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Drip Irrigation Control System based on Mamdani Fuzzy Logic and Internet of Things (IoT)

Abstract. Irrigation System is an alternative way of irrigating rainfed land in the dry season. Selecting Irrigation methods depends on factors such as water availability, type of soil and its topography, and plant type. On the other hand, there are a lot of remote controls nowadays developing using the concept of IoT (Internet Of Things). IoT tries to expand human interdependence, for example, interaction, contribution, and collaboration on something. Based on the description, an automatic drip irrigation system based on Arduino is proposed using the concepts of fuzzy logic and IoT. The application of remote control for automatic drip irrigation systems on chili plants is to use an android application where there is frame monitoring and control. The application can monitor sensor parameters and can control the solenoid valve anywhere and anytime. Testing data transmission throughout the system where the data transmission has an average time is 3.9 seconds and the success rate in sending the data was appropriate in 10 trials.

*Streszczene. System nawadniania to alternatywny sposób nawadniania gruntów zasilanych deszczem w porze suchej. Wybór metody nawadniania zależy od takich czynników, jak dostępność wody, rodzaj gleby i jej topografia oraz rodzaj roślin. Z drugiej strony, obecnie istnieje wiele pilotów rozwijających się w oparciu o koncepcję IoT (Internet Of Things). Internet rzeczy próbuje rozszerzyć współzależność między ludźmi, na przykład interakcję, wkład i współpracę nad czymś. Na podstawie opisu zaproponowano automatyczny system nawadniania kropelkowego oparty na Arduino wykorzystujący koncepcje logiki rozmytej i IoT. Zastosowanie zdalnego sterowania do automatycznych systemów nawadniania kropelkowego roślin chili polega na wykorzystaniu aplikacji na Androida, która umożliwia monitorowanie i sterowanie ramą. Aplikacja może monitorować parametry czujnika i sterować elektrozaworem w dowolnym miejscu i czasie. Testowanie transmisji danych w całym systemie, gdzie średni czas transmisji danych wynosi 3,9 sekundy, a skuteczność przesyłania danych była odpowiednia w 10 próbach. (**System kontroli nawadniania kroplowego oparty na Mamdani Fuzzy Logic i Internecie rzeczy (IoT)**)*

Introduction

Indonesia has quite extensive agricultural resources, as well as a water system (irrigation) that is capable enough to irrigate rice fields. The irrigation system is an alternative way of irrigation of rainfed land in the dry season. There are several types of irrigation systems, namely surface irrigation, sub-surface irrigation, bulk irrigation, and drip irrigation. The choice of irrigation method depends on the availability of water and soil type, land topography, and plant types. At this time, drip irrigation is the best solution because the use of water can be controlled. For drip irrigation, water is distributed through a tank containing water at a higher position than the crop to be irrigated, then from the tank, the water flows through an irrigation hose to the plants. In drip irrigation, water control is needed to prevent water shortages or excesses [1-4].

Several studies for drip irrigation have been done before. One of them is drip irrigation using an Arduino Microcontroller-Based ON/OFF Control System Based on the Temperature and Humidity of The Soil used to grow plants. Another one is Drip Irrigation Research Using Fuzzy Logic Control Based on Temperature and Soil Moisture. All supported systems have communication lines that allow the system to be monitored, controlled, and scheduled via short messages. This system can quickly and accurately calculate the amount of plant water demand so that the system can provide control over water use savings[510] .

On the other hand, the remote control is currently developing a lot using the IoT concept. The concept is that it connects all devices to the internet and allows IoT devices to communicate with each other via the internet. By doing so, each device will learn from the experiences gained from other devices, just like humans. IoT tries to expand human interdependence, for example, interaction, contribution, and collaboration on something .Based on the description above, Automatic Drip Irrigation System is proposed using Arduino and the concept of Fuzzy Logic and IoT. The Fuzzy method used in this study uses the Mamdani Fuzzy Inference System (FIS). This system uses input from soil moisture and temperature sensors that have been placed around the land where the crops are planted to regulate the ignition of the valve as a water distribution. Water is from a tank that has been filled. This system can also be controlled remotely using an Android application that has been designed in such a way via the Internet based on IoT[11-22].

SKU: SEN0193 Soil Moisture Sensor

The soil moisture sensor used is SKU: SEN0193 which is capacitive to prevent corrosion of the sensor material. The sensor works at a voltage of 3.3 – 5.5 V DC and a current of 5 mA. The sensor produces an analog output of 0 – 3 V DC. The sensor can be applied to a plant medium such as soil and can be used continuously because there is no corrosion on the sensor material [2]. Figure 1 below shows the mechanical design of the sensor.

