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Expert System for Autoclave Damage Detection Using the Fuzzy Logic Method

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***Abstract**. As a resource supporting public health services, management of electromedical equipment must be carried out quickly, accurately and integratedly so that function, safety, security and benefits can be optimized. The management of electromedical equipment is regulated in the Republic of Indonesia Minister of Health Regulation Number 65 of 2016 concerning Electromedical Service Standards. The expected result of this research is an expert system that can accurately detect damage to sterile electromedical equipment, especially autoclaves. This expert system can then assist electromedical technicians in finding damage and as an assessment in making decisions for appropriate and validated actions to be taken. From the results of testing and analysis of the expert system for detecting damage to Autoclaves using the fuzzy logic method, the following conclusions were obtained. The damage detection expert system application in the Autoclave has been proven to be able to provide 100% diagnosis results. This system can assess the degree of damage of 11.6235981%. based on the input symptoms provided, thus providing decisions that are close to the actual conditions. The expert system built is able to speed up the damage detection process compared to manual methods. This helps in taking quicker action to prevent further damage to the autoclave.*

***Keywords** expert system, autoclave, fuzzy logic, damage.*

1. INTRODUCTION

Health care facilities such as hospitals, health centers, clinics, and other health facilities require resource support to provide health services to the community. One of these resource supports is medical devices [1]. Medical devices are grouped into 3 (three) groups according to the Decree of the Minister of Health of the Republic of Indonesia Number 118/MENKES/SK/IV/2014, namely electromedical medical devices, non-electromedical medical devices, and in vitro diagnostic products. According to the Regulation of the Minister of Health of the Republic of Indonesia Number 220/Men.Kes/Per/IX/1976, what is meant by medical devices are goods, instruments, apparatus or tools including each component, part or equipment that is produced, sold or intended for use in health research and care, diagnosis, cure, mitigation or prevention of disease, abnormalities in body condition or symptoms in humans [2]. Meanwhile, electromedical devices are medical devices that use an electric power supply. In the Joint Decree of the Minister of Health and the State Civil Service Agency Number 717/Menkes/SKB/V/2003, electromedical devices are classified based on 3 (three) levels of technology, namely simple, medium, and high technology [3]. As a supporting resource for public health services, management of electromedical devices must be carried out quickly, accurately, and integrated so that function, safety, security, and benefits can be optimized. Management of these

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electromedical devices is regulated in the Regulation of the Minister of Health of the Republic of Indonesia Number 65 of 2016 concerning Electromedical Service Standards [4]. The expected result of this study is an expert system that can detect damage to sterile electromedical devices, especially autoclaves, accurately. The expert system can then assist electromedical technicians in finding damage and as an assessment in decision making for actions to be taken appropriately and validated.

2. LITERATURE REVIEW

Figya (2024) conducted a study on the Utilization of Expert Systems for the selection of Hospital Emergency Rooms in Sidoarjo City. The results of his research stated that the Emergency Room selection system is very much needed because it helps users or patients in making referral selection decisions based on the patient's condition and location. [5]. Dwi, Indra, Zulaini (2021) in his research stated that the Expert System for online referral selection at the Pemntang Siantar Branch Office is based on local laws and regulations and policies and the data has been validated with the patient's identity. However, this system is web-based which requires system updates at all times. [6]. Assauqi.Marzali (2024) in his research stated that preventive measures to prevent damage to the Electrosurgery Unit equipment are by checking manually in the database. However, this manual system has not been integrated with the system. The electromedical equipment management information system as developed by Assauqi.Marzali (2024) cannot yet be applied to detect damage to electromedical equipment. [7] So in this study an expert system will be created for detecting damage to sterile electromedical devices, especially autoclaves, using the fuzzy logic method. This expert system will be developed using PHP programming. The expected results of this study are expert systems that can detect damage to sterile electromedical devices, especially autoclaves, accurately. The expert system can then help electromedical technicians find damage and as an assessment in decision making for actions to be taken appropriately and validated.

A. Expert system

Expert systems are one of the fields of artificial intelligence (artificial intelligence) which is defined as a program designed to make decisions like an expert, where in making these decisions knowledge (knowledge base), facts and ways of thinking are used to solve problems. which can usually only be completed by an expert [8].In developing an expert system, knowledge (knowledge base) comes from an expert or is knowledge taken from media such as magazines, books, journals, and others. Then in expert systems knowledge is specific to only one particular problem domain. The more sources of knowledge that are included in the expert system, the better it will be at acting and taking solutions so that it almost resembles a real expert [9].

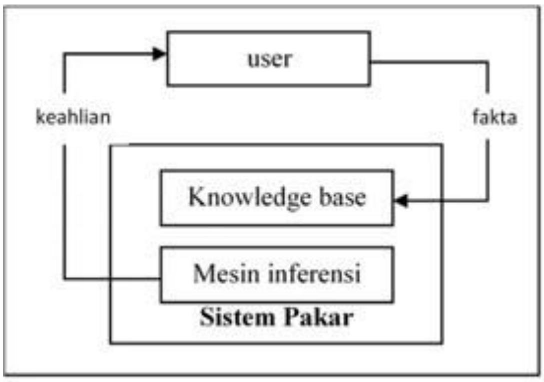


Figure 1 Expert system concept

Figure 1 above is the basic concept of an expert system, where the user submits information based on actual facts to the expert system [9], then the information will be entered into the knowledge base and processed by the inference engine (inference mechanism), so that the system will provide a response in the form of expertise or answers based on the knowledge it has [10].

