CHAPTER 5
IMPLEMENTATION AND RESULTS

5.1. Documentation

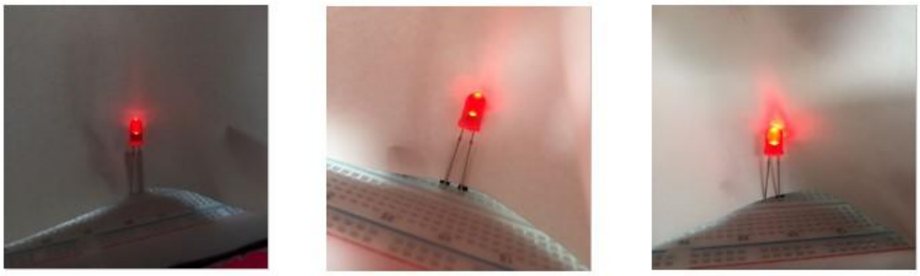
5.1.1. Daytime Trial

Figure 8 *Ultrasonic Sensor Trial During the Day*

In Figure 8, I did a test on the Ultrasonic sensor to get distance data by asking my friend to help me stand in front of the sensor. That way I can tell if my sensors and programs are working properly.

Figure 9 *LM35 Sensor Trial During the Day*

In Figure 9, I tested the LM35 sensor. I did a test outside the house during the day to see if my sensors and programs were working as I expected. I also use a lighter to get a temperature value that is higher than the temperature outside the house.



(a) (b) (c)

Figure 10 *LED Output During Daytime*

In Figure 10 (a) is the dim LED output when doing a test outside the house. While Figure 10 (b) is the LED output when it is brightly lit. Then in Figure 10(c) is when the LED is very bright.

5.1.2. Trial At Night

Figure 11 *LM35 Sensor Trial at Night*

In Figure 11, I did a prototype test at night. To get a higher temperature, then I use a lighter.

(a) (b)

Figure 12 *LED Output at Night*

In Figure 12(a) is the state when the LED is Off. Then for Figure 12 (b) is the state when the LED is dimmed.

5.2. Implementation of the Fuzzy Sugeno Algorithm

Fuzzy Sugeno is a fuzzy method that uses a linear equation as the output whose rules (inference) are represented in the form of IF – THEN.

5.2.1. Fuzzification

Fuzzification is the determination of the membership function and the degree of membership which is presented in the form of a fuzzy set of input variables.

The following figure shows the temperature input membership function curve.

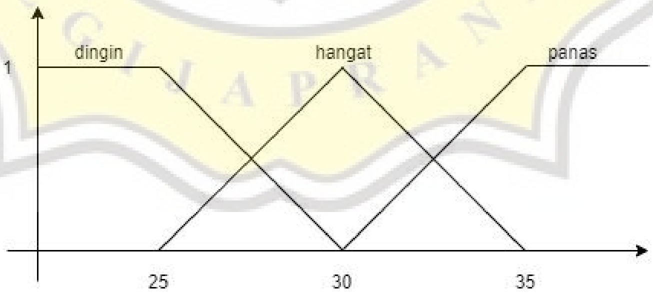


Figure 13 *Temperature Membership Function Curve*

The following table shows the domain range of the temperature input membership function.

Table 1 *Domain Range Input Temperature*

No.	Membership Function	Range
1	Cold	[≤ 30]
2	Warm	[25 – 35]
3	Hot	[≥ 30]

The following figure shows the input distance membership function curve.

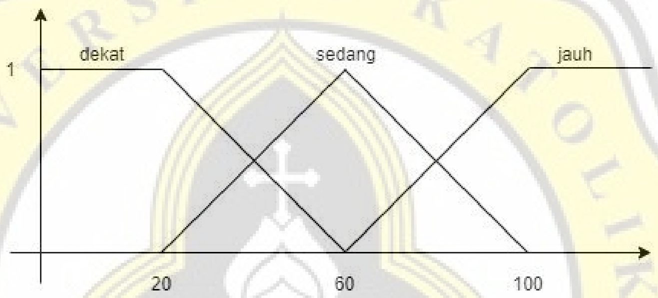


Figure 14 *Membership Function Curve Distance*

The following table shows the domain range of the distance input membership function.

Table 2 *Domain Range Input Distance*

No.	Membership Function	Range
1	Near	[≤ 60]
2	Medium	[20 – 100]
3	Far	[≥ 60]

The following table will show the domain range of the fan speed output membership function.

