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Application of Fuzzy Logic Controller for Measurement of Body Temperature and Heart Rate

Ekawati Prihatini[1*✉], Yeni Irdayanti[1], Muhammad Rafly[1]
[1]Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia
*Corresponding Author: ekawati_p@polsri.ac.id

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ABSTRACT

The integration of technology, particularly in the field of electronics and robotics, has significantly impacted various aspects of everyday life. This development has extended into the realm of medicine, notably through the use of socially assistive robots (SAR) to aid in tasks and support emotional health, especially for autistic children experiencing anxiety-related challenges. These SAR robots employ interaction systems using speech, gestures, and facial expressions to alleviate anxiety levels in children. Central to their function is the monitoring of vital signs such as heart rate and body temperature, crucial parameters in assessing a child's health. Fuzzy logic, with its capability to handle ambiguous or uncertain data, plays a pivotal role in interpreting the sensor data gathered by SAR robots, aiding in determining the child's condition accurately. This research aims to investigate the effectiveness of SAR robots in assessing and responding to the anxiety levels of autistic children by analyzing the data from temperature and heart rate sensors through a fuzzy logic controller. From the tests that have been carried out, it shows that the body temperature and heart rate sensors work according to the way each sensor works and can be seen from the method that has been chosen, namely the fuzzy logic controller which produces graphs according to the input and output. This research has successfully proven that by using the fuzzy logic method the GY906 and MAX30100 sensor controllers work optimally so as to produce an output (servo motor) which has 2 conditions of moving (180º) and not moving (0) which is an indicator that the child is in a condition of temperature and pulse. abnormal heart.

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1. INTRODUCTION

Everyone has been affected by the development of technology in everyday life. Electronics is a field that constantly advances, beginning with very basic concepts. Additionally, the development of electronic technology, particularly robotics, has allowed for applications in the field of medicine, notably for measuring. As well as health control equipment, medical aid equipment, and others, it can also be used for other purposes [1].

Robot is a unit in the form of either mechanical or physical or virtual that has intelligence. In general, robots are in the form of electromechanical circuits that can move and have ideas. In general, a robot must have characteristics or characteristics such as being able to feel the state of the environment, be programmable, be able to move and have a certain level of intelligence [2]. The function of robots, especially SAR (Socially Assistive Robot) robots, is to replace human tasks, entertain or become a means for human health, especially for the emotional health of autistic children who have varying levels of anxiety and high fear so that they can create feelings who are uncomfortable and can make themselves more aggressive, like to hurt themselves and throw tantrums for no reason marked by a rapid heartbeat and body temperature that can fluctuate. Heart rate and body temperature rate are essential vital sign parameters for paramedics to determine a child's health [3].

A socially assistive robot (SAR) is a robot with an interaction system that uses speech, facial expressions, and communicative gestures to provide assistance in accordance with a specific context of assistance. SAR robots are very effective at lowering children's anxiety levels. [4].

The average heart rate is 75 beats per minute and the normal range is 60 to 100 beats per minute. A heart rate increase to more than 100 beats per minute is referred to as tachycardia. Bradycardia is designed to be used for heart rates under 60 beats per minute. A heart rate between 140 and 250 beats per minute is considered abnormal tachycardia. [5].

The body temperature is a measure of the balance between the production and expenditure of heat from the body. Degrees represent the amount of heat produced and expended. Temperature refers to the heat or cold of a substance. There is a calcification of body temperature, namely hypothermia with a temperature <36°C, normal temperature 36°C to 38°C, hot body temperature 38.1°C to 40°C, and hyperthermia with a temperature > 40°C [6].

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Fuzzy is linguistically referred to as vague or blurry. A value has the same potential to be true or untrue. The degree in fuzzy has a known range of values from 0 (zero) to 1 (one). Contrary to the tight set, which can only have a value of 1 (yes) or 0 (no). Fuzzy logic is a type of logic that has an ambiguity (obscurity) value between true and false. In the theory of fuzzy logic, two statements can both be true or untrue.. But how much there exists as well as the faults of something depends on the spewing weight it has. Fuzzy logic has a combination degree in the range 0 to 1 [7].