The purpose of an expert system is to transfer the expertise of an expert into a [11]:

1. Knowledge Acquisition (from experts or other sources).
2. Knowledge Representation (into the computer).
3. Knowledge Inferencing (do knowledge inference).
4. Knowledge Transferring (transferring knowledge to the user).

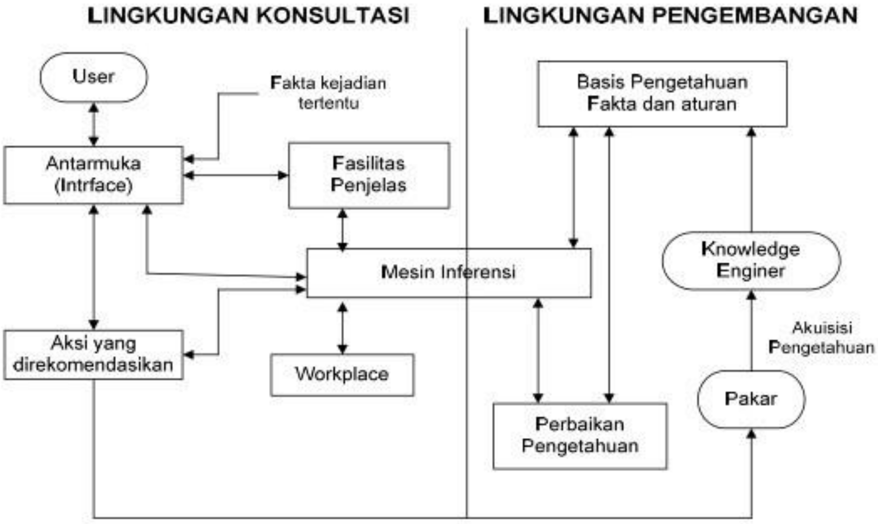


Figure 2 Expert system architecture

Figure 2 is a picture of the expert system architecture [12]. The components contained in the expert system architecture consist of a user interface, knowledge base: facts and rules, knowledge acquisition, inference mechanisms, workplace, explanation facilities, knowledge improvement [13].Knowledge Base is part of an expert system that stores knowledge (domain knowledge). The knowledge base contained in an expert system differs from one to another, depending on the field of expertise of the system being built. The inference engine is tasked with finding a match between the facts in the working memory with the facts about a particular domain knowledge that is in the knowledge base, then the inference engine will draw / draw conclusions from the problems submitted to the system [14]. The user interface provides communication facilities between the user and the system, provides various information facilities and various descriptions that aim to direct the flow of problem tracing until a solution is found. Knowledge acquisition is the process of collecting knowledge data from knowledge sources (originating from real experts or media) into the inference engine [15].

B. Autoclave

Autoclave is a closed heating device used to sterilize surgical equipment and laboratory equipment using steam at a temperature of (121℃,) and a pressure of 1.5 Psi (Pounds per Square inch) for approximately 15 minutes [16]. At this high temperature and pressure, microorganisms will be killed, especially aimed at killing endospores, which are resistant cells produced by bacteria, these cells are resistant to heating and antibiotics, in the same species, endospores can also survive in environmental conditions that can kill the vegetative cells of the bacteria. In principle, autoclave sterilization uses heat and pressure from water vapor, usually to sterilize the media using a temperature of 121 ℃ with a pressure of 2 bar for 15 minutes, the reason for using a temperature of 121 ℃ is because at that time it shows a pressure of 2 bars which will help kill microorganisms on an object, for atmospheric pressure at sea level, water boils at a temperature of 100 ℃ while an autoclave placed at the same height, using a pressure of 2 bars, the water will boil at a temperature of 121 ℃ [17]. When the heat source is turned on, the water in the autoclave will boil over time and the water vapor formed will press the air filling the autoclave, after all the air in the autoclave is replaced with water vapor, the air valve in the autoclave is closed so that the air pressure in the autoclave will increase, when the pressure is reached accordingly, the sterilization process begins [18].

C. Fuzzy Logic

Fuzzy logic was first introduced by Prof. Lotfi A. Zadeh from the University of California in 1965. Zadeh argued that the true and false values in conventional logic are unable to overcome the problem of infinite gradation in the real world. To overcome this problem, Zadeh then developed the theory of fuzzy sets [19]. Unlike logic which only has two values, namely true and false, fuzzy logic has continuous values. The true or false value in fuzzy logic is not absolute, depending on the degree of membership it has, namely in the range of 0 to 1, so that at the same time a condition can be said to be true and false. Therefore, the role of the degree of membership is very important and is a characteristic of fuzzy reasoning [20].

3. METHODS

A. Research Steps

The steps for working on an expert system to determine the symptoms of Autoclave damage using the fuzzy logic method are shown in Figure 3.