Table 3 *Domain Range Output Fan Speed*

No.	Membership Function	PWM
1	Off	≤ 15
2	Slow	≤ 70
3	Fast	≤ 150
4	Very Fast	≤ 255

The following table will show the membership range domains of LED brightness output.

Table 4 *LED Brightness Output Domain*

No.	Membership Function	PWM
1	Off	≤ 5
2	Dim	≤ 64
3	Bright	≤ 130
4	Very Bright	≤ 255

After determining the value of the membership function, then look for the membership representation. There are several representation functions that can be used, namely :

1. Trapezoidal Curve Representation

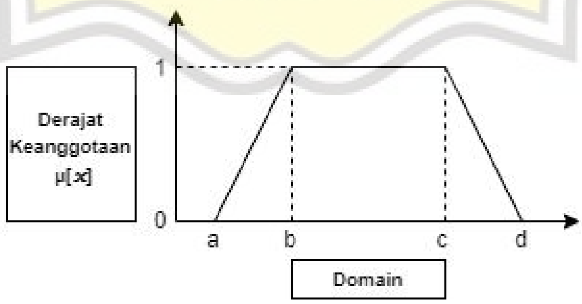


Figure 15 *Trapezoidal Curve Representation*

The following is the formula for the membership function of the trapezoid curve :

$$\mu[x]\begin{cases} 0\ ;\ x\ \leq\ a \text{ atau } x\ \geq \mathrm{d} \\ (x-a)/(\mathrm{b}-a)\ ;\ a \leq x \leq \mathrm{b} \\ 1\ ;\ \mathrm{b} \leq x \leq c \\ (\mathrm{d}-x)/(\mathrm{d}-c)\ ;\ c \leq x \leq \mathrm{d} \end{cases}$$

2. Triangle Curve Representation

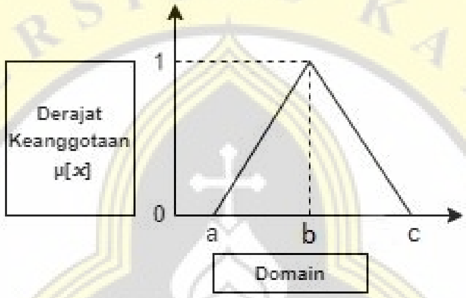


Figure 16 *Triangle Curve Representation*

The following is the formula for the membership function of the triangular curve :

$$\mu[x]\begin{cases} 0\ ;\ x \leq a \text{ atau } x \geq c \\ (x-a)/(\mathrm{b}-a)\ ;\ a \leq x \leq \mathrm{b} \\ (c-x)/(c-\mathrm{b})\ ;\ \mathrm{b} \leq x \leq c \end{cases}$$

5.2.2. Inference (Rules Fuzzy)

Inference is the process of making fuzzy rules. This formation is used to express the relationship between input variables and output variables.

After that, search for the min value from the results of the fuzzification of temperature and distance variables.

***Table 5** Rules Fuzzy*

Fuzzy Rules FAN Speed and LED Brightness		DISTANCE		
		Near	Medium	Far
TEMPERATURE	Cold	Off Off	Off Off	Off Off
	Warm	Slow Dim	Slow Dim	Fast Bright
	Hot	Fast Bright	Very Fast Very Bright	Very Fast Very Bright

5.2.3. Defuzzification

Defuzzification is a crisp output calculation which will then be implemented on Arduino Uno.

Here's the formula for calculating defuzzification :

Weighted Average (WA)

$$WA = \frac{\Sigma(nilai\ min * nilai\ output)}{\Sigma(nilai\ min)}$$

The following table shows the results of the comparison of the sensor algorithm with matlab and manual calculations using excel.

***Table 6** Comparison of Algorithms with Sensors and Manuals.*

NO	TEMPERATURE	DISTANCE	SENSOR		MATLAB		MANUAL	
			FAN	LED	FAN	LED	FAN	LED
1	32.71	13	113.36	99.77	113	99.8	113.4	99.8
2	36.62	1	150	130	150	130		
3	35.64	5	150	130	150	130		
4	35.64	180	255	255	255	255		
5	36.13	2	150	130	150	130		
6	34.67	43	194.01	185.8	194	186	194	185.8
7	32.23	5	105.68	93.44	106	93.4		
8	30.76	19	82.16	74.03	82.2	74		
9	27.34	71	55.56	44.99	55.6	45		
10	27.34	4	40.74	32.61	40.7	32.6		
11	31.37	18	91.92	82.08	91.9	82.1	91.92	82.08
12	28.13	3	49.43	41.93	49.4	41.9		
13	26.86	90	57.65	45.83	57.6	45.8		
14	29.79	31	65.74	59.43	65.7	59.4		
15	30.27	6	74.32	67.56	74.3	67.6		
16	30.27	41	82.92	76.53	82.9	76.5	83	77
17	32.23	104	196.83	185.75	197	186		
18	32.23	94	188.91	179.69	189	180		
19	27.12	52	39.51	31.3	39.5	31.3		
20	33.34	23	128.53	114.79	129	115		
21	32.71	125	206.91	197.75	207	198	206.91	197.75
22	32.71	24	121.55	109.73	122	110		
23	32.71	61	171.8	168.71	172	169		
24	31.64	27	113.42	104.79	113	105		
25	31.64	39	122.49	114.9	122	115		

