{,}2}; 30 < x < 40 \\ 0; x \ge 40 \end{cases}$$

For the light category, it will be worth 1 if the x value is smaller than 30, if the x value is between 30 and 40 then the formula 40 minus the x value applies then the value will be divided by subtracting 40 minus 30. If the x value is greater than 40 then the input value is included in the set with the value 0.

$$\mu\, Sedang\,(x) = \begin{cases} 0; x \le 30\ atau\ x \ge 70 \\ \dfrac{x - 30}{40 - 30}; 30 < x < 40 \\ \dfrac{70 - x}{70 - 60}; 60 \le x < 70 \\ 1; 40 \le x \le 60 \end{cases}$$

In the medium category, the input value will be in data group 0 if the value of x is smaller, equals 30 or x is greater, equals 70. If the value of x is between 30 and 40 then the formula x minus 30 divided by 40 minus 30 applies. has a value between 60 and 70, then the formula 70 is applied minus the x value, then the results are divided by subtracting between 70 minus 60. If the x value is between 40 and 60 then it will be included in a group with a membership degree value of 1.

$$\mu\, Parah\,(x) = \begin{cases} 1; x \ge 70 \\ \dfrac{x - 60}{70 - 60}; 60 < x < 70 \\ 0; x \le 60 \end{cases}$$

In the group of variables with severe linguistic values, it can be seen that if the x value is greater than 70 then the data falls into a group with a membership degree value of 1. If the input x value is between 60 and 70 then the formula applies x minus 60 is divided by the result of the subtraction between 70 and 60. If the value of x is less than 60 then the membership degree value is 0. These three formulas also apply to other input variables like plaque (X1), inflamed gums (X2), pain (X3) in the first layer.

The second layer membership function is created by finding the average value of the existing training data. The centroid value obtained from this data will later be used as a fuzzy membership function range value for each disease in the second layer such as gingivitis, periodontitis and advanced periodontitis. In the second layer of training data, patient data with signs of pain (X3) are not used because the three diseases in the second layer are not related at all to pain. The following is the training data used.

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Table 2. Dataset Second Layer

No.	Data							Expert Predictions
	X1	X2	X4	X5	X6	X7	X8	
1	40	45	45	50	55	10	10	gingvitis
2	40	50	50	50	55	55	25	periodontitis
3	35	75	40	45	40	40	40	periodontitis
4	40	75	55	50	55	40	35	periodontitis
5	45	45	45	45	45	45	35	periodontitis
6	65	65	70	45	45	35	35	advance periodontitis
7	75	55	55	45	45	40	40	advance periodontitis
8	55	55	50	50	50	50	40	periodontitis
9	75	70	55	50	40	40	35	advance periodontitis
10	30	30	25	20	20	10	10	periodontitis
11	55	65	45	45	45	35	10	gingvitis
12	80	75	60	50	50	35	35	advance periodontitis
13	85	80	70	60	55	45	45	advance periodontitis
14	43	55	37	45	52	13	17	gingvitis
15	44	60	29	32	50	40	15	gingvitis
16	50	43	29	44	42	32	10	gingvitis
17	62	50	55	63	54	32	34	periodontitis
18	43	47	62	46	51	37	45	periodontitis
19	75	68	72	80	69	40	82	advance periodontitis
20	86	61	68	50	52	43	84	advance periodontitis
21	72	52	60	75	79	52	79	advance periodontitis

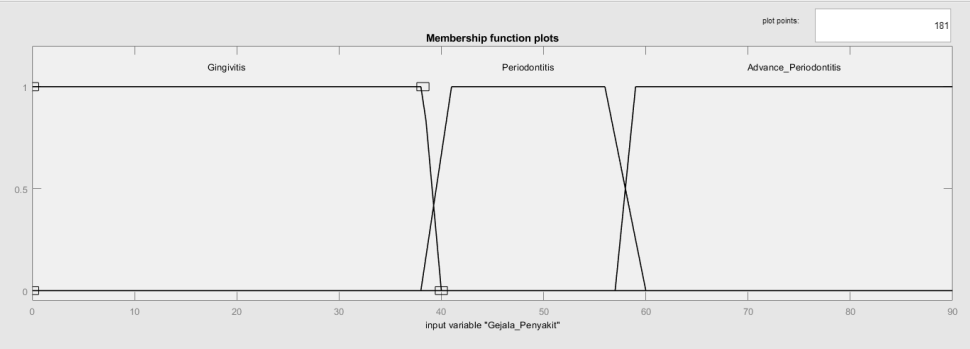
In this research, the average value will be calculated from the results of the dataset grouping, then the centroid value will be used as a reference for the fuzzy set in the second layer. The data below is the average value of each disease cluster in the training data.

