Design of Automatic Watergate System Using ESP32 Microcontroller Based on Fuzzy Logic Method

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***Abstract*— Automatic watergate systems are designed to allow the watergate to run automatically based on an ideal condition for agricultural land. The sensor will be a crucial role in this automation system. In this system, the input of the system is come from ultrasonic and moisture sensor, while the output is how big watergate will be open. The ultrasonic sensor is widely used in the design of watergate system because they provide effectively measuring a water level. And also, soil moisture sensor was used to measure the percentage of humidity of the land. In order to process this input, we used a fuzzy logic to determined the output, which is the percentage of watergate will be open. By using Fuzzy logic, the machine can do an output based on conditions in the input that has been programmed. In this research, a Fuzzy Logic Control method system will be implemented to control the watergate so it's can be opened level to level. Authors exert three levels of watergate open, that are 0%, 50%, and 100%. The input in this study is the water level and the humidity of land. Simulations have been carried out to get the value of the membership function. The simulation is carried out using a case study, where the input from the ultrasonic sensor is 6 cm and 88% on soil moist sensor.**

Keywords*— *automatic watergate, ultrasonic sensor, microcontroller, fuzzy logic.

I. Introduction

Based on data from The World Bank in 2013, around 2.5 billion people from 86% of rural areas around the world still depend on agricultural production as a source of income. Agricultural land cannot be separated from the irrigation system. Irrigation itself is an activity related to obtaining irrigation to support agricultural activities such as rice fields, rice fields, or plantations. An agricultural irrigation system is an effort made by farmers to maintain consistency of air on agricultural land [1].

This water management is intended to meet water demand evenly in every land. However, the management of water gates on agricultural land cannot be managed properly so that water use on agricultural land is often not suitable with the needs of the land [2][3].

There has been some research on automatic sluices. In 2017, Faisal et al. conducted research using Arduino Uno and motor driver controllers. In this study, a water level sensor (tide and drainage) was used as input which was then processed by the Arduino Uno microcontroller. Then the incoming output comes from the DC motor to open the sluice or pump, depending on the arduino uno instructions. From this research, the researcher tries to make an automatic sluice gate design on a smaller scale with an economical budget compared to previous studies [4].

Meanwhile, Hajjaj et al. in 2020 also researched on automatic floodgates with the internet of things scheme using the Raspberry Pi as a microprocessor [4]. This automatic floodgate was developed with a real-time centralized pattern which is also supported by the publication of visualized data to the cloud network. So that monitoring can be done by the user anytime and anywhere. Antother research has been done with using the MQTT protocol for message brokers to avoid stacking orders [5][6][7].

The important point is that this design is embedded with fuzzy logic. With fuzzy logic, we can adjust the membership function based on more complex conditions to make it more flexible [8][9][10][11]. The fuzzy logic-based controller is a kind of control method belonging to artificial intelligence [12][13]. So that the watergate can be open half or even only a quarter of the opening depending on the needs in the fields.

In this paper, the author tries to represent the design of an automatic sluice gate that is driven by a wireless design. The author uses the radio module as a communication protocol to transmit data from the sensor to the master microcontroller that controls the dc motor to open the floodgates. The method of communication with a radio module can be an alternative to using the internet in places where signals are still difficult to reach, such as in remote areas. In addition, the authors try to use waterproof hardware with high measurement quality so that it has an impact on the quality of measurement data and the performance of this design [8].

The paper is organized as follows. Section 1 gives a general introduction, while Section 2 described the design and implementation. In Section 3 describes the results. Finally, Section 4 presents the conclusion and future works.

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II. DESIGN AND IMPLEMENTATION

A. Block Diagram System

The first step in this research is the design of this automatic floodgate. We made made 2D modeling of the design in order to make it easier to imitate before assembling the hardware and carry out the implementation. The overall model of this design can be seen in Fig. 1.