5.3. Results

***Table** 7 TEST SCENARIO ALGORITHM ON LED*

SENSOR LM35	RIGHT ULTRASONIC	FUZZY SUGENO	LED	RESULT
32.71	13	99.77	DIM	TRUE
36.62	1	130	BRIGHT	TRUE
35.64	5	130	BRIGHT	TRUE
35.64	180	255	VERY BRIGHT	TRUE
36.13	2	130	BRIGHT	TRUE
34.67	43	185.8	BRIGHT	TRUE
32.23	5	93.44	DIM	TRUE
30.76	19	74.03	DIM	TRUE
27.34	71	44.99	OFF	TRUE
27.34	4	32.61	OFF	TRUE
31.37	18	82.08	DIM	TRUE
28.13	3	41.93	OFF	TRUE
26.86	90	45.83	OFF	TRUE
29.79	31	59.43	OFF	TRUE
30.27	6	67.56	DIM	TRUE
30.27	41	76.53	DIM	TRUE
32.23	104	185.75	BRIGHT	TRUE
32.23	94	179.69	BRIGHT	TRUE
27.12	52	31.3	OFF	TRUE
33.34	23	114.79	DIM	TRUE
32.71	125	197.75	BRIGHT	TRUE
32.71	24	109.73	DIM	TRUE
32.71	61	168.71	BRIGHT	TRUE
31.64	27	104.79	DIM	TRUE
31.64	39	114.9	DIM	TRUE

From the Algorithm test table for LEDs, it can be seen that the Fuzzy Sugeno algorithm can determine the speed and brightness of the LED from the data obtained by the LM35 sensor and Ultrasonic sensor. The trial results have a 100% precision ratio and 100% recall. So it has an average comparison of precision and recall that is weighted at 100%.

Here's the calculation :

Table 8 ***CALCULATION OF PRECISION, RECALL AND F1 SCORE ON TABLE 7***

Precission	= ((TP) / (TP + FP)) * 100 % = ((25) / (25 + 0)) * 100 % = ((25) / (25)) * 100 % = 1 * 100 % = 100 %
Recall	= ((TP) / (TP + FN)) * 100 % = ((25) / (25 + 0)) * 100 % = ((25) / (25)) * 100 % = 1 * 100 % = 100 %
F1 Score	= 2 * ((Recall + Precission) / (Recall + Precission)) = 2 * ((100 % * 100 %) / (100 % + 100 %)) = 2 * ((10000 %) / (200 %)) = 2 * 50 % = 100 %

- TP (True Positive) is predicted match and TRUE corresponds to 25.
- FP (False Positive) is predicted to match and turns out to be inappropriate (FALSE) is 0.
- FN (False Negative) is predicted to not match and turns out to be correct (FALSE) there are 0.
- PRECISSION is the ratio of positive correct predictions to the overall positive predicted data.
- RECALL is the ratio of true positive predictions to the total number of true positive data.
- F1 SCORE is a weighted comparison of the average precision and recall.

Table 9 *Watt Comparison Simulation using Algorithm without using Algorithm*

Experiment	Value	Time	Amount
Using Algorithm	Off (0 watt)	-	((64 x 12) + (64 x 11) + (64 x 9) + (64 x 53) + (64 x 12) + (130 x 44) + (130 x 21) + (130 x 34) + (130 x 70) + (130 x 4) + (130 x 30)) = 32,598 wattxsecond
	Dim (64 watt)	12 second 11 second 9 second 53 second 12 second	
	Bright (130 watt)	44 second 21 second 34 second 70 second 4 second 30 second	
	Very Bright (255 watt)	-	
Not Using Algorithm	Off (0 watt)	-	5 minute = 300 second 255 x 300 = 76,500 wattxsecond
	On (255 watt)	5 minute	

The table above is a simulation to find a comparison of the required wattage using an algorithm without using an algorithm within five minutes. From the table, it can be seen that using the algorithm can save electricity more because it consumes 32,598 wattsxsecond. Meanwhile, those who do not use the algorithm spend 76,500 wattsxsecond.