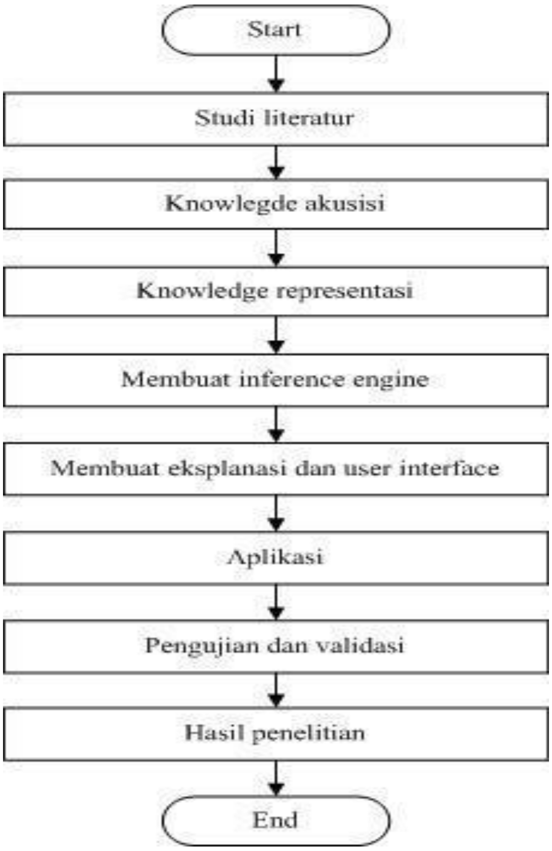


Figure 3 Flowchart diagram of research steps

In this study, a literature study was conducted to obtain information about the damage factors to be studied, namely the Autoclave. The damage that is the focus of the study is on the heater, sensor, and alarm components with 3 (three) damage conditions, namely tube temperature, alarm sound, and the difference between measured pressure and pressure on the display.The study was conducted by interviewing experts to determine the signs of damage and the type of damage. The normal parameter value for tube temperature is between 121-134 ℃. The normal parameter value for the alarm sound is between 60-80db. While the difference between measured pressure and pressure on the display is given a range of 0.3 bar. The signs and types of damage are then represented in tabular form. This study uses the fuzzy logic method to determine expert values and draw conclusions. Then an application design can be made to determine the type of damage to the autoclave sterile device.

B. Expert system algorithm design

The expert system algorithm design using Tsukamoto fuzzy can be seen in Figure

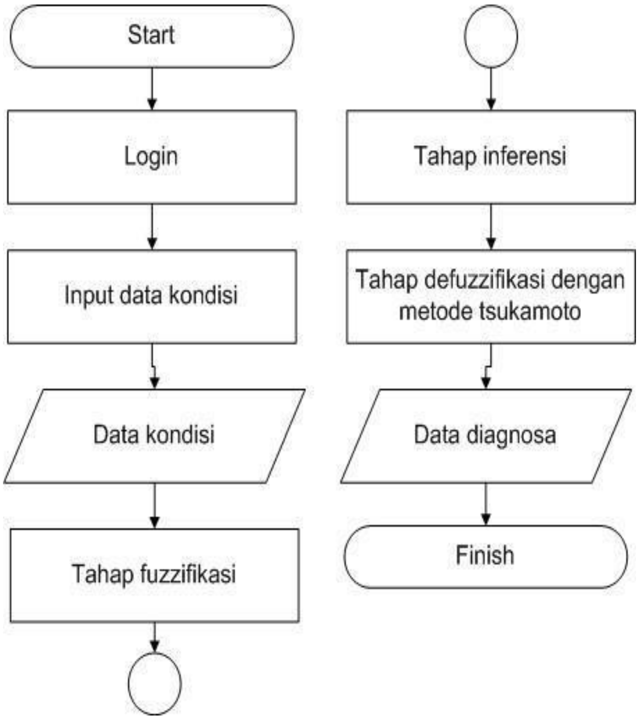


Figure 4 Expert system algorithm design

Based on Figure 4, the initial process in the expert system is the user inputting the autoclave conditions, namely the results of temperature measurements, the results of alarm noise level measurements, and the difference between the measured pressure and the pressure on the display. The measurement results will enter the fuzzy logic process with the Tsukamoto method. The first stage in fuzzy logic is fuzzification. The fuzzification process changes the measurement results into fuzzy numbers. The next stage is the inference stage. At the inference stage, fuzzy numbers are interpreted into each rule or rule to produce new fuzzy output. The fuzzy output results are processed into the defuzzification stage. The defuzzification process produces a crips number which is used to determine or diagnose damage to the autoclave.

4. RESULTS AND DISCUSSION

The expert system that has been designed has been tested by entering the input of the results of damage condition data measurements from the field as in Table 3.2. The system output results are then compared with the diagnosis results by experts. Based on data number 1, the fuzzy value can be calculated using the manual method as below. Calculation of fuzzy values on autoclave damage with the following parameters:

Temperature = 120.9 °C

Alarm sound = 20dB

Reading = 0.71

Based on the data above, manual calculations are carried out using the Tsukamoto fuzzy method.

1. Fuzzification stage

Temperature fuzzy set (G1)

Temperature fuzzy set, obtained x = 120.9 enters the low and medium sets, so that the following membership degree equation can be obtained.

x = 120

$$\mu_{G1rendah}\,[120{,}9] = \frac{127 - 120{,}9}{127 - 121}$$
$$\mu_{G1rendah}\,[120{,}9] = \frac{6{,}1}{6}$$
$$\mu_{G1rendah}\,[120{,}9] = 1{,}016$$
$$\mu_{G1sedang}\,[120{,}9] = \frac{120{,}9 - 121}{127 - 121}$$
$$\mu_{G1sedang}\,[120{,}9] = \frac{-0{,}1}{6}$$
$$\mu_{G1sedang}\,[120{,}9] = 0{,}016$$

Fuzzy set of alarm sounds (G2)

