

CHAPTER 5

IMPLEMENTATION AND TESTING

5.1. Implementation

In this chapter I will explain how my code works in this project. I use the eFFL library for the Fuzzification and Defuzzification process, I will explain this code process below.

```
1. //----- MOISTURE -----
2. int msensor = A1;
3. int msvalue = 8;
4. int led = 13;
5. boolean flag = false;
6. //----- DTH11 -----
7. #define DHT11_PIN 53
8. #include <dht.h>
9. dht DHT;
10. //----- BH1750 -----
11. #include <Wire.h>
12. #include <BH1750.h>
13. BH1750 lightMeter;
14. float lux;
15. //----- POMPA -----
16. int pin_pompa = 7;
17. float pompa;
18. //----- BLYNK -----
19. #define BLYNK_PRINT Serial
20. #include <ESP8266_Lib.h>
21. #include <BlynkSimpleShieldEsp8266.h>
22.
23. char auth[] = "wM1LbbGf3yTiKojdhOlsonMdfK1MHEE";
24. char ssid[] = "Eiskalteswasser ";
25. char pass[] = "Guten Morgen";
26.
27. #define EspSerial Serial3
28. #define ESP8266_BAUD 115200
29. ESP8266 wifi(&EspSerial);
```

Lines 1-14 serve to declare the three sensors that I use, namely soil moisture, temperature, and light intensity sensors. Lines 15-17 serve to declare the mini pump I'm using. Lines 18-29 serve to declare the Blynk Library, on lines 23-25 are lines where I fill in the authentication that has been given to my email, the name of the WiFi I use to connect my Arduino board, and my wifi password.

```

30. Fuzzy *fuzzy = new Fuzzy();           ----- INPUT -----
31. //-----
32. // INPUT MOISTURE
33. FuzzySet *kering      = new FuzzySet(0, 0, 0, 35);
34. FuzzySet *lembab     = new FuzzySet(25, 50, 50, 80);
35. FuzzySet *basah      = new FuzzySet(70, 100, 100, 100);
36.
37. //INPUT TEMP
38. FuzzySet *dingin    = new FuzzySet(0, 0, 0, 15);
39. FuzzySet *hangat    = new FuzzySet(12, 20, 20, 31);
40. FuzzySet *panas     = new FuzzySet(30, 40, 40, 40);
41.
42. //INPUT LUX
43. FuzzySet *gelap      = new FuzzySet(0, 0, 167, 300);
44. FuzzySet *redup      = new FuzzySet(170, 300, 360, 470);
45. FuzzySet *terang     = new FuzzySet(360, 475, 660, 660);
46.
47. //----- OUTPUT -----
48. // OUTPUT POMPA
49. FuzzySet *OFF        = new FuzzySet(0, 0, 0, 0);
50. FuzzySet *ON         = new FuzzySet(1, 1, 1, 1);

51. //INPUT MOISTURE
52. FuzzyInput *moisture = new FuzzyInput(1);
53.
54. moisture->addFuzzySet(kering);
55. moisture->addFuzzySet(lembab);
56. moisture->addFuzzySet(basah);
57.
58. fuzzy->addFuzzyInput(moisture);
59.
60.
61. //INPUT TEMP
62. FuzzyInput *temperature = new FuzzyInput(2);
63.
64. temperature->addFuzzySet(dingin);
65. temperature->addFuzzySet(hangat);
66. temperature->addFuzzySet(panas);
67.
68. fuzzy->addFuzzyInput(temperature);
69.
70.
71. //INPUT LUX
72. FuzzyInput *lux = new FuzzyInput(3);
73.
74. lux->addFuzzySet(gelap);
75. lux->addFuzzySet(redup);
76. lux->addFuzzySet(terang);
77.
78. fuzzy->addFuzzyInput(lux);
79.
80.
81. //OUTPUT POMPA
82. FuzzyOutput *pompa = new FuzzyOutput(1);

```

```

83.
84.     pompa->addFuzzySet(OFF) ;
85.     pompa->addFuzzySet(ON) ;
86.
87.     fuzzy->addFuzzyOutput(pompa) ;