Gingivitis: $$\sum \frac{Xn}{n} = \frac{40 + 45 + 45 + 50 + 55 \ldots + 10}{35} = 38{,}2$$

Periodontitis: $$\sum \frac{Xn}{n} = \frac{40 + 50 + 50 + 50 + 55 \ldots + 45}{49} = 44{,}125$$

Advance Periodontitis: $$\sum \frac{Xn}{n} = \frac{65 + 65 + 70 + 45 + 45 \ldots + 79}{56} = 59$$

Based on the centroid values obtained, the fuzzy set graph for each disease is as follows.



Gambar 4. Layer 2 Fuzzy Set

The degree of membership of the layer 2 fuzzy set is as follows:

Gingivitis (x) = $$\begin{cases} 1; x \leq 38{,}2 \\ \frac{40-x}{40-38{,}2}; 38{,}2 < x < 40 \\ 0; x \geq 40 \end{cases}$$

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Periodontitis (x) = $\begin{cases} 0; x \leq 38 \; atau \; x \geq 60 \\ \frac{x-38}{40-38}; 38 < x < 40 \\ \frac{60-x}{60-59}; 59 \leq x < 60 \\ 1; 41 \leq x \leq 56 \end{cases}$

Advance Periodontitis = $\begin{cases} 1; x \geq 59 \\ \frac{x-57}{60-57}; 57 < x < 60 \\ 0; x \leq 57 \end{cases}$

In the second layer the degree of membership for gingivitis is shown in equation 19 where the input value will be 1 if x is smaller than 38.2. If the x value is between 38.2 and 40 then the formula applies 40 minus the x value then the calculation results will be distributed by the difference between 40 and 38.2. If the input value is greater than 40 then the membership degree is 0 and this can be confirmed that the input value does not represent gingivitis.

For the periodontitis disease group, it is shown in the 20th equation where the x value will be 0 or an input value is declared not to be periodontitis if the x value is smaller than 38 and greater than 60. If the x value is between 38 and 40 then the formula applies , x minus 38 is divided by the difference between 40 and 38. If the x value is between 59 and 60 then the formula applies, x minus 59 is divided by the difference between 60 and 59, and finally the x value will be declared as periodontitis if the x value is between 41 and 56.

In the Advanced Periodontitis disease group, if the x value is above 59, then it can be ascertained that the value is in the periodontitis disease group. If the x value is between 57 and 60 then the formula applies, x minus 57 divided by the difference between 60 and 57, and the disease is not included. advanced periodontitis group if the x value was smaller than 57.

3. RESULT AND DISCUSSION

3.1 Result

This research was carried out by testing patients who came from the Harun Dental Clinic, Desa Kampung Lalang, Kecamatan Medang Deras, Kabupaten Batubara, North Sumatra Province. Testing was carried out 15 times from 15 dental patients who visited the clinic. The test results display the entire algorithm for testing the system that has been created.

Table 3. Test Result

No.	X1	X2	X3	X4	X5	X6	X7	X8	Expert Predictions	System Results
1	20	20	89	50	20	20	20	3	Pulpitis	Pulpitis
2	20	20	44	75	10	10	10	5	Pulpitis	Pulpitis
3	25	25	55	70	28	27	26	10	Pulpitis	Pulpitis
4	15	15	69	65	20	20	20	20	Pulpitis	Pulpitis
5	34	55	5	27	10	10	20	10	Gingivitis	Gingivitis
6	40	45	45	45	50	55	10	15	Gingivitis	Gingivitis
7	70	20	20	50	50	55	55	43	Periodontitis	Periodontitis
8	12	23	79	20	20	20	20	10	Pulpitis	Pulpitis
9	62	75	65	55	50	59	60	70	Advance Periodontitis	Advance Periodontitis
10	40	32	20	33	40	42	30	20	Gingivitis	Gingivitis
11	10	19	37	25	41	30	20	10	Pulpitis	Pulpitis
12	90	80	70	86	67	89	62	70	Advance Periodontitis	Advance Periodontitis
13	28	45	20	25	30	26	10	5	Gingivitis	Gingivitis
14	34	37	38	45	50	50	10	10	Gingivitis	Gingivitis
15	75	70	60	55	69	78	50	70	Advance Periodontitis	Advance Periodontitis