Fuzzy set of alarm sounds, x = 20 is included in the low set, so the following membership degree equation can be obtained. X= 20

$$\mu_{G2\ rendah}[20] = \frac{50-20}{50-15}$$

$$\mu_{G2\ rendah}[20] = \frac{30}{35}$$

$$\mu_{G2\ rendah}[20] = 0{,}8571$$

Temperature difference fuzzy set (G3)

Temperature difference fuzzy set, obtained x = 0.71 is included in the low and medium sets, so that the following membership degree equation can be obtained.

x = 0.71

$$\mu G3\ rendah[0{,}71] = \frac{1-0{,}71}{1-0{,}75}$$

$$\mu G3\ rendah[0{,}71] = \frac{0{,}29}{0{,}3}$$

$$\mu G3\ rendah[0{,}71] = 0{,}96$$

A. Inference stage

Based on the calculation of the μ value and referring to Table 3.3, a combination of 12 rules and predicate rules is obtained for the assessment of the existing parameters as follows.

[R1] IF G1 low AND G2 low AND G3 low THEN K1 AND K2 AND K3 Not identified

Based on the membership function, the data membership values are obtained, namely:

α-*predikat* $_1$ =min(μ_{G1} Rendah ∩ μ_{G2} Rendah ∩ μ_{G3} Rendah)

α-*predikat* $_1$ =min(1,016 ; 0,8571 ; 0,96)

α-*predikat* $_1$ = 0,85

Then calculate the Z1 value, the Z1 value is obtained as follows.

$$\mu TT\ [z1] = \left(\frac{50-Z1}{50-4} = 0{,}85\right)$$

$$\mu TT[z1] = \frac{50-z1}{46} = 0{,}85$$

$$\mu TT[Z1] = 50 - Z1 = 0{,}85 * 46$$

$$\mu TT[Z1] = 50 - Z1 = 39{,}1$$

$$\mu TT[Z1] - Z1 = 39.1 - 50$$

$$\mu[Z1] \quad Z1 = 10{,}9$$

R10] IF G1 is medium AND G2 is low AND G3 is low THEN K1 And K2 And K3 Not Damaged

Based on the membership function, the data membership values are obtained, namely:

α-*predikat* $_{10}$ =min (μ_{G1} sedang ∩ μ_{G2} rendah ∩ μ_{G3} Rendah)

α-*predikat* $_{10}$ =min (0,016 ; 0,8571 ; 0,96)

α-*predikat* $_{10}$ = 0,016

Then calculate Z10 then the Z10 value is obtained as follows.

$$\mu TR[z10] = \left(\frac{Z_{10} - 25}{50 - 25} = 0{,}016\right)$$

$$\mu TR[z10] = \left(\frac{z10 - 25}{25} = 0{,}016\right)$$

$$\mu TR[z10] = (z10 - 25 = 0{,}016 * 25)$$

$$\mu TR[z10] = (z10 - 25 = 17{,}5)$$

$$\mu TR[z10] = (z10 = 0{,}4 + 25)$$

$$\mu TR[z10] = (z10 = 25{,}4)$$

$$\mu TR[z10.2] = \left(\frac{75 - z10}{75 - z10} = 0{,}016\right)$$

$$\mu TR[z10.2] = 0{,}016$$

B. Defuzzification

Defuzzification is done to return the fuzzy value to a crisp value again. In the Tsukamoto fuzzy method, defuzzification uses the average method in equation 2.5 as follows.