Fig 1. SKU: SEN0193 Soil Moisture Sensor [14]

The sensor works by measuring the water content in the soil. The sensor probe consists of several soil moisture sensors. A neutron moisture meter takes advantage of the moderating properties of water for neutrons. Soil moisture content can be determined through its effect on the dielectric constant by measuring two electrodes embedded in the soil, where most of the soil moisture is in the form of free water. For example, in sandy soil, it is directly proportional to the water content. The probe usually gives a frequency excitation to allow measurement of the dielectric constant. The reading from the probe is not linear with moisture content and is affected by soil type and soil temperature [14].

DS18B20 Temperature Sensor

Chemical sensors detect the amount of a chemical substance by converting the quantities into electrical quantities, usually involving some chemical reaction. Examples of chemical sensors are PH sensors and gas sensors. Temperature sensor DS18B20 serves to change the amount of heat captured into the amount of voltage. The type of temperature sensor used in this system is IC DS18B20 with high precision. This sensor is very simple with only a 3-pin. The First Pin is connected to the power source, the second to the output or data, and another connected to the ground.

The sensor works by converting temperature quantities into voltage quantities. The ideal voltage that comes out has a ratio of 100 equivalent to 1 volt. This sensor has self-heating of less than 0.1, can be operated using a single power supply, and can be connected to the control circuit interface very easily [15]

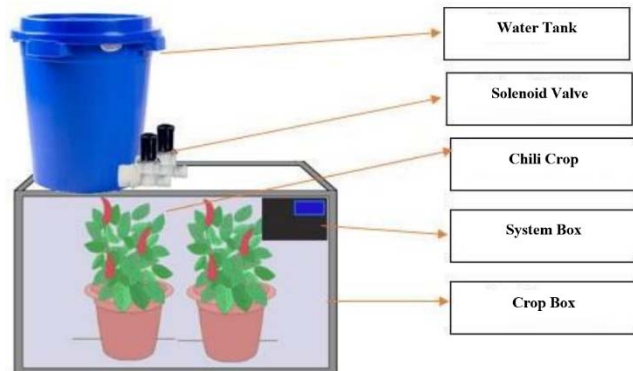
Fig 2. DS18B20 Temperature Sensor [15]

Fig 3. Mechanical Design

Mamdani Fuzzy Inference System (FIS)

The Mamdani Fuzzy Method is very useful for drawing the best formula or decision in an unpredicted situation. This method is using linguistic rules and stored fuzzy algorithms that can be analyzed mathematically so that it is easier to understand [6].

The decision-making process using the Fuzzy Mamdani Method is through some stages, namely the fuzzy sets preparation, implication benefit application, rules composition, and defuzzification. The advantage of the method is specifically more listening to what will be produced in every fuzzy environment, so it will result in more accurate statements.

Meanwhile, the method is compatible if the input is received from the human. The disadvantage of the method is it can only be used in the quantitative information composition, not in qualitative information.

Research Method
Mechanical Design

Figure 3 above shows the mechanical design of the system. It consists of Water Tank, Solenoid Valve, System Box, and Box for Crop. There are two crops for the research

sample. The System Box is applied as the container for the overall electrical system. Figure 4 below shows the system running flow.
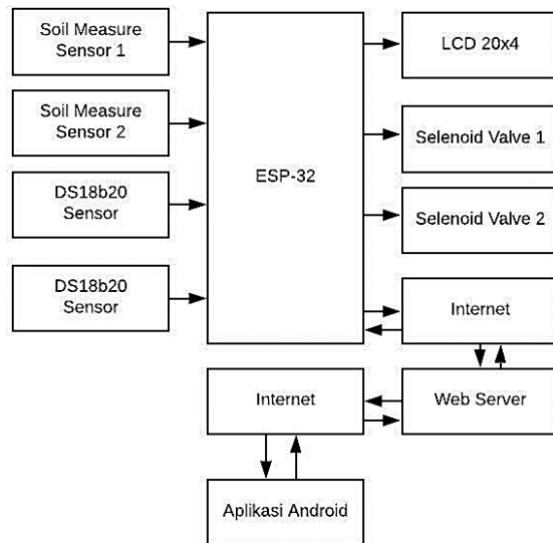