The role of the SAR robot is so important for the health of autistic children who are experiencing conditions that are not normal, such as anxiety and sudden illness as indicated by the robot's hand movements. When the GY906 sensor detects that the child's body temperature has exceeded normal or hot limits, the robot's hand will move, and also detects the child's heart rate using the MAX30100 sensor, so the role of fuzzy logic is very important to see the response of the two sensors working normally or not. The aim of this research is to find out whether the child's condition is anxious and to find out how the body temperature and heart rate sensors measure work using a fuzzy logic controller.

2. THE COMPREHENSIVE THEORETICAL BASIC

2.1. MAX30100 Sensor

The MAX30100 sensor is a sensor that can be used for medical devices. This sensor functions as a heart rate detector. To measure oxygen levels in the body, light and the pulse of blood flow in the arteries will be absorbed by the sensor using the properties of hemoglobin. The way this sensor works after being connected to the Raspberry Pi 4 board is by placing your thumb on the sensor, the sensor will immediately work by displaying your heart rate and blood oxygen levels simultaneously. This sensor is a heart rate monitor and pulse oximeter sensor that incorporates two LEDs, a photodetector, optimized optics and analog signals with low noise and uses software-adjustable 1.8V and 3.3V power with negligible standby current allowing the power supply to stay connected all the time [8].

2.2. GY906 Sensor

The GY-906 sensor is an infrared sensor for non-contact temperature measurement. The signal conditioner integrated into the MLX90614 is a low noise amplifier, 17-bit ADC and a robust DSP unit that achieve the great accuracy and resolution of a thermometer. The MLX9061 sensor has 2 outputs: near temperature and object temperature. The MLX9061 sensor material integrates an infrared sensitive thermal sensor as well as an ASIC signal conditioning chip into the TO39 sensor housing. Signal conditioning takes the form of a low-noise amplifier, 17-bit ADC, and powerful DSP, providing high-resolution, high-precision thermometers. The sensor is calibrated with a SMBus digital output and measures the entire temperature range with a resolution of 0.02°C. The sensor can measure near temperatures from -40 to 125°C as well as object temperatures from -70 to 380°C [9], [10].

2.3. Arduino UNO

Open source sports computing platform Arduino is built on straightforward input/output (I/O) circuits and development areas that use the Processing programming language. You can use Arduino to create interactive independent objects or you can connect it to PC software like Flash, Processing, VVVV, or Max/MSP. The series is available for purchase or manual assembly. Arduino's Ilham (Integrated Development Environment) is free source software. A basic system board called the Arduino Uno R3 is based on the AVR microcontroller of type ATmega328P. The Arduino Uno R3 contains a 16 MHz crystal oscillator, 6 PWM outputs, 14 digital inputs and outputs, 6 analog inputs, a USB port, a power jack, and an ICSP header. In general Arduino consists of 2 parts, namely hardware input / output (I / O) boards and Arduino applications including ideas for writing programs, drivers for connecting to a PC, sample programs and libraries for program development. [9].

2.4. Servo Motor

The servo motor has a closed feedback loop that requires the control circuit inside the servo motor to be notified of the motor's location. A motor, a set of gears, a potentiometer, and a control circuit make up this motor. The potentiometer is used to establish the servo rotation's maximum angle. On the other hand, the pulse width transmitted via the motor cable's signal leg is used to determine the angle of the servo motor axis. It can be seen in the photo that the pulse is 1.5 ms in a period of 2 ms wide so that the angle of the motor axis will be in the middle position. Continue to increase the width of the OFF pulse until it continues to increase the axis movement in the clockwise direction and continues to become small the OFF pulse increases until it continues to increase the axis movement in the anti-clockwise direction [11].

2.5. Fuzzy Logic

Fuzzy logic was first introduced by Lotfi A. Zadeh, a professor from the University of California. Fuzzy logic has degrees of membership in the range 0 (zero) to 1 (one), in contrast to digital or discrete logic which only has 2 values, namely one (1) or zero (0). Fuzzy logic is used to translate a quantity that is expressed using language (linguistics) and aims to represent and solve problems of uncertainty or partial truth. A linguistic variable is a numerical interval and has linguistic values, whose semantics are defined by their membership meaning. A system based on fuzzy rules consists of 3 main components: Fuzzification, Inference and Defuzzification. [12]-[13].