Based on the test results above, it can be seen that the test results that have been carried out 15 times on the symptoms of dental disease show very good results with the frequency of pulpitis disease tested as many as 6 symptoms, gingivitis disease as many as 5 symptoms, periodontitis disease as many as 2 symptoms and advance periodontitis disease as many as 2 symptoms.

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

Below is shown a graph of the test results by comparing the results of expert predictions with the classification results carried out by the system by applying a multi layer fuzzy inference system by adding the k-means method to the input and fuzzy set in the second layer as shown in the figure below.

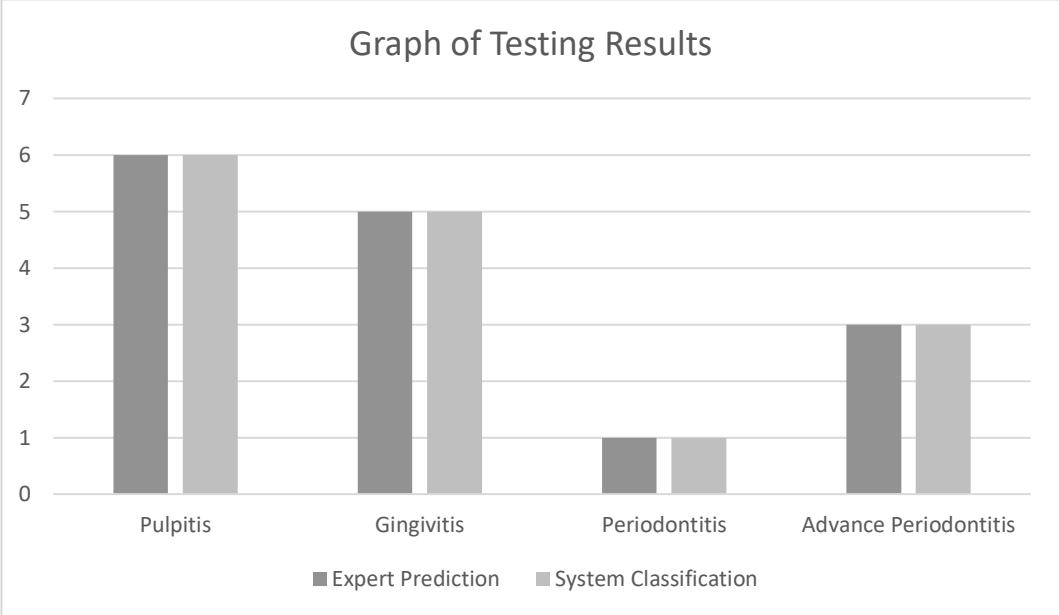


Figure 5. Graph of Testing Results

In graph 5 above shows that the tests that have been carried out show very good results where expert predictions on each type of disease can be done well by the system with the following percentage.

$$\% \text{ Accuracy} = \frac{\text{Total Corresponding Tests}}{\text{Total Test Data}} \times 100\%$$

$$\% \text{ Accuracy} = \frac{15}{15} \times 100\% = 100\%$$

From the results of the percentage calculation above, 15 tests have been carried out and data that is in accordance with expert predictions as many as 15 tests have not found results that are different from expert predictions so that in this test it is stated that the accuracy of the designed system is 100%.

3.2 Discussion

This research uses 21 training data from experts then the training data is processed following fuzzy rules with a multilayer system so that it becomes 13 fuzzy rules, where the first layer uses 10 rule bases and the second layer uses 3 rule bases.