```

Line 32-50 serves to declare numeric sets to linguistic sets as well as to declare what membership function is used. Line 51-87 serves to declare the linguistic sets that have been created and declare them into the input/output category.

```

88. //1=BASAH,DINGINELAP,OFF
89.     FuzzyRuleAntecedent *basah_dingin_1 = new FuzzyRuleAntecedent();
90.     basah_dingin_1->joinWithAND(basah, dingin);
91.
92.     FuzzyRuleAntecedent *a_gelap = new FuzzyRuleAntecedent();
93.     a_gelap->joinSingle(gelap);
94.
95.     FuzzyRuleAntecedent*basah_dingin_gelap_1 = new FuzzyRuleAntecedent();
96.     basah_dingin_gelap_1->joinWithAND(basah_dingin_1, a_gelap);
97.
98.     FuzzyRuleConsequent *OFF_1 = new FuzzyRuleConsequent();
99.     OFF_1->addOutput(OFF);
100.
101.    FuzzyRule*fuzzyRule1 = new FuzzyRule(1, basah_dingin_gelap_1, OFF_1);
102.    fuzzy->addFuzzyRule(fuzzyRule1);
103.
104.
105. //2=BASAH,DINGIN.REDUP, OFF
106.     FuzzyRuleAntecedent *basah_dingin_2 = new FuzzyRuleAntecedent();
107.     basah_dingin_2->joinWithAND(basah, dingin);
108.
109.     FuzzyRuleAntecedent *b_redup = new FuzzyRuleAntecedent();
110.     b_redup->joinSingle(redup);
111.
112.     FuzzyRuleAntecedent*basah_dingin_redup_2 = new FuzzyRuleAntecedent();
113.     basah_dingin_redup_2->joinWithAND(basah_dingin_2, b_redup);
114.
115.     FuzzyRuleConsequent *OFF_2 = new FuzzyRuleConsequent();
116.     OFF_2->addOutput(OFF);
117.
118.    FuzzyRule*fuzzyRule2 = new FuzzyRule(2, basah_dingin_redup_2, OFF_2);
119.    fuzzy->addFuzzyRule(fuzzyRule2);
120.

121. //3=BASAH,DINGIN.TERANG, OFF
122.     FuzzyRuleAntecedent *basah_dingin_3 = new FuzzyRuleAntecedent();
123.     basah_dingin_3->joinWithAND(basah, dingin);
124.
125.     FuzzyRuleAntecedent *c_terang = new FuzzyRuleAntecedent();
126.     c_terang->joinSingle(terang);
127.
128.     FuzzyRuleAntecedent*basah_dingin_terang_3 new FuzzyRuleAntecedent();

```

```

129. basah_dingin_terang_3->joinWithAND(basah_dingin_3, c_terang) ;
130.
131. FuzzyRuleConsequent *OFF_3 = new FuzzyRuleConsequent();
132. OFF_3->addOutput(OFF);
133.
134. FuzzyRule*fuzzyRule = new FuzzyRule(3, basah_dingin_terang_3, OFF_3);
135. fuzzy->addFuzzyRule(fuzzyRule3);
136.
137. // RULES 1-27
138.
139.
140. //27=KERING,PANAS,TERANG, ON
141. FuzzyRuleAntecedent *kering_panas_27 = new FuzzyRuleAntecedent();
142. kering_panas_27->joinWithAND(kering, panas);
143.
144. FuzzyRuleAntecedent*kering_panas_terang_27=newFuzzyRuleAntecedent();
145. kering_panas_terang_27->joinWithAND(kering_panas_27, c_terang);
146.
147. FuzzyRuleConsequent *ON_27 = new FuzzyRuleConsequent();
148. ON_27->addOutput(ON);
149.
150. FuzzyRule*fuzzyRule27=newFuzzyRule(27,kering_panas_terang_27,
151. ON_27);
151. fuzzy->addFuzzyRule(fuzzyRule27);

```

Line 88-151 is a fuzzy example of Fuzzy Rules, I didn't include all the rules because most of these rules are just lines that are repeated so I only take the most important part of these rules. Line 89 serves to create a new unique function in Rule 1 (basah_dingin_1), then line 90 serves to tell fuzzy that we want to combine (basah_dingin_1) into "AND". On line 92 I created the 3rd function (a_gelap), unlike the function above which I created specifically for Rule 1, I separated this function so that other rules can call this function for the next rule and because this library can only accept 2 fuzzy sets in 1 function. On line 95 I combine the two functions that I have created into 1 input function based on "AND". On line 98 I created another unique function for output(OFF_1) and on line 99 I ordered this function to be inputted into Fuzzy Set Output (OFF). On lines 101 and 102 I declare the input and output functions that I have created above (1, basah_dingin_gelap_1, OFF_1) as Fuzzy Rule number 1.

```

152. //-----SERIAL MONITOR-----
153.   Serial.print("Moisture    ");
154.   Serial.print(msvalue);
155.   Serial.print("Temperature ");
156.   Serial.println(DHT.temperature);
157.   Serial.print("Light      ");
158.   Serial.println(lux);
159.
160.
161. //-----Fuzzification-----
162.   fuzzy->setInput(1, msvalue);
163.   fuzzy->setInput(2, DHT.temperature);
164.   fuzzy->setInput(3, lux);
165.   fuzzy->fuzzify();
166.
167. //-----Defuzzification-----
168.   pompa = fuzzy->defuzzify(1);
169.
170.
171.
172.   if(pompa > 0)
173.   {
174.     Serial.print("Pompa: ON -- Output :  ");
175.     Serial.println(round(pompa));
176.     Serial.println("-----");
177.
178.     digitalWrite(7, LOW);
179.     delay(1000);
180.     digitalWrite(7, HIGH);
181.
182.     Blynk.notify("Pompa: Menyiram Tanaman . . .");
183.     delay(1000);
184.   }
185.
186.   else
187.   {
188.     Serial.print("Pompa: OFF -- Output :  ");
189.     Serial.println(round(pompa));
190.     Serial.println("-----");
191.     delay(1000);
192.   }