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2.6. Scilab

SciLab is software whose license is free of charge and open source for numerical computations that are often used in the fields of science and engineering. This software is almost the same as Matlab, as an interactive program for numerical computing and information visualization. 5. Scilab can be installed on a computer or laptop with the GNU/Linux operating system, Windows XP/Vista/7/8 and Mac OS X. At first the developer This application is INRIA and ENPC but currently the development of this software is under the Scilab consortium. This software with the GNU GPL license is very similar to Matlab Simulink because it also has a programming feature using blocks, namely xcos [14], [15].

3. RESEARCH METHOD

Data analysis and observation methods were used to collect data information in this study, using the Arduino IDE software to program the process from the MAX30100 sensor and GY906 sensor with the MG995 servo output. For this study, Fuzzy Logic was used to analyze sensors and servo output whether they were working optimally or not.

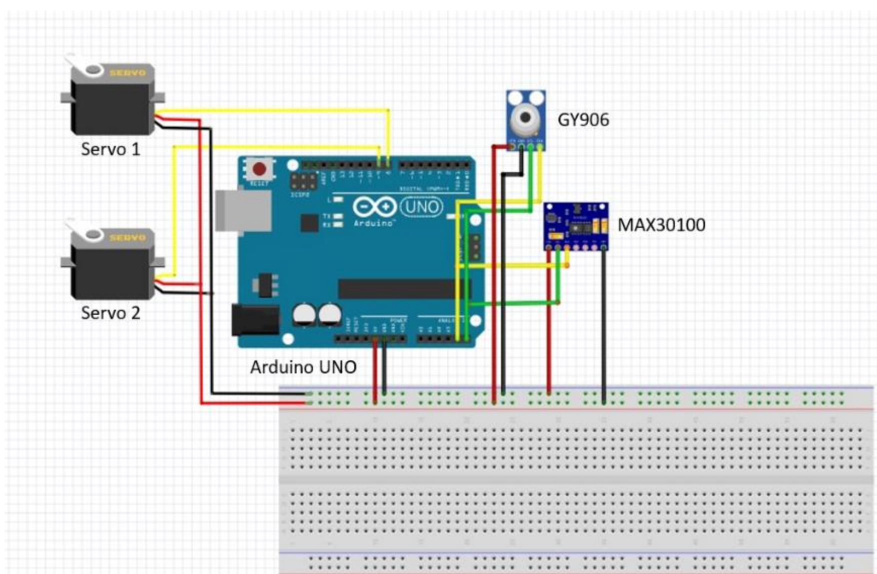

Figure 1. Schematic of the MAX30100 and GY906 3D sensor circuits

The components used are the GY-906 and MAX30100 sensors as input and use Arduino as a microcontroller to process the input signal, using the MG995 servo motor as an output that functions to move the robot's hand. And will be communicated between arduino and raspberry to send data from the input signal to the telegram application. For the division of work functions and component roles can be seen from block diagram in Figure 2 below.

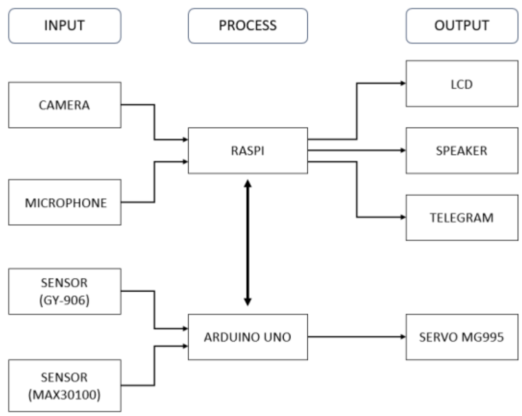

Figure 2. Block diagram Socially Assistive robot for children with Autism Spectrum Disorder

Then the Flowchart to describe the work process of the system discussed is shown on Figure 3 below.