In the first layer, the expected output target is only to determine whether the symptoms experienced by the patient are included in the pulpitis disease group or not, if the symptoms suffered by a patient are included in pulpitis disease, then the system will stop the classification process and display the results that the disease suffered is pulpitis disease, but if the symptoms classified are not included in the set of pulpitis diseases then the system will continue to perform calculations towards the second layer.

In the second layer, the centroid data value of the test data will be searched where the results obtained will be tested in the fuzzy set graph, where previously the determination of the value on the fuzzy graph was also calculated for the centroid value, the results of calculating the centroid value of the training data are then presented in the fuzzy set graph in the second layer. After testing 15 times, the results were obtained with a very good accuracy value. The use of multilayer in this expert system fuzzy inference system is very efficient because it can eliminate readings with high ambiguity values, if the multilayer system is not applied, there will be system errors in classifying pulpitis and gingivitis diseases due to numerical value factors or data proximity that is not far apart between the two types of diseases so it is very possible for system errors to occur in classification, with the multilayer system, the expert system can run well and provide very high accuracy values.

The application of the K-Means method in the second layer also provides excellent results where the purpose of the K-Means method is to determine the centroid location of the data so that fuzzy inference can be done more easily with very good accuracy. The complexity of the FIS method with K-Means makes the value of fuzzy data more controllable because the data is in a more balanced centroid, making it easier for the system to perform inference with very short computation time, minimal training data and high accuracy.

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

4. CONCLUSION

After testing 15 times, results were obtained with very good accuracy values. The use of multilayers in the fuzzy inference system of this expert system is very efficient because it can eliminate readings with high ambiguity values. If the multilayer system is not applied, there will be system errors in classifying pulpitis and gingivitis due to numerical value factors or the proximity of data that are not far apart. between these two types of disease so that it is very possible for system errors to occur in classifying, with the existence of a multilayer system, the expert system can run well and provide very high accuracy values. The application of the K-Means method on the second layer also gives very good results where the aim of the K-Means method is to determine the location of the centroid of the data so that fuzzy inference can be done more easily with very good accuracy. The combination of the FIS method with K-Means makes fuzzy data values more controllable because the data is at a more balanced centroid, making it easier for the system to perform inference with very short computing time, minimal training data and high accuracy.

REFERENCES

[1] N. Fadhilah Arifin, S. O. Fadhillah Mattalitti, and T. Jaya, "Hubungan Tingkat Pengetahuan Teori dan Kemampuan Interpretasi Gambar Radiografi Panoramik Kedokteran Gigi pada Mahasiswa Kepaniteraan Klinik," *DENThalib J.*, vol. 1, no. 2, pp. 28–32, 2023, [Online]. Available: https://journal.fkg.umi.ac.id/index.php/denthalib/article/view/29

[2] R. Cilmiaty, A. Prayitno, W. Susanti, B. Saptiwi, and F. T. Rahutami, "Pendidikan Pengetahuan Kesehatan Gigi dan Mulut pada Kader Posyandu Lansia di Wilayah Kerja Puskesmas Gondangrejo Karanganyar," *Abdimas Univers.*, vol. 5, no. 1, pp. 88–91, 2023, doi: 10.36277/abdimasuniversal.v5i1.158.

[3] M. Kabu, E. Ngaga, and A. A. J. Sinlae, "Penerapan Certainty Factor dalam Diagnosa Penyakit Gigi dan Mulut Berbasis Web di Puskesmas Halilulik," *JUKI J. Komput. dan Inform.*, vol. 5, no. 1, pp. 110–123, 2023, [Online]. Available: https://www.ioinformatic.org/index.php/JUKI/article/view/184

[4] I. Mariana, O. Fadriyanti, and V. Ningrum, "Effectiveness of Duration Time to Use the Digital Dental Calculator Application on DMFT Index Measurement," 2024, pp. 1–7, doi: 10.32793/jida.v7i1.1134.

[5] S. M. Hardi, A. Triwiyono, and Amalia, "Expert System for Diagnosing Osteoarthritis with Fuzzy Tsukamoto Method," *J. Phys. Conf. Ser.*, vol. 1641, no. 1, 2020, doi: 10.1088/1742-6596/1641/1/012107.