__Table 10__ TEST SCENARIO ULTRASONIC 1 ON SERVO

RIGHT ULTRASONIC	SERVO	RESULT
90	Not moving to the right	FALSE
4	Move to the right	TRUE
7	Move to the right	TRUE
14	Move to the right	TRUE
15	Not moving to the right	FALSE
18	Not moving to the right	FALSE
12	Not moving to the right	FALSE
1	Move to the right	TRUE
3	Move to the right	TRUE
10	Move to the right	TRUE
16	Move to the right	TRUE
21	Move to the right	TRUE
13	Move to the right	TRUE
12	Move to the right	TRUE
17	Move to the right	TRUE
49	Move to the right	TRUE
57	Not moving to the right	FALSE
3	Not moving to the right	FALSE
27	Not moving to the right	FALSE
29	Not moving to the right	FALSE
20	Move to the right	TRUE
77	Not moving to the right	FALSE
82	Not moving to the right	FALSE
65	Not moving to the right	FALSE
37	Move to the right	TRUE

The table above has a precision of 56% and recall of 100%, so the comparison of the average precision and recall that is weighted is 71.8% because there are still several failed attempts.

Here's the calculation :

Table 11 *CALCULATION OF PRECISION, RECALL AND F1 SCORE ON TABLE 10*

Precission	= ((TP) / (TP + FP)) * 100 % = ((14) / (14 + 11)) * 100 % = ((14) / (25)) * 100 % = 0.56 * 100 % = 56 %
Recall	= ((TP) / (TP + FN)) * 100 % = ((14) / (14 + 0)) * 100 % = ((14) / (14)) * 100 % = 1 * 100 % = 100 %
F1 Score	= 2 * ((Recall + Precission) / (Recall + Precission)) = 2 * ((100 % * 56 %) / (100 % + 56 %)) = 2 * ((5600 %) / (156 %)) = 2 * 35.9 % = 71.8 %

- TP (True Positive) is predicted match and TRUE corresponds to 14.
- FP (False Positive) is predicted to match and turns out to be inappropriate (FALSE) is 11.
- FN (False Negative) is predicted to not match and turns out to be correct (FALSE) there are 0.

__Table 12__ TEST SCENARIO ULTRASONIC 2 ON SERVO

LEFT ULTRASONIC	SERVO	RESULT
41	Move left	TRUE
1	Move left	TRUE
2	Move left	TRUE
9	Move left	TRUE
16	Move left	TRUE
5	Move left	TRUE
61	Don't move left	FALSE
12	Move left	TRUE
56	Don't move left	FALSE
20	Don't move left	FALSE
45	Move left	TRUE
43	Don't move left	FALSE
15	Move left	TRUE
7	Move left	TRUE
60	Don't move left	FALSE
17	Move left	TRUE
13	Move left	TRUE
52	Move left	TRUE
24	Move left	TRUE
7	Don't move left	FALSE
4	Move left	TRUE
18	Move left	TRUE
31	Move left	TRUE
38	Don't move left	FALSE
35	Don't move left	FALSE

The table above has a precision of 68% and recall of 100%, so the comparison of the average precision and recall that is weighted is 80.96% because there are still several failed attempts.

Here's the calculation :

***Table 13** CALCULATION OF PRECISION, RECALL AND F1 SCORE ON TABLE 12*

Precission	= ((TP) / (TP + FP)) * 100 % = ((17) / (17 + 8)) * 100 % = ((17) / (25)) * 100 % = 0.68 * 100 % = 68 %
Recall	= ((TP) / (TP + FN)) * 100 % = ((17) / (17 + 0)) * 100 % = ((17) / (17)) * 100 % = 1 * 100 % = 100 %
F1 Score	= 2 * ((Recall + Precission) / (Recall + Precission)) = 2 * ((100 % * 68 %) / (100 % + 68 %)) = 2 * ((6800 %) / (168 %)) = 2 * 40.48 % = 80.96 %

- TP (True Positive) is predicted match and TRUE corresponds to 17.
- FP (False Positive) is predicted to match and turns out to be inappropriate (FALSE) is 8.
- FN (False Negative) is predicted to not match and turns out to be correct (FALSE) there are 0.

From the two test tables of the right and left ultrasonic sensors on the servo, it can be seen that the servo has not been able to work properly. There were several failed attempts because the servo did not move to the right or left when there was an object in front of the right or left ultrasonic sensor.