```

Line 152-158 is used to print sensors reading on the three sensors I use. Line 161-165 the process where fuzzification occurs, the program will retrieve the results of the sensor reading data that has been taken and fuzzyfy the data. After that on line 168 the defuzzification process occurs, I use the Sugeno method, the data from the Fuzzification results are taken and the data will be calculated using the Weight Average method and the defuzzification results will be obtained. Line 172-192 is the process of printing the result of Defuzzification which is then implemented on the pump. If the result is above 0 then the pump will turn on for 1 second, but if the result is 0 the

pump will not turn on, this process will be repeated repeatedly in the loop until the soil moisture does not need watering anymore

5.2. Testing

In this project I did 4 experiments, 1 experiment consisted of 5 different sensor variables, each of which I tried 3 times for a total of 60 trials. The purpose of this experiment is to find out how long the plants will be watered to reach a moisture level of 70% from several different sensor variables. I did this experiment on a device that I had made and I tried this experiment on a 45x25 cm pot. For the first day, the soil that I use contains fertile soil, husk charcoal, manure. For the second day, the soil that I use contains fertile soil, cockpit, compost, husks. I change the soil in the pot every few times according to the needs of the device. here are the results of my experiments:

| Day 1 | | | | | | | | |
|--------------|----------|-------------|-----|---------|-----------------|---------|---------|--------------|
| Experiment 1 | | Input | | | Output (Second) | | | |
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average | Moisture/1 % |
| 1.1 | 10-70 | 25 | 600 | 20,35 | 18,41 | 19,86 | 19,54 | 0,3257 |
| 1.2 | 20-70 | 25 | 600 | 12,79 | 36,28 | 6,37 | 18,48 | 0,3696 |
| 1.3 | 30-70 | 25 | 600 | 17,83 | 14,42 | 15,67 | 15,97 | 0,3993 |
| 1.4 | 40-70 | 25 | 600 | 13,34 | 17,46 | 13,45 | 14,75 | 0,4917 |
| 1.5 | 50-70 | 25 | 600 | 6,58 | 4,43 | 4,87 | 5,29 | 0,2647 |
| | | | | | | | | 0,3702 |

Table 5.1 Experiment 1

| Experiment 2 | | | | | | Output (Second) | | |
|--------------|----------|-------------|-----|---------|---------|-----------------|---------|--------------|
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average | Moisture/1 % |
| 2.1 | 10-70 | 25 | 320 | 13,42 | 16,71 | 15,46 | 15,20 | 0,2533 |
| 2.2 | 20-70 | 25 | 320 | 13,82 | 17,32 | 17,62 | 16,25 | 0,3251 |
| 2.3 | 30-70 | 25 | 320 | 16,81 | 10,17 | 9,62 | 12,2 | 0,3050 |
| 2.4 | 40-70 | 25 | 320 | 14,53 | 14,23 | 13,24 | 14 | 0,4667 |
| 2.5 | 50-70 | 25 | 320 | 6,01 | 6,73 | 6,42 | 6,39 | 0,3193 |
| | | | | | | | | 0,3339 |

Table 5.2 Experiment 2

| Day 2 | | | | | | | | |
|--------------|----------|-------------|-----|---------|-----------------|---------|---------|--------------|
| Experiment 3 | | Input | | | Output (Second) | | | |
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average | Moisture/1 % |
| 3.1 | 10-70 | 35 | 600 | 15,92 | 14,38 | 16,18 | 15,4933 | 0,2582 |
| 3.2 | 20-70 | 35 | 600 | 15,93 | 15,78 | 22,38 | 18,03 | 0,3606 |
| 3.3 | 30-70 | 35 | 600 | 16,06 | 6,85 | 15,25 | 12,72 | 0,3180 |
| 3.4 | 40-70 | 35 | 600 | 10,96 | 4,87 | 8,29 | 8,04 | 0,2680 |
| 3.5 | 50-70 | 35 | 600 | 8,96 | 4,87 | 9 | 7,61 | 0,3805 |
| | | | | | | | | 0,3171 |