[6] N. A. Mufid, "Klasifikasi Besar Potensi Kemunculan Batu Ginjal Menggunakan Fuzzy Inference System (FIS) Metode Mamdani," *J. Pendidik. Mat.*, vol. 1, no. 1, p. 15, 2023, doi: 10.47134/ppm.v1i1.110.

[7] Sylfanie Sekar Mayang and Ade Eviyanti, "Expert System for Diagnosing Early Symptoms of Stroke Using the Fuzzy Mamdani Method," *Procedia Eng. Life Sci.*, vol. 1, no. 2, 2021, doi: 10.21070/pels.v1i2.969.

[8] N. Alfianty, Y. Maulita, and D. Saripurna, "Application of Fuzzy Sugeno Method for Nutrition Management in Patients With," vol. 3, no. May, pp. 90–102, 2024.

[9] W. Mohammad Alfiandy, Iwan Wahyudin, "Expert System to Diagnose Diabetes Using Web-Based Fuzzy Mamdani Method," *Mobile-Based Natl. Univ. Online Libr. Appl. Des.*, vol. 4, no. 1, pp. 1–7, 2020.

[10] Y. W. Kerk, K. M. Tay, and C. P. Lim, "Monotone Interval Fuzzy Inference Systems," *IEEE Trans. Fuzzy Syst.*, vol. 27, no. 11, pp. 2255–2264, 2019, doi: 10.1109/TFUZZ.2019.2896852.

[11] M. N. Taukid, I. Elzandy, A. P. Adyani, and ..., "Program Pengendali Kipas Angin Berdasarkan Suhu dan Kelembaban Menggunakan Logika Fuzzy," *Pros. Semin. ...*, vol. 3, pp. 42–52, 2023, [Online]. Available: http://santika.upnjatim.ac.id/submissions/index.php/santika/article/view/186%0Ahttp://santika.upnjatim.ac.id/submissions/index.php/santika/article/download/186/90

[12] A. T. Wahyudi, I. Giyanti, and B. V. Kritiana, "Studi Penentuan Jumlah Produksi Botol Kemasan Minuman Yang Optimal Dengan Fuzzy Time Series Markov Chain Dan Fuzzy Inference System," *JISI J. Integr. Sist. Ind.*, vol. 10, no. 2, p. 99, 2023, doi: 10.24853/jisi.10.2.99-110.

[13] D. Hendra Fachrudin, N. Kumala Dewi, and M. Rafif Novanil, "Optimalisasi Jumlah Produksi Teh Botol Sosro Dan Fruit Tea Menggunakan Metode Fuzzy Inference System Tsukamoto (Studi Kasus : Pt. Sinar Sosro Palembang)," *J. Ilm. Sain dan Teknol.*, vol. 1, no. 3, pp. 56–68, 2023.

[14] A. Wantoro, A. Verdian, R. Rusliyawati, and Y. T. Utami, "Penerapan Logika Fuzzy Dengan Fis Mamdani Untuk Kontrol Volume Televisi," *J. Tek. dan Sist. Komput.*, vol. 4, no. 1, pp. 38–48, 2023, doi: 10.33365/jtikom.v4i1.2693.

[15] M. Rinku, "Study of Fuzzy Inference System (FIS), its Characteristics and Approaches for Fuzzy Inference System," no. December, pp. 187–191, 2022.

[16] A. Maulidinnawati A K Parewe and W. Firdaus Mahmudy, "Dental Disease Identification Using Fuzzy Inference System," *J. Enviromental Eng. Sustain. Technol.*, vol. 3, no. 1, pp. 33–41, 2016, doi: 10.21776/ub.jeest.2016.003.01.5.

[17] R. E. Subarja and B. Hendrik, "Evaluasi Kinerja Pelayanan Pegawai Kantor Camat Padangsidimpuan Utara Menggunakan Pendektan Fuzzy Inference System Sugeno," *Indo Green J.*, vol. 1, no. 3, pp. 90–95, 2023, doi: 10.31004/green.v1i3.17.