$$Z^* = \frac{(0,85 * 10,9) + (0,016 * 50)}{(0,85 + 0,016)}$$

$$Z^* = \frac{9,265 + 0,8}{0,856}$$

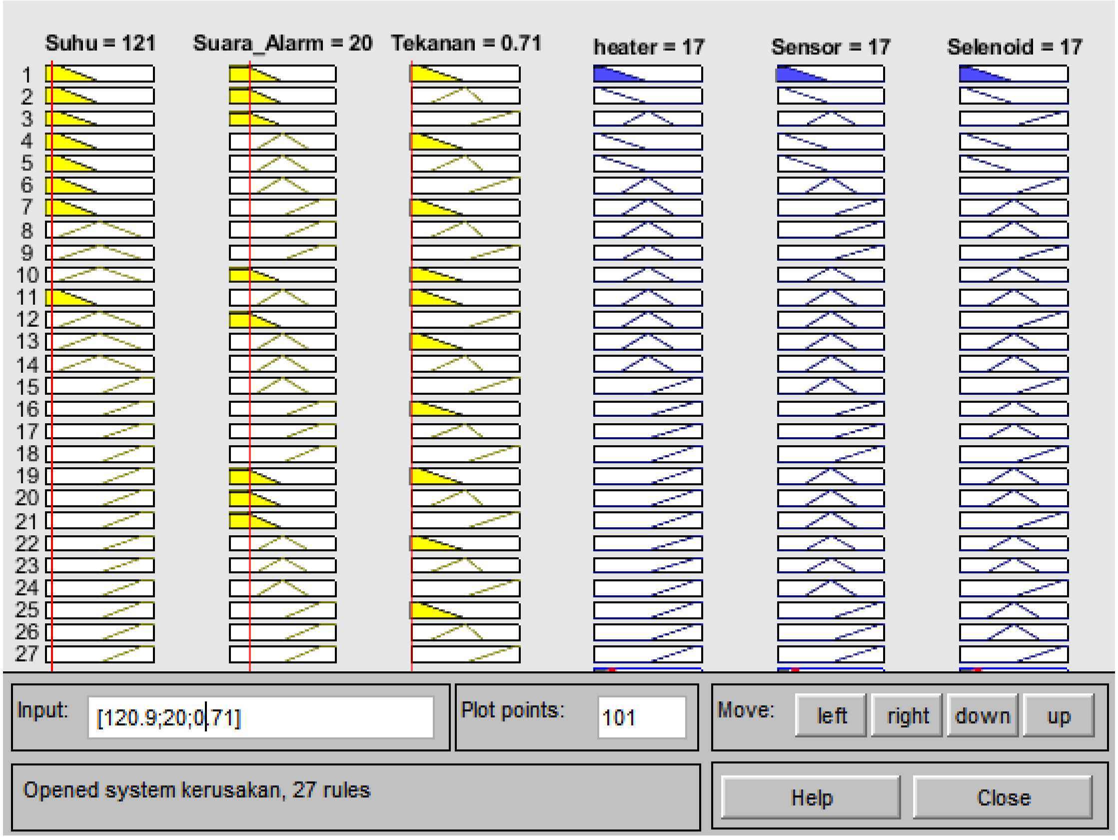
$$Z^* = \frac{10,065}{0,856}$$

$$Z^* = 11,6235981$$

So, if the temperature is 120.9 °C, the alarm sound is 20dB, and the temperature measurement difference is 0.71 , then the damage is 11.6235981%.

C. Testing results with Matlab

To obtain system diagnosis results, testing results is carried out using Matlab. In Figure 5, testing was carried out using the Matlab fuzzy mamdani method with measured temperature parameters of 120.9 °C, alarm sound of 20dB, and temperature difference of 0.71 resulting in a heater z value of 17; sensor of 17; and solenoid of 17. The results of manual calculations in point 4.1.1 show a damage value of 10.62% using Tsukamoto fuzzy. The results between manual calculations and Matlab are different but not significant, because Matlab uses the fuzzy mamdani method. When viewed from the fuzzy output set graph, the results of the diagnosis of the heater are not damaged, the sensor is not damaged/not identified, and the alarm is not damaged. The results of the system diagnosis are then compared with the results of the expert diagnosis in Table 4.1.



Input: [120.9;20;0.71]

Plot points: 101

Opened system kerusakan, 27 rules

Figure 5 Fuzzy rules results

Table 1 Comparison of expert and system diagnosis results

No	Temperature	Alarm Sound	Temperature Difference	Expert diagnosis results			Hasil Diagnosa sistem			Ket
				Heater	Sensor	Alarm	Heater	sensor	Selenoid	
1	120,9	20,0	0,71	TT	TT	TT	TT	TT	TT	appropiate
2	124,1	31,7	0,79	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
3	124,3	58,7	0,79	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
4	123,2	60,4	0,69	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
5	122,9	20,0	0,66	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
6	122,6	20,0	0,77	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
7	124,5	50,0	0,78	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
8	125,4	40,7	0,92	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
9	124,5	48,7	0,76	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
10	128,4	57,8	0,71	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
11	126,6	53,8	0,75	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
12	128,7	47,3	0,84	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
13	128,1	48,5	0,70	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
14	130,1	10,7	0,92	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate

Based on the comparison results in Table 4.1, the number of diagnostic matches between the expert and the system is 20 diagnoses. This shows that the system has a match of 20/20*100%=100%

Table 2 Comparison of expert diagnostic results, the Matlab system and the system

No	Temperature	Alarm Sound	Temperature Difference	Expert diagnosis results			Matlab diagnosis results			System Diagnostic Results			Ket
				Heater	Sensor	Alarm	Heater	sensor	Selenoid	Heater	sensor	Selenoid	
1	120,9	20,0	0,71	TT	TT	TT	TT	TT	TT	TT	TT	TT	appropiate
2	124,1	31,7	0,79	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
3	124,3	58,7	0,79	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
4	123,2	60,4	0,69	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
5	122,9	20,0	0,66	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
6	122,6	20,0	0,77	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
7	124,5	50,0	0,78	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
8	125,4	40,7	0,92	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
9	124,5	48,7	0,76	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate
10	128,4	57,8	0,71	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	Not damaged	appropiate

D. Analysis of Results

The results of running the expert system application for detecting damage to sterile autoclave equipment can be seen in Figure 6.