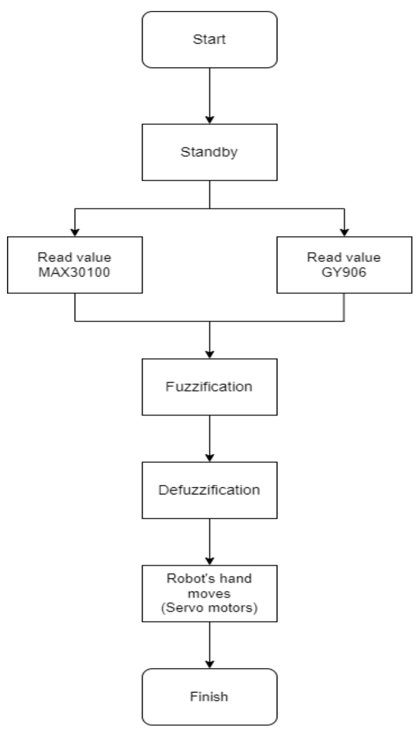

Figure 3. Flowchart Sensors Socially Assistive Robot

The sensor flowchart GY-906 and MAX30100, first is sensor initialization then retrieves data from the two sensors for anxiety and health classification marked by heart rate and body temperature. There are three levels for the GY-906 sensor, namely hypothermia, normal, and hyperthermia, while for the MAX30100 sensor, there are two levels, namely normal and abnormal. If the GY906 sensor detects a child's temperature at the hyperthermia level or the temperature reaches more than 38.1°C and the MAX30100 sensor detects a child's heart rate of more than 100 bpm (beats per minute), the servo will move in as a robot hand or signal that the child is anxious or sick.

4. RESULT AND DISCUSSION

4.1. Fuzzy Logic Controller Simulation

In this research, the use of Fuzzy Logic Controller was carried out in an effort to optimize the use of sensors on SAR (Socially Assistive Robot) robots. The researcher conducted a simulation on the scilab application. In the Fuzzy Logic Controller simulation in the scilab application, there are 2 membership functions, namely the membership function Input and output. In the membership function input there are 2 sensors (inputs), namely the GY906 voltage sensor and the MAX30100 sensor. For GY906 sensor data values to be processed between 0 to 40°C and MAX30100 sensor data values 0 to 140 bpm (beats per minute). The condition for the reading value of the GY906 sensor for the child's body temperature to be processed is:

1. Cold = 0 to 36°C
2. Normal = 36 to 38°C
3. Heat = 38 to 40°C

While the conditions for reading the MAX30100 sensor for heart rate are:

1. Weak = 0 to 60 bpm
2. Normal = 60 to 100 bpm

Fast = 100 to 140 bpm

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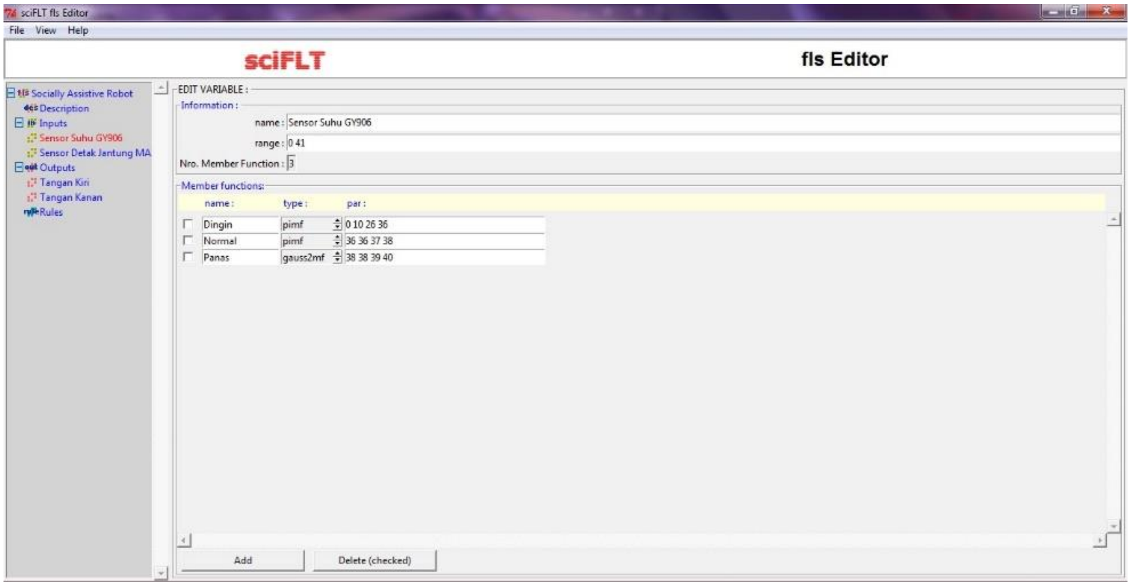