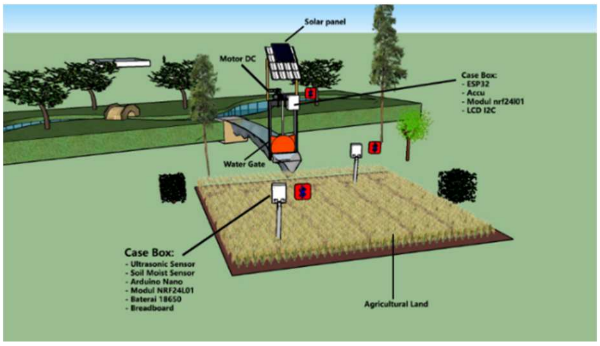

Fig. 1. The design of our proposed system.

The predicament in this paper is how to make a water gate design that runs automatically based on the needs of agricultural land. In this case, the input from the ultrasonic sensor and the soil moisture sensor combined with the mamdani fuzzy logic method. The early phase of designing a tool is indispensable an initial explanation of how the framework works from the device. This control framework employment the near circle concept. The block diagram of this research is embodied in Fig. 2.

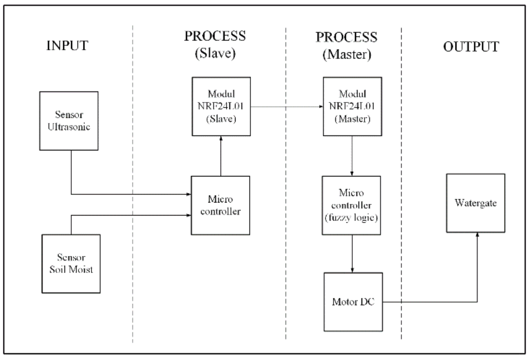

Fig. 2. Block Diagram System.

B. Hardware Design

The material in this design uses metal as a floodgate in order to be able to withstand the water flow that hits it well, with a width and height of 30cm. In Figure 3. You can see the floodgate design in 2D format. The floodgate design built by the author has been connected to a microcontroller which is located in the case box and is driven by using a dc motor and the help of a mechanical chain. So that the floodgates can run automatically.

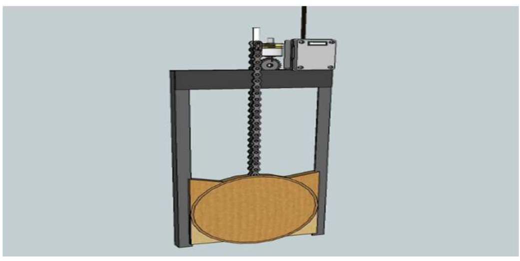

Fig. 3. Design of proposed watergate system.

In Fig. 4 and Fig. 5. Explained the working principle of the ultrasonic sensor and soil moisture sensor used in this engineering design. These two sensors are used to obtain input data for this design.

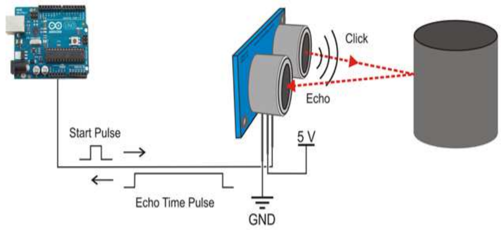

Fig. 4. The working primciple of ultrasonic sensor.

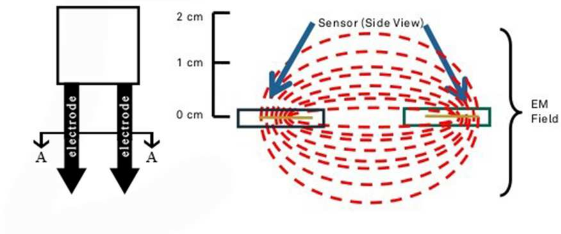

Fig. 5. The working primciple of soil moisture sensor.