Tambah Data Alat

Data Alat > Tambah Data Alat

Kode Alat
Masukan Kode Alat

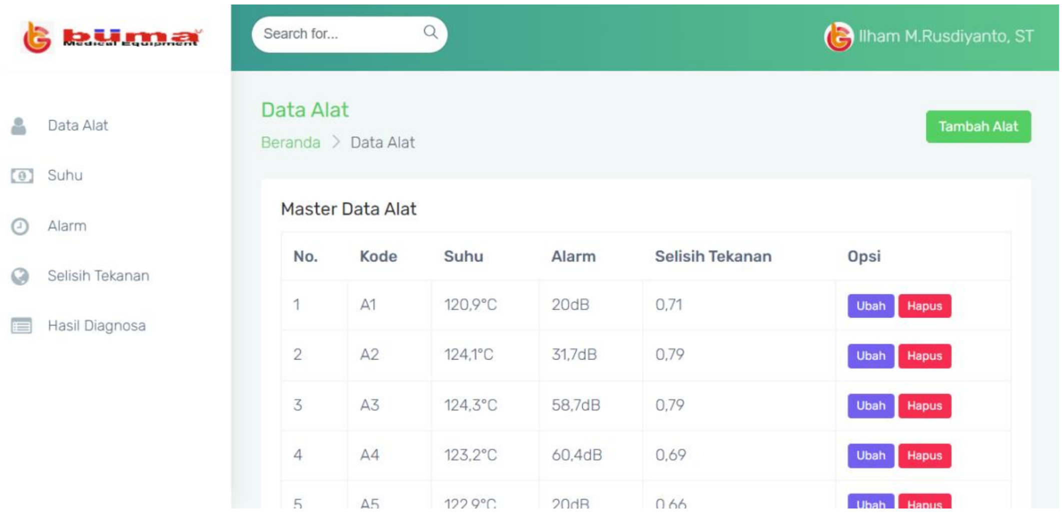
Suhu
Masukan Suhu

Alarm
Masukan Alarm

Selisih Tekanan
Masukan Selisih Tekanan

Figure 6 initial condition of tool condition input

Figure 6 is the initial display when you want to input tool conditions including tool code, temperature conditions, alarm conditions and pressure differences.

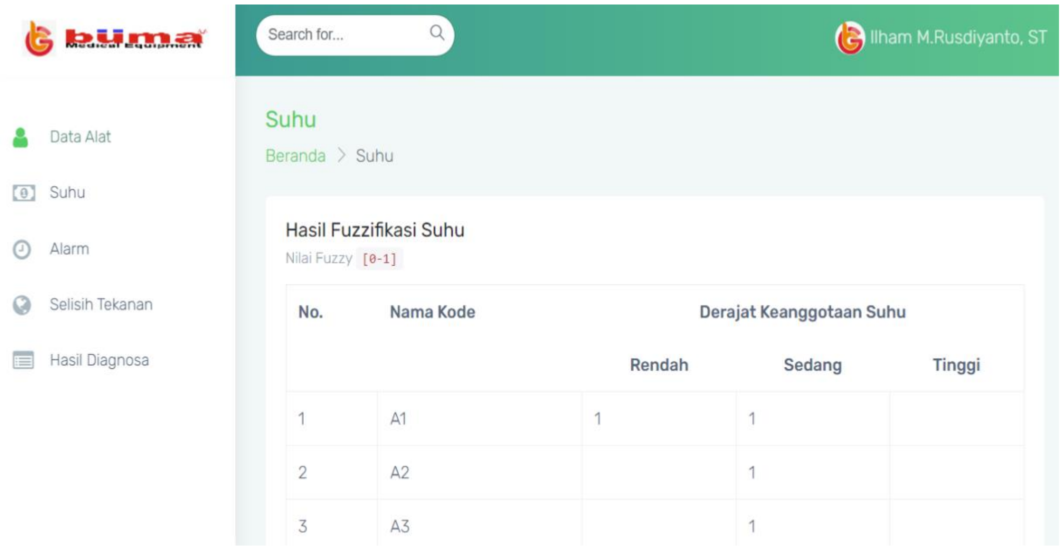


Master Data Alat

No.	Kode	Suhu	Alarm	Selisih Tekanan	Opsi
1	A1	120,9°C	20dB	0,71	Ubah Hapus
2	A2	124,1°C	31,7dB	0,79	Ubah Hapus
3	A3	124,3°C	58,7dB	0,79	Ubah Hapus
4	A4	123,2°C	60,4dB	0,69	Ubah Hapus
5	A5	122,9°C	20dB	0,66	Ubah Hapus

Figure 7 Tool Data Page

Figure 7 is a page for editing data on tool condition or symptoms of damage for users.



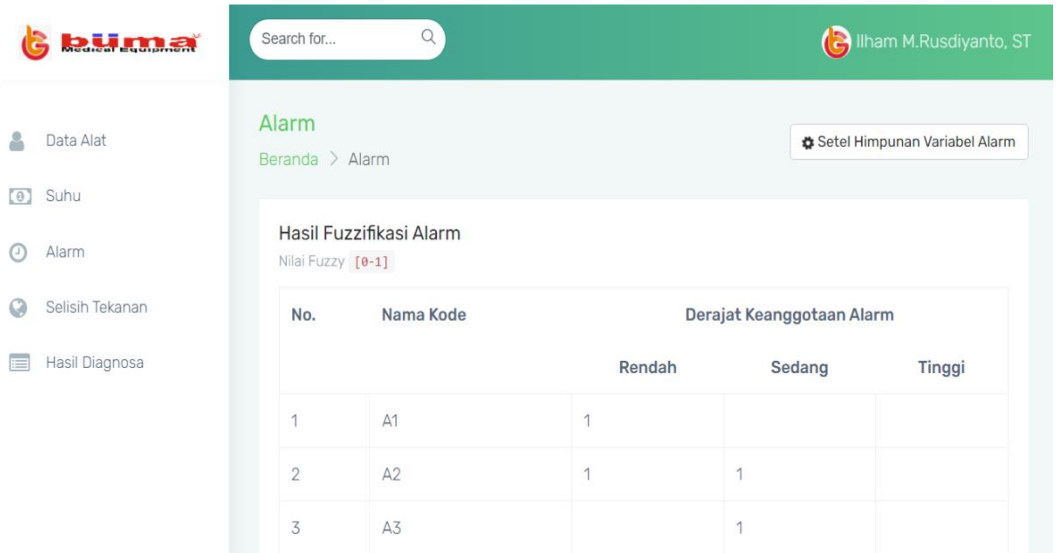
Hasil Fuzzifikasi Suhu

Nilai Fuzzy `[0-1]`

No.	Nama Kode	Derajat Keanggotaan Suhu		
		Rendah	Sedang	Tinggi
1	A1	1	1	
2	A2		1	
3	A3		1	

Figure 8 Temperature fuzzification results

Figure 8 is the result of inputting temperature input conditions, whether the temperature entered is in the low, medium or high category.