Figure 4. Function Membership of Input GY906

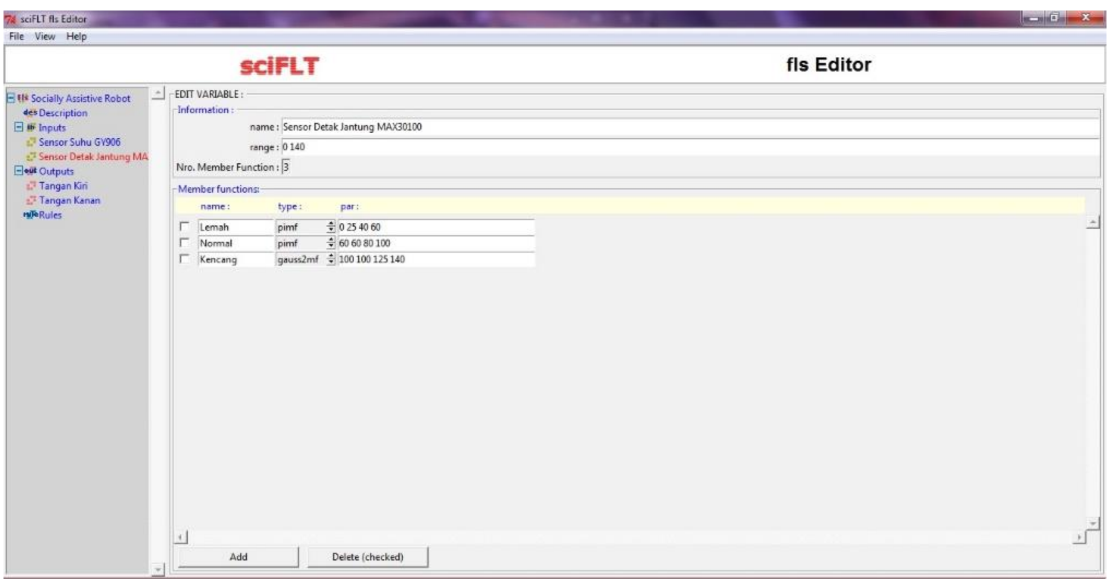

Figure 5. Function Membership of Input MAX30100

After filling in the input conditions from the GY906 and MAX30100 sensor membership functions along with the values for each condition, you can see a graph of the data that has been processed by the Fuzzy Logic Controller simulation as shown in Figure 6 below. Each colored line shows each condition and its value. On the GY906 sensor, the blue line indicates that the body temperature is cold, the green line indicates that the body temperature is normal and the red line indicates that the body temperature is hot. On the

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MAX30100 sensor the blue line indicates the heart rate is weak, the green line indicates the heart rate is normal and the red line indicates the heart rate is fast.