C. Fuzzy Model Design

In this study, the mamdani fuzzy logic method is used in decision making, this is expected to help improve water management compared to the traditional sluice system. Fig. 6. Represent the block diagram of fuzzy logic in this research. linguistic term of input

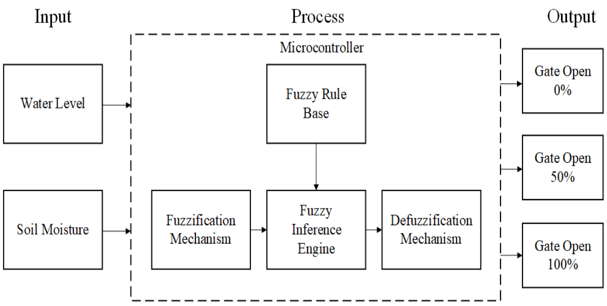

Fig. 6. Fuzzy logic model

In this plan, there are 2 input factors and 1 yield variable. The input variable consists of the ultrasonic sensor in the form of distance in cm and also from the soil moisture sensor in the form of the humidity value in percent. The Table of input variables in linguistic terms can be seen in Table I and Table II.

TABLE I. LINGUISTIC TERM OF INPUT FROM ULTRASONIC SENSOR.

Linguistic Term	Sensor Value (cm)
Low	[0 0 2 2.5]
Normal	[2 2.5 5 6]
High	[5 6 7 7]

TABLE II. LINGUISTIC TERM OF INPUT FROM SOIL MOISTURE SENSOR.

Linguistic Term	Sensor Value (%)
Dry	[0 0 60 70]
Normal	[60 70 80 85]
Wet	[80 85 100 100]

The input variable of the ultrasonic sensor is formed into three-member groups, namely low, sufficient, and high, which can be seen in Fig. 7. For the member set, a trapezoidal curve is used. The second input variable from the soil moisture sensor is formed into three-member groups, namely dry, moderate, and wet, which can be seen in Fig. 8. The trapezoidal curve for the member set.

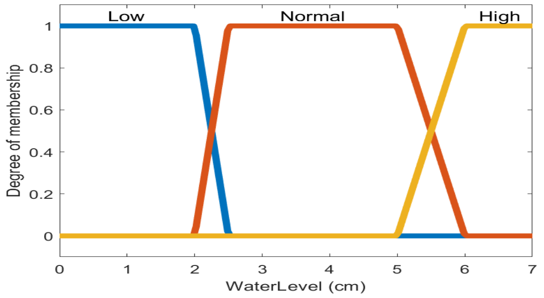

Fig.7. MF imput of ultrasonic sensor

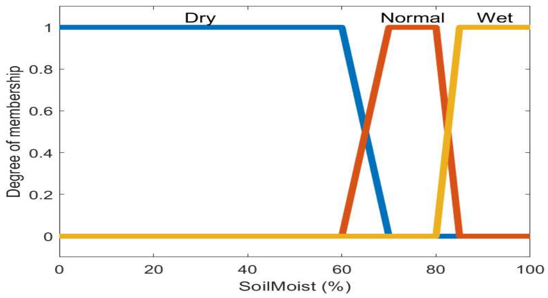

Fig. 8. MF input of soil moisture sensor

The membership function of output has shown in Fig. 6 and 7, using trapezoidal shapes. The mathematical equations of this membership function can be seen in Table III and IV. Table IV.

TABLE III. EQUATION TERM OF MF ULTRASONIC SENSOR.

Linguistic Term	µ of Ultrasonic Sensor
Low	$\mu_{re} = \begin{cases} 1, & x \le 2 \\ \frac{2{,}5 - x}{0{,}5}, & 2 \le x \le 2{,}5 \\ 0, & x \ge 2{,}5 \end{cases}$
Normal	$\mu_{cu} = \begin{cases} \frac{x-2}{0{,}5}, & 2 \le x \le 2{,}5 \\ 1, & 2{,}5 \le x \le 5 \\ \frac{6-x}{1}, & 5 \le x \le 6 \end{cases}$
High	$\mu_{ja} = \begin{cases} \frac{x-5}{1}, & 5 \le x \le 6 \\ 1, & 6 \le x \le 7 \\ 0, & x \ge 7 \end{cases}$