Fig 4. System Running Flow
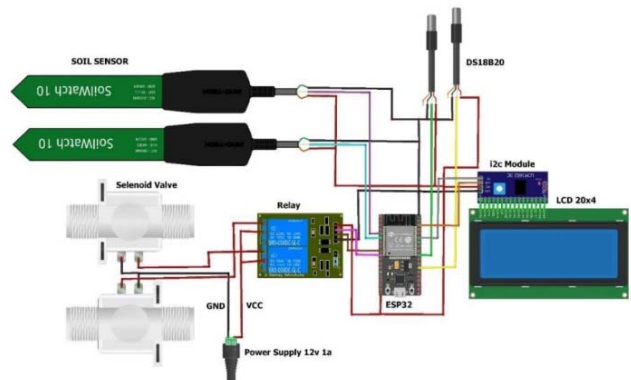
Electrical Design

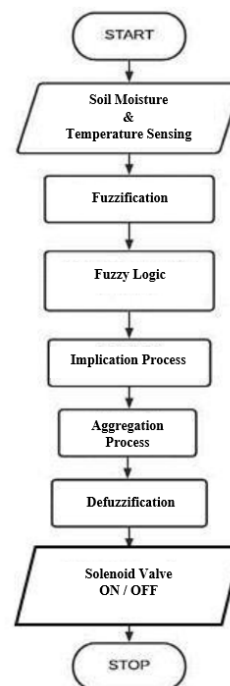
Fig 4. System Components Wiring

Fig 6. System Program Flowchart

Figure 5 above shows the electrical wiring of the system's components. The input of the system consists of DS18B20 and two Soil Moisture Sensors. The output of the system is an LCD to display the status data and two valves to execute the command according to the program. The electrical wiring is supplied by Power Supply 12V [23] .

Software Design

Figure 6 above shows the flowchart of the Program System Flowchart. The program applied Mamdani Fuzzy System as a decision-making algorithm. It starts with Fuzzification or Membership Function and is followed by Fuzzy Rules for the system. It ended with defuzzification for Solenoid Valve commands.
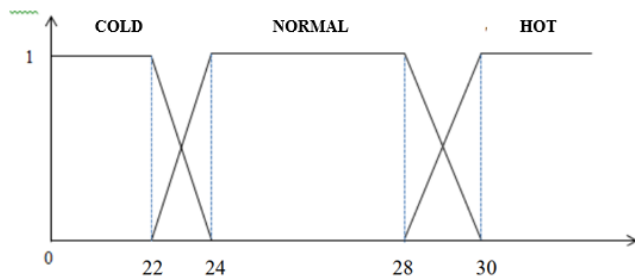
Temperature's Membership Function

Fig 7. Temperature's Fuzzy Membership Function

$$\mu H\ cold[x] = \begin{cases} 1 & x \leq 22 \\ \dfrac{24 - x}{2} & 22 \leq x \leq 24 \\ 0 & x \geq 24 \end{cases}$$

$$\mu\ normal[x] = \begin{cases} 0 & x \leq 22\ or\ x \geq 30 \\ \dfrac{x - 22}{2} & 22 \leq x \leq 24 \\ \dfrac{30 - x}{2} & 28 \leq x \leq 30 \\ 1 & 22 \leq x \leq 30 \end{cases}$$

$$\mu H\ warm[x] = \begin{cases} 1 & x \leq 28 \\ \dfrac{x - 28}{2} & 28 \leq x \leq 30 \\ 0 & x \geq 30 \end{cases}$$
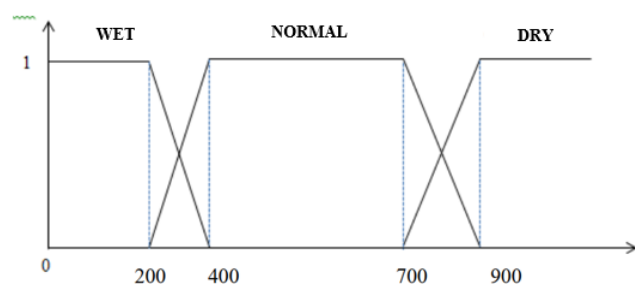
Humidity's Membership Function

Fig 8. Humidity's Fuzzy Membership Function

$$\mu\ wet[x] = \begin{cases} 1 & x \leq 200 \\ \dfrac{400 - x}{200} & 200 \leq x \leq 400 \\ 0 & x \geq 400 \end{cases}$$

$$\mu\ normal[x] = \begin{cases} 0 & x \leq 200\ or\ x \geq 900 \\ \dfrac{x - 200}{200} & 200 \leq x \leq 400 \\ \dfrac{900 - x}{200} & 700 \leq x \leq 900 \\ 1 & 400 \leq x \leq 700 \end{cases}$$

$$\mu\ dry[x] = \begin{cases} 1 & x \leq 700 \\ \dfrac{x - 700}{200} & 700 \leq x \leq 900 \\ 0 & x \geq 900 \end{cases}$$

Valve Command Membership Function