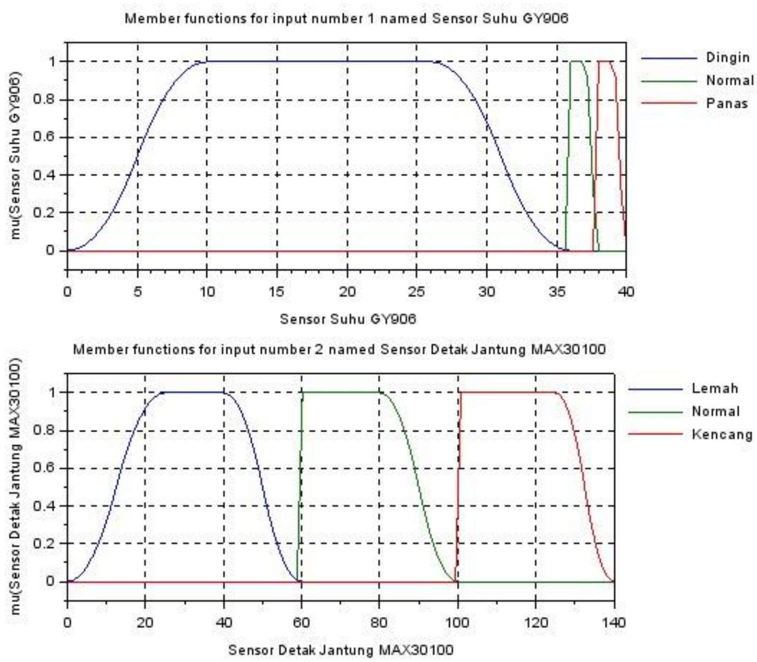

Figure 6. Membership Function Input Graph

In the membership function output, there are 2 outputs, namely the rotation of the servo motor. This output will be adjusted according to the input that we have set in such a way that the value of each condition is. In the membership function output fuzzy logic controller servo motor 1 (left hand) this SAR robot has 2 conditions, are:

1. Rest = 0 - 0°
2. Move = 0 - 180°

Likewise with servo motor 2 (right hand) has the same conditions, are:

1. Rest = 0 - 0°
2. Move = 0 - 180°

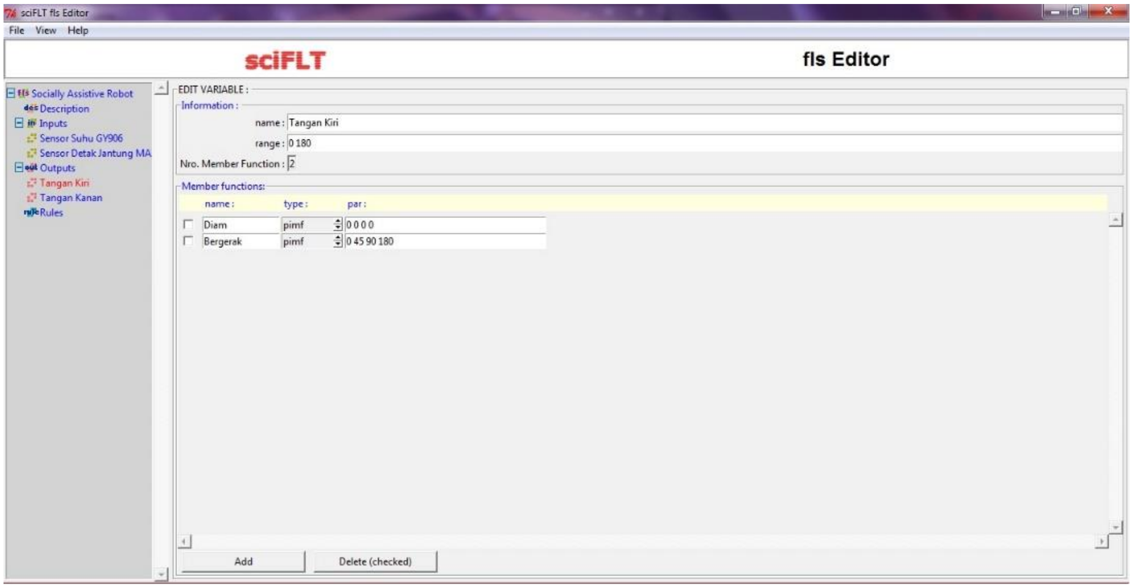

Figure 7. Membership Function Output Servo Motor 1 (left hand)