[18] N. Nafara Rofiq, N. Rofiq, and A. Salim, "RESOLUSI : Rekayasa Teknik Informatika dan Informasi Prediksi Harga Bawang Merah menggunakan Algoritma Fuzzy Inference System (FIS)," *Media Online*, vol. 3, no. 4, pp. 128–136, 2023, [Online]. Available: https://djournals.com/resolusi

[19] A. Gani and A. Mujianto, "PREDIKSI KEKUATAN TARIK DAN BENDING KOMPOSIT SERAT TKKS MENGGUNAKAN ARTIFICIAL NEURO FAZZY INFERENCE SYSTEM (ANFIS)," vol. 3, no. 1, pp. 103–110, 2024.

[20] N. Singla, H. Sadawarti, J. Singla, and B. Kaur, "Development of multilayer fuzzy inference system for diagnosis of renal cancer," *J. Intell. Fuzzy Syst.*, 2020, doi: 10.3233/JIFS-191785.

[21] A. A. hussian Hassan, W. M. Shah, M. F. I. Othman, and H. A. H. Hassan, "Evaluate the performance of K-Means and the fuzzy C-Means algorithms to formation balanced clusters in wireless sensor networks," *Int. J. Electr. Comput. Eng.*, vol. 10, no. 2, pp. 1515–1523, 2020, doi: 10.11591/ijece.v10i2.pp1515-1523.

[22] P. S. Ramadhany, F. Yunus, and A. D. Susanto, "Lung Function and Respiratory Symptoms of Petrol Station Attendants in Central and North Jakarta and Its Contributing Factors," *Respir. Sci.*, vol. 1, no. 1, pp. 46–60, 2020, doi:

Building of Informatics, Technology and Science (BITS)
Volume 6, No 2, September 2024 Page: 1231−1239
ISSN 2684-8910 (media cetak)
ISSN 2685-3310 (media online)
DOI 10.47065/bits.v6i2.5737

10.36497/respirsci.v1i1.7.
[23] D. Budi Elnursa, M. Tahir, A. Azis Jakfar, and R. M. Resnanda, "Sistem Klasifikasi Citra Simplisia Fructus dalam Obat Tradisional Madura menggunakan Transfer Learning pada Algoritma CNN," *J. Ilm. Edutic Pendidik. dan Inform.*, vol. 10, no. 1, pp. 68–79, 2023, [Online]. Available: https://doi.org/10.21107/edutic.v10i1.22957
[24] J. Saputra, Y. Sa, V. Yoga Pudya Ardhana, and M. Afriansyah, "RESOLUSI : Rekayasa Teknik Informatika dan Informasi Klasifikasi Kematangan Buah Alpukat Mentega Menggunakan Metode K-Nearest Neighbor Berdasarkan Warna Kulit Buah," *Media Online*, vol. 3, no. 5, pp. 347–354, 2023, [Online]. Available: https://djournals.com/resolusi
[25] G. Selvachandran *et al.*, "A New Design of Mamdani Complex Fuzzy Inference System for Multiattribute Decision Making Problems," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 4, pp. 716–730, 2019, doi: 10.1109/TFUZZ.2019.2961350.
[26] F. H. Awad, M. M. Hamad, and L. Alzubaidi, "Robust Classification and Detection of Big Medical Data Using Advanced Parallel K-Means Clustering, YOLOv4, and Logistic Regression," *Life*, vol. 13, no. 3, 2023, doi: 10.3390/life13030691.
[27] A. Aidil, J. P. Sugiono, E. I. Setiawan, and A. S. Putra, "Pembentukan Aturan Fuzzy Untuk Pemberian Rekomendasi Penerima Bantuan Keluarga Berumah Tidak Layak Huni Menggunakan K-means Clustering," *J. Intell. Syst. Comput.*, vol. 4, no. 2, pp. 85–92, 2022, doi: 10.52985/insyst.v4i2.216.
[28] A. S. Ari and U. Budiyanto, "Prediksi Jumlah Produksi Perakitan Komponen Menggunakan ANFIS Yang Dioptimasi Dengan Algoritma K-Means," *CogITo Smart J.*, vol. 9, no. 2, pp. 252–265, 2023, doi: 10.31154/cogito.v9i2.513.252-265.
[29] J. Zhang, R. Wang, A. Jia, and N. Feng, "Optimization and Application of XGBoost Logging Prediction Model for Porosity and Permeability Based on K-means Method," *Appl. Sci.*, vol. 14, no. 10, 2024, doi: 10.3390/app14103956.