Table 5.3 Experiment 3

| Experiment 4 | | | | | | | | |
|--------------|----------|-------------|-----|---------|-----------------|---------|---------|--------------|
| Experiment 4 | | Input | | | Output (Second) | | | |
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average | Moisture/1 % |
| 4.1 | 10-70 | 35 | 320 | 18,07 | 16,3 | 28,2 | 20,86 | 0,3476 |
| 4.2 | 20-70 | 35 | 320 | 13,68 | 13,77 | 20,07 | 15,84 | 0,3168 |
| 4.3 | 30-70 | 35 | 320 | 15,7 | 19,82 | 17,25 | 17,59 | 0,4398 |
| 4.4 | 40-70 | 35 | 320 | 9,37 | 8,81 | 11,12 | 9,77 | 0,3256 |
| 4.5 | 50-70 | 35 | 320 | 8,79 | 9,01 | 10,94 | 9,58 | 0,4790 |
| | | | | | | | | 0,3817 |

Table 5.4 Experiment 4

In the next experiment I will compare which watering method is better, using a small portion of watering, namely the pump will flush for 1 second and the sensor will read whether the soil still needs water or the large portion of the watering method, namely the pump will flush for 5 seconds and the sensor will read whether the soil still needs water need water.

| Small Portion | | | Pump | | |
|---------------|------------------|-----------------------|----------------------|----------------------------|-----------------------------------|
| Moisture (%) | Temperature (°C) | Light Intensity (Lux) | Watering Time (/1 s) | Last Moisture Readings (%) | Moisture increase rate per 1% (s) |
| 0 | 32 | 600 | 23,11 | 70% | 0,3301 |
| 0 | 32 | 600 | 23,65 | 70% | 0,3379 |
| 0 | 32 | 600 | 22,93 | 70% | 0,3276 |
| 55 | 31 | 600 | 8,77 | 70% | 0,5847 |
| 80 | 31 | 600 | 0 | 0% | 0 |
| 85 | 31 | 600 | 0 | 0% | 0 |
| 86 | 30 | 600 | 0 | 0% | 0 |
| 86 | 29 | 600 | 0 | 0% | 0 |
| 86 | 29 | 600 | 0 | 0% | 0 |
| 86 | 29 | 600 | 0 | 0% | 0 |

Table 5.5 Experiment 5

| Big Portion | | | Pump | | |
|--------------|------------------|-----------------------|----------------------|------------------------|-----------------------------------|
| Moisture (%) | Temperature (°C) | Light Intensity (Lux) | Watering Time (/5 s) | Last Moisture Readings | Moisture increase rate per 1% (s) |
| 0 | 32 | 600 | 25 | 75% | 0,3333 |
| 0 | 32 | 600 | 25 | 81% | 0,3086 |
| 0 | 32 | 600 | 25 | 81% | 0,3086 |
| 55 | 31 | 600 | 10 | 75% | 0,5000 |
| 80 | 31 | 600 | 0 | 0% | 0 |
| 85 | 31 | 600 | 0 | 0% | 0 |
| 86 | 30 | 600 | 0 | 0% | 0 |
| 86 | 29 | 600 | 0 | 0% | 0 |
| 86 | 29 | 600 | 0 | 0% | 0 |

Table 5.6 Experiment 6

The Influence of Planting Media

Soil Composition: Fertile soil, charcoal husks, manure

| Experiment 1 | | Input | | | Output (Second) | | |
|--------------|----------|-------------|-----|---------|--------------------|---------|--------------|
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average Time |
| 1.1 | 10-70 | 25 | 600 | 20,35 | 18,41 | 19,86 | 19,54 |
| 1.2 | 20-70 | 25 | 600 | 15,46 | 17,83 | 17,47 | 16,92 |
| 1.3 | 30-70 | 25 | 600 | 17,83 | 14,42 | 15,67 | 15,97 |
| 1.4 | 40-70 | 25 | 600 | 13,34 | 17,46 | 13,45 | 14,75 |
| 1.5 | 50-70 | 25 | 600 | 6,58 | 4,43 | 4,87 | 5,29 |

Table 5.7

Experiment 7

Soil Composition: Fertile soil, cockpit, compost

| Experiment 2 | | Input | | | Output (Second) | | |
|--------------|----------|-------------|-----|---------|--------------------|---------|--------------|
| No. | Moisture | Temperature | Lux | Trial 1 | Trial 2 | Trial 3 | Average Time |
| 1.1 | 10-70 | 25 | 600 | 16,84 | 17,45 | 14,17 | 16,15 |
| 1.2 | 20-70 | 25 | 600 | 14,72 | 15,92 | 13,26 | 14,63 |
| 1.3 | 30-70 | 25 | 600 | 14,55 | 13,45 | 12,25 | 13,42 |
| 1.4 | 40-70 | 25 | 600 | 10,05 | 12,44 | 13,75 | 12,08 |
| 1.5 | 50-70 | 25 | 600 | 5,71 | 5,35 | 4,78 | 5,28 |

Table 5.8 Experiment 8