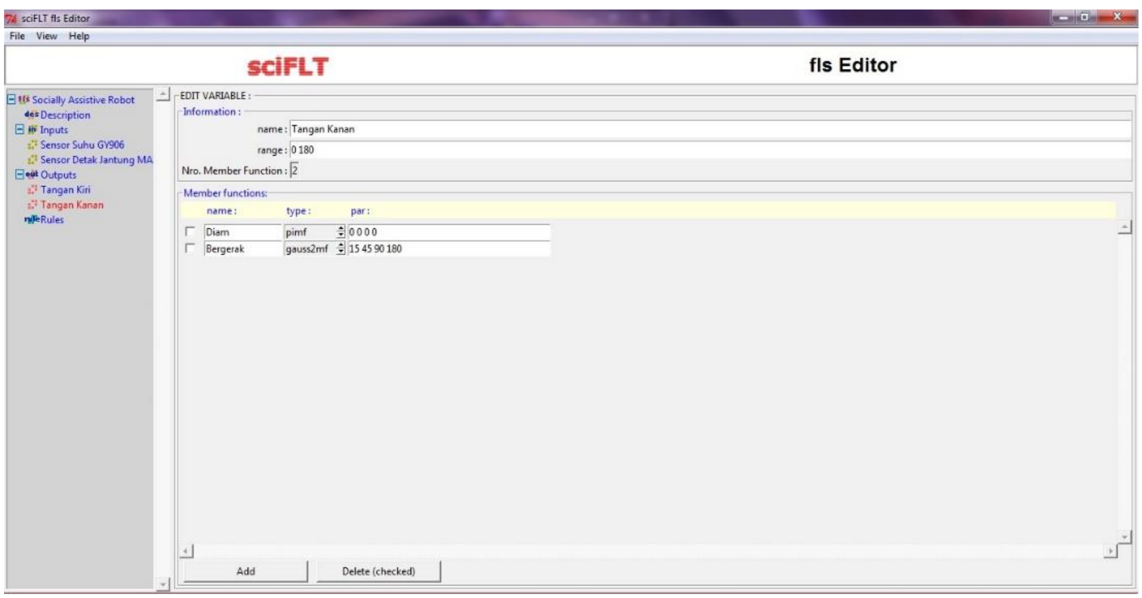

Figure 8. Membership Function Output Servo Motor 2 (right hand)

After filling in the membership function output conditions along with the values for each condition, you can see a graph of the data that will be processed by the Fuzzy Logic Controller simulation as shown in Figure 9 below. Each colored line shows each condition and its value. On servo motor 1 (left hand) the blue line is stationary (not moving) and the green line indicates the servo motor is moving. On servo motor 2 (right hand) it is the same as servo motor one, namely the blue line indicates the servo motor is stationary and the

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green line indicates the servo motor is moving, the graph of which can be seen in the image below.