TABLE IV. EQUATION TERM OF MF SOIL MOIST SENSOR

Linguistic Term	µ of Soil Moist Sensor
Dry	$\mu_{ke} = \begin{cases} 1, & x \le 50 \\ \frac{70 - x}{10}, & 60 \le x \le 70 \\ 0, & x > 70 \end{cases}$
Normal	$\mu_{cuk} = \begin{cases} \frac{x-60}{10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 80 \\ \frac{85-x}{5}, & 80 \le x \le 85 \end{cases}$
Wet	$\mu_{ba} = \begin{cases} \frac{x-80}{1}, & 80 \le x \le 85 \\ 1, & 85 \le x \le 100 \\ 0, & x \ge 100 \end{cases}$

TABLE V. LINGUISTIC TERM OF OUTPUT FROM WATERGATE

Linguistic Term	Watergate Value
Open 0%	[0 0 40 50]
Open 50%	[40 50 60 70]
Open 100%	[60 70 100 100]

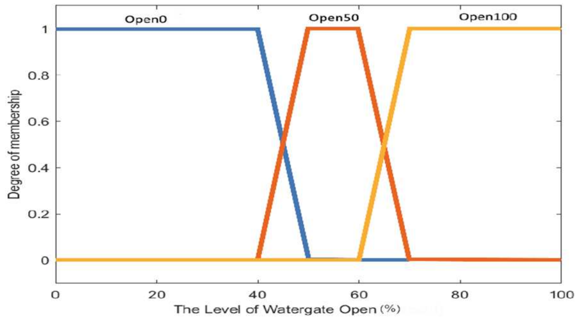

Fig. 9. MF output of the level of opening watergate

Of these 2 input variables, it will be an indicator for 1 output variable, namely the floodgate that will open in a percentage of 0%, 50%, or 100%. The fuzzy logic used in this study is Mamdani inference where it is configured with Multiple Input Single Output (MiSo). Could be seen in Fig. 9.

TABLE VI. EQUATION TERM OF MF SOIL MOIST SENSOR

µ of Watergate
$\mu_{op0} = \begin{cases} 1, & x \le 20 \\ \frac{40 - x}{10}, & 20 \le x \le 40 \\ 0, & x \ge 41 \end{cases}$
$\mu_{op50} = \begin{cases} \frac{x-40}{10}, & 40 \le x \le 50 \\ 1, & 50 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \end{cases}$
$\mu_{op100} = \begin{cases} \frac{x-60}{10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 100 \end{cases}$

TABLE VII. FUZZY LOGIC RULES

No	Variable		
	Input		Output
	Water Level	Soil Moist	Water Gate
1	Low	Dry	Open 100%
2	High	Wet	Open 0%
3	Normal	Normal	Open 0%
4	Low	Normal	Open 50%
5	Low	Wet	Open 50%
6	Normal	Dry	Open 50%
7	Normal	Wet	Open 0%
8	High	Dry	Open 50%
9	High	Normal	Open 0%

D. Implementation

Watergate's material is made of alumunium metal with 2 cm of thickness. The measurements or estimate of the planned watergate's circuit is 50 cm × 100 cm. Fig. 10 appears the shape of the programmed watergate outlined.

Fig. 10. Implementation of watergate system.

III. Result and Analysis

These following are the test results of the measured voltage controller. The emergence of the input voltage and yield stress is shown in Table VI.

TABLE VIII. HARDWARE TESTING

Components	Exemplary Voltage (Volt)	Experiment Voltage (Volt)
NodeMCU ESP32	2.3 - 3.6 Volt	3.3 Volt
Ultrasonic Sensor HC-SR04	5 Volt	5 Volt
Capacitive Soil Moist	3.3 - 5.5 Volt	3.3 Volt
Arduino Nano	7-12 Volt	12.2 Volt
Modul NRF24L01 (with adapter)	3.3 Volt	3.3 Volt

Table VIII appears the comes about of the stretch test, specifically that the stack gotten a normal of 12.2 V since the voltage given by the battery is 12.2 V. Some the components require a step up or step down trafo to make it run optimally.