Alarm

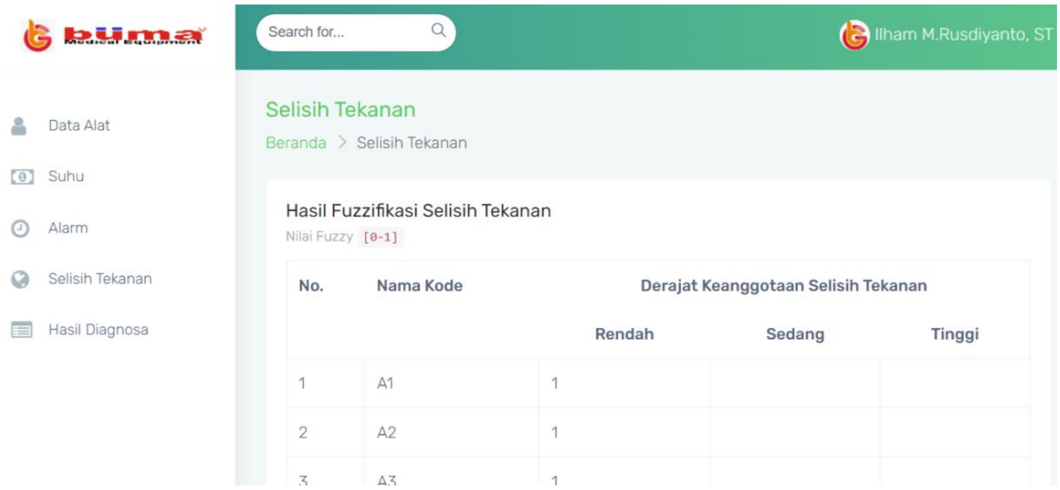
Hasil Fuzzifikasi Alarm

Nilai Fuzzy `[0-1]`

No.	Nama Kode	Derajat Keanggotaan Alarm		
		Rendah	Sedang	Tinggi
1	A1	1		
2	A2	1	1	
3	A3		1	

Figure 9 results of alarm fuzzification

Figure 9 is the result of inputting alarm input conditions, whether the alarm conditions entered are in the low, medium or high category.



Selisih Tekanan

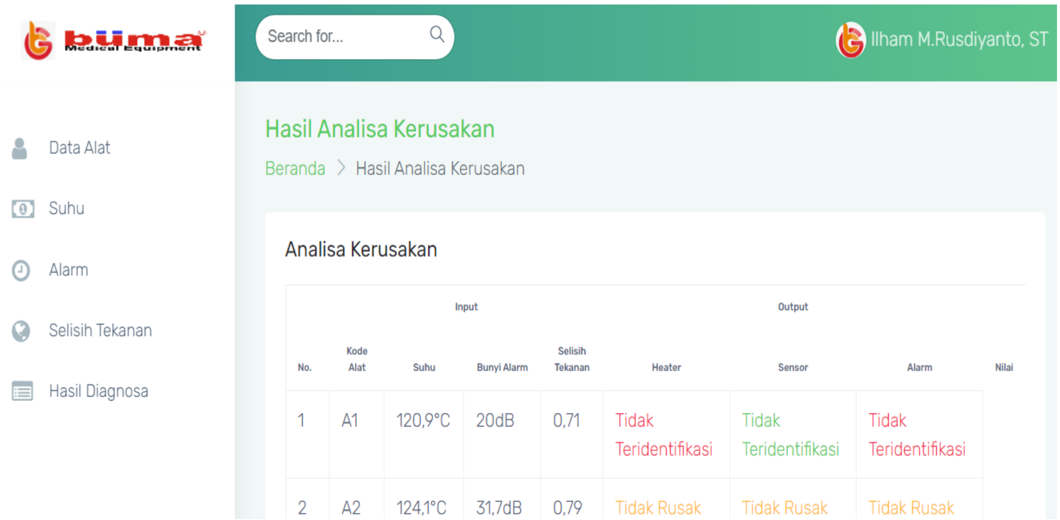
Hasil Fuzzifikasi Selisih Tekanan

Nilai Fuzzy `[0-1]`

No.	Nama Kode	Derajat Keanggotaan Selisih Tekanan		
		Rendah	Sedang	Tinggi
1	A1	1		
2	A2	1		
3	A3	1		

Figure 10 results of pressure difference fuzzification

Figure 10 is the result of inputting the pressure difference input conditions, whether the pressure conditions entered are in the low, medium or high category.



Hasil Analisa Kerusakan

Beranda > Hasil Analisa Kerusakan

Analisa Kerusakan

	Input				Output			
No.	Kode Alat	Suhu	Bunyi Alarm	Selisih Tekanan	Heater	Sensor	Alarm	Nilai
1	A1	120,9°C	20dB	0,71	Tidak Teridentifikasi	Tidak Teridentifikasi	Tidak Teridentifikasi	
2	A2	124,1°C	31,7dB	0,79	Tidak Rusak	Tidak Rusak	Tidak Rusak	

Figure 11 Damage Analysis Results

Figure 11 is the result of the diagnosis of damage to the heater, sensor and solenoid.

5. CONCLUSION

From the results of testing and analysis of the expert system for detecting damage to the Autoclave using the fuzzy logic method, the following conclusions were obtained.

1. The application of the expert system for detecting damage to the Autoclave has been proven to be able to provide a diagnosis result of 100%. This system can assess the degree of damage by 11.6235981%. based on the input of the symptoms given, thus providing a decision that is close to the actual condition.
2. The expert system that was built is able to accelerate the damage detection process compared to the manual method. This helps in taking faster action to prevent further damage to the autoclave

6. REFERENCES

Barjis, J., Kolfschoten, G., & Maritz, J. (2013). A sustainable and affordable support system for rural healthcare delivery. *Decision Support Systems*, 56, 223-233.

Hutagalung, A. O., & Hasibuan, S. (2019). Determining the Priority of Medical Equipment Maintenance with Analytical Hierarchy Process. *International Journal of Online & Biomedical Engineering*, 15(10).

Lai, A., Spano, I. L., Marongiu, I., & Gatto, G. (2016, September). EMC assessment of a switching mode power supply for electromedical devices. In 2016 International Symposium on Electromagnetic Compatibility-EMC EUROPE (pp. 676-681). IEEE.

Gao, T., Massey, T., Selavo, L., Crawford, D., Chen, B. R., Lorincz, K., ... & Welsh, M. (2007). The advanced health and disaster aid network: A light-weight wireless medical system for triage. IEEE Transactions on biomedical circuits and systems, 1(3), 203-216.

Saputri.Figya,“ Pemanfaatan Sistem Pakar untuk Pemilihan IGD Rumah Sakit di kota Sidoarjo Mengunakan Metode Forward Chaining ,” Universitas Narotama, 2024.

Ratna.Dwi, Gunawan.Indra, Naustion,“Sistem Pakar Untuk Pemilihan Rujukan Online Pada Klinik Murni Kantor CabangPematang Siantar Menerapkan Metode Forward Chaining,”Stikom Tunas Bangsa,2021.

Assauqi.Marzali ,“ Analisa Pemeliharaan Preventif Electrosirgical Unit Di rumah Sakit Kota Subussalam ,” Universitas Sari Mutiara, 2024.

Gaba, D. M. (2022). Artificial intelligence and expert systems. In Control and Automation in Anaesthesia (pp. 22-36). Berlin, Heidelberg: Springer Berlin Heidelberg.

Ho, G. T., Tang, Y. M., Tsang, K. Y., Tang, V., & Chau, K. Y. (2021). A blockchain-based system to enhance aircraft parts traceability and trackability for inventory management. Expert Systems with Applications, 179, 115101.

Blagoveshchenskiy, I. G., Blagoveshchenskiy, V. G., Besfamilnaya, E. M., & Sumerin, V. A. (2020, December). Development of databases of intelligent expert systems for automatic control of product quality indicators. In Journal of physics: conference series (Vol. 1705, No. 1, p. 012019). IOP Publishing.

Zhou, L., & Sordo, M. (2021). Expert systems in medicine. In Artificial intelligence in medicine (pp. 75-100). Academic Press.

Meera, S., & Geerthik, S. (2022). Natural language processing. Artificial intelligent techniques for wireless communication and networking, 139-153.

Garcia, M. B., Mangaba, J. B., & Tanchoco, C. C. (2021, September). Virtual Dietitian: A Nutrition Knowledge-Based System Using Forward Chaining Algorithm. In 2021 International Conference on Innovation and Intelligence for Informatics, Computing, and Technologies (3ICT) (pp. 309-314). IEEE.

Prati, E., Peruzzini, M., Pellicciari, M., & Raffaeli, R. (2021). How to include User eXperience in the design of Human-Robot Interaction. Robotics and Computer-Integrated Manufacturing, 68, 102072.

Chandrappa, R., & Das, D. B. (2024). Biomedical Waste. In Solid Waste Management: Principles and Practice (pp. 243-297). Cham: Springer International Publishing.

Saleh, N. S., Hussain, H. H., & Abdelhalim, A. (2024). Performance and Efficiency of an Autoclave Made from Local Materials in Winter and Summer in Iraq. Al-Mustansiriyah Journal of Science, 35(1), 8-16.

Deliiski, N., Niemz, P., Vitchev, P., Angelski, D., & Tumbarkova, N. (2023). Mathematical description of the operating temperature in regimes for autoclave steaming and subsequent air conditioning of wood. Wood Material Science & Engineering, 18(5), 1816-1826.

Fogarty, P. (2021). Fuzzy logic, a logician's perspective. In Fuzzy Logic: Recent Applications and Developments (pp. 1-9). Cham: Springer International Publishing.

Prajapati, S., & Fernandez, E. (2020, October). Performance evaluation of membership function on fuzzy logic model for solar PV array. In 2020 IEEE international conference on computing, power and communication technologies (GUCON) (pp. 609-613). IEEE.

Özyurt, F., Sert, E., & Avcı, D. (2020). An expert system for brain tumor detection: Fuzzy C-means with super resolution and convolutional neural network with extreme learning machine. Medical hypotheses, 134, 109433..