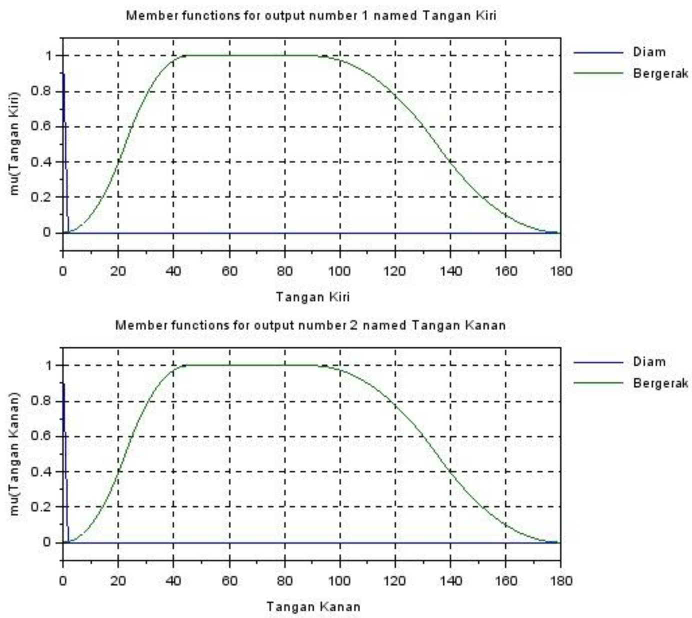

Figure 9. Membership Function Output Graph

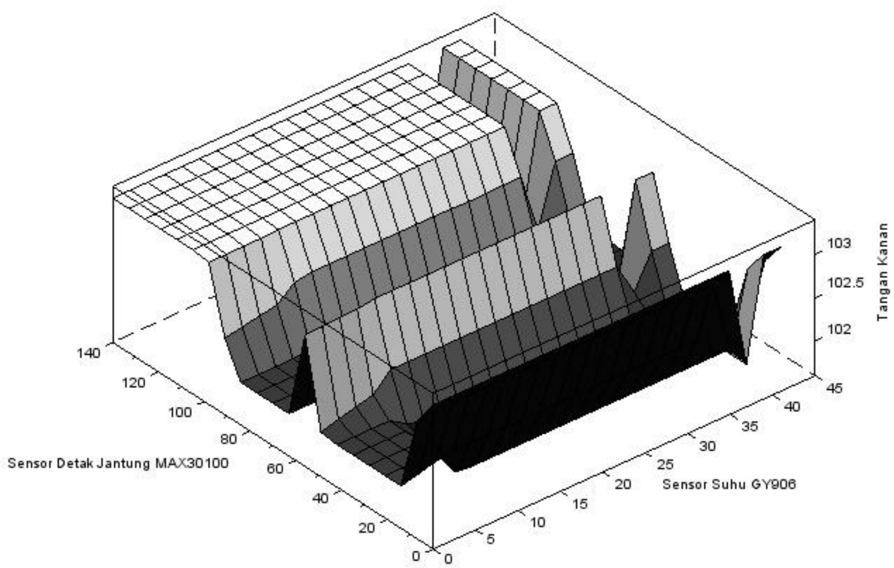

Figure 10. 3D Graph of Fuzzy Logic Input and Output Results

Figure 10 shows the results of how the 3D Fuzzy Logic Controller works from the GY906 temperature sensor and MAX30100 heart rate sensor, regarding the rotation of the SAR robot servo motor. The graph explains that the servo motor moves and does not move (still) according to the input conditions that have been set on the GY906 and MAX30100 sensors. where data from the input set (GY906 and MAX30100 sensors) and output (servo motor 1 and servo motor 2) can be seen in section 4.2. Table 1 also shows the conditions (moving and still) of the robot hand from the input that has been set.

4.2. Fuzzy Logic Controller Simulation

In this study, obtained data on optimization of the GY906 and MAX30100 sensors on socially assistive robots for children with autism spectrum disorder, in table 1. The data includes body temperature (ºC) values detected by the GY906 sensor and heart rate (bpm / beats per minute) detected by MAX30100 sensors. From these data it can be seen how optimal the use of the two socially assistive robot sensors is for the robot's output and condition.

Table 1. Data input and output with Fuzzy Logic Controller

GY906	MAX30100	Servo Motors 1	Servo Motors 2	Robot Condition
0 - 36ºC	0 – 60 bpm	180º	0	Move (Left Hand)
0 - 36ºC	60 – 100 bpm	0	0	Rest
0 - 36ºC	100 – 140 bpm	180º	180º	Move (All Hand)
36ºC - 38ºC	0 – 60 bpm	0	0	Rest
36ºC - 38ºC	60 – 100 bpm	0	0	Rest
36ºC - 38ºC	100 – 140 bpm	0	180º	Move (Right Hand)
38ºC - 40ºC	0 – 60 bpm	180º	0	Move (Left Hand)
38ºC - 40ºC	60 – 100 bpm	0	0	Rest
38ºC - 40ºC	100 – 140 bpm	180º	180º	Move (All Hand)

Based on the table above, when the body temperature is cold (0 - 36ºC) and the heart rate is weak (0 - 60 bpm), the robot's left hand will move 180º. And when the body temperature is cold (0 - 36ºC) and the heart rate is fast (100 - 140 bpm), the two robot arms will move 180º. If the body temperature is normal (36ºC - 38ºC) while the heart rate is fast, the robot's right hand will move 180º. And in conditions where the body temperature is hot (38ºC - 40ºC) while the heart rate is weak (0 - 60 bpm), the robot's left hand moves 180º. And the final condition is if the body temperature is hot (38ºC - 40ºC) and the heart rate is fast (100 - 140 bpm) then both robot arms will move 180º.

Figure 11. The conditions of the robot hand moving

Figure 12. Measurement results data sent via the Telegram application

5. CONCLUSION

From the research that has been done, socially assistive robots for children with autism spectrum disorder are made with the aim of helping and monitoring autistic children when they are in an unhealthy or anxious condition, with marked body temperature and abnormal heart rate, the socially assistive robot will move The hands are in accordance with the conditions that have been made in the table rules in table 1. And the socially assistive robot will also send data results from the GY906 and MAX30100 sensors to the Telegram application to be monitored by the teacher. By implementing a fuzzy logic controller, we can determine the robot's hand movements according to the child's body temperature and heart rate. The meaning of the moving robot hand indicates that the condition of the child playing with the socially assistive robot is in an abnormal condition such as being sick or in a state of anxiety. Of course the application of the fuzzy logic controller is able to optimize the use of sensors compared to not using a fuzzy logic controller.

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