TABLE IX. ULTRASONIC SENSOR TEST

Measurement (cm)		Difference error (cm)	Difference error (%)
HC-SR04	*Ruler*		
3	3.8	0.8	0.26667
8	8.3	0.3	0.0375
16	17	1	0.0625
30	33	3	0.1

Ultrasonic sensor assessment with a comparison between the sensor and a ruler. In Table IX. The test used 4 sample cases with a distance of 3 cm and, 8 cm, 16 cm, and 30 cm. The biggest difference is in the distance of 3 cm around 0.26667%. Because the sensor runs better when the object it's not too close and not too far from the sensor. Analyze from the result test of ultrasonic sensor, its really depending on objects around the track of the sensor area. So it's crucial to making sure that the line of sight from the sensor is clear.

TABLE X. SOIL MOIST SENSOR TEST

Measurement	
Actual Data	Result Prediction
350	352
380	377
477	479
430	429
389	390

In this paper, the condition set for soil moist sensor is ≥ 85 is wet, $65 - 80$ is normal, and ≤ 75 is dry. While the data from sensor using values from 100 – 900 to describe the humidity level. So, the value was scaled to 1-100 (percent) to get easier when reading the data. The result prediction was obtained from doing defuzzification of calculation result from the above step then, calculating prediction result that result shown in Table XI.

TABLE XI. MODUL NRF24L01 TEST

Distance (m)	Packages Received (s) (With Obstacle)	Packages Received (s) (Without Obstacle)
2	0.34	0.37
10	1.3	0.49
50	3.21	0.82
80	3.61	0.94
100	3.66	0.95

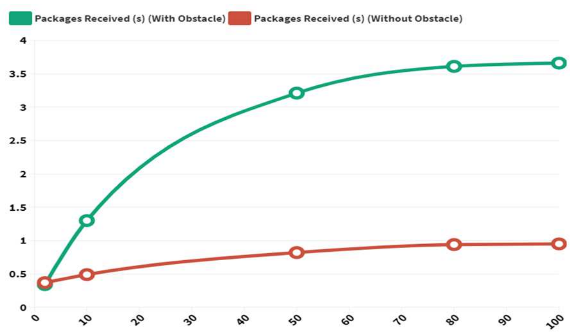

Fig. 11. Graphic of comparison package transmission

In this test section, a simulation is carried out in the Mathlab application and compares with manual calculations to see the suitability of the Fuzzy control system that has been created. And also, a case was taken where the ultrasonic sensor proffer input of 2 cm with the humidity is 82% from sensor soil moisture. These are the following results of the tests that have been carried out.

Step 1. Determine the fuzzy set

Ultrasonic Sensor HC-SR04

In order to determine the fuzzy set, we must first determine the degrees of membership of the represented membership function. Fig. 2 shows the front side sensor distance of 2 cm with input conditions, then the value of 24 cm is inserted into the HIGH fuzzy set, resulting in Table III based on formulae.:

$$\mu_{ti}[6] = \frac{6-5}{0.5} = 0.5 \quad (1)$$

$$\mu_{ti}[6] = \frac{6-0}{1} = 6 \quad (2)$$

This demonstrates that the LOW fuzzy set has a membership degree of 1 on the front side sensor with a distance of 2 cm, while NORMAL has a membership degree of 0.5.

Soil Moisture Sensor

With the input condition from soil moisture sensor of 88% can be seen In Fig. 3, the value of 88% belongs to the NORMAL fuzzy set and WET fuzzy set, so that based on equation Table 4 obtained:

$$\mu_{cuk}[88] = \frac{85-88}{5} = 0.6 \quad (3)$$

$$\mu_{ba}[88] = \frac{88-80}{5} = 1.6 \quad (4)$$

Step 2. The function implication

Because the fuzzy rule base is an AND function, the implication function employed in this process is the MIN function. The MIN function returns the minimum membership degree from the input value. Based on the illustrated rule base Table 5 shows that just four rules provide value in this case: [R2], [R3], [R4], and [R5].

[R2] : IF ultrasonic sensor is High **And** soil moist sensor is Normal **Then** Watergate is open 50% :

$$\alpha_{R1} = \mu_{ti} \cap \mu_{cuk}$$
$$\alpha_{R1} = \min(\mu_{ti}, \mu_{cuk})$$
$$\alpha_{R1} = \min(0.5, 0.6) = 0.3 \quad (5)$$

[R3] : IF ultrasonic sensor is High **And** soil moist sensor is Wet **Then** Watergate is open 50% :

$$\alpha_{R2} = \mu_{ti} \cap \mu_{ba}$$
$$\alpha_{R2} = \min(\mu_{ti}, \mu_{ba})$$
$$\alpha_{R2} = \min(0.5, 1.6) = 0.8 \quad (6)$$

[R4] : IF ultrasonic sensor is High **And** soil moist sensor is Normal **Then** Watergate is open 0% :

$$\alpha_{R2} = \mu_{ti} \cap \mu_{cuk}$$
$$\alpha_{R2} = \min(\mu_{ti}, \mu_{cuk})$$
$$\alpha_{R2} = \min(6, 0.6) = 3.6 \quad (7)$$

[R5] : IF ultrasonic sensor is High **And** soil moist sensor is Wet **Then** Watergate is open 0% :

$$\alpha_{R2} = \mu_{ti} \cap \mu_{ba}$$
$$\alpha_{R2} = \min(\mu_{ti}, \mu_{ba})$$
$$\alpha_{R2} = \min(6, 1.6) = 9.6 \quad (8)$$

Step 3. Defuzzification

Defuzzification is the process of converting the fuzzy set membership degrees into a definite choice or real value. The center of gravity technique is a widespread and useful defuzzification technique. In the most typical procedure, all of these trapezoids are layered one on top of the other to make a single geometric shape. The fuzzy centroid is then determined as the centroid of this form. Fig. 12 is a diagram.

The *x* coordinate of the centroid is the defuzzified value, called Z^*. So, the output of this fuzzy logic:

$$Z = \frac{\int_0^{35} 0.4z\,dz + \int_{35}^{36}\left(\frac{40}{10}-\frac{1}{10}z\right)z\,dz + \int_{44}^{64} 0.4z\,dz + \int_{64}^{70}\left(\frac{70}{10}-\frac{1}{10}z\right)z\,dz}{(0.45)+(17.5)+(17.6)+(1.2)}$$

$$Z^* = \frac{796.2}{36.75} = 21.66530612 \quad (9)$$

The results of a fuzzy model in a system constructed on a watergate system utilizing ultrasonic sensor HC-SR04 and capacitive soil moist based on fuzzy logic control are displayed in simulation Fig. 13 and Fig. 14 as well. Display the performance of the input to the output using fuzzy rules.

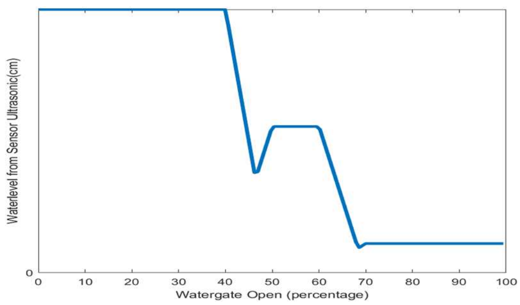

Fig. 13. Ultrasonic sensor graph against watergate opened

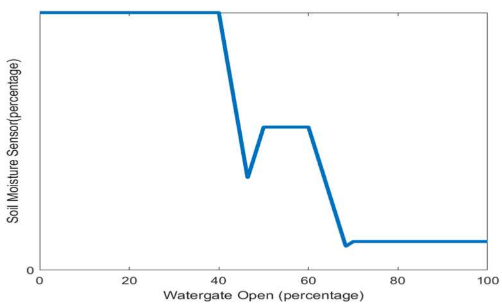

Fig. 14. Soil moist sensor graph against watergate opened

IV. Conclusion

In this study, the performance of the watergate that controlled by motor dc power window to open automatically based on the ideal condition. This watergate works controlled using a motor dc power window as giving orders for the watergate to opened by level to level. In designing the system, the Matlab application is used to design rules that will be applied to the watergate. For example, when the ultrasonic sensor gets an input of 6 cm and 88% on the soil moist sensor, the watergate will open for 100%. The results of the calculation produce a watergate output of 21.66530612. With the results of this manual calculation it can be seen that the system is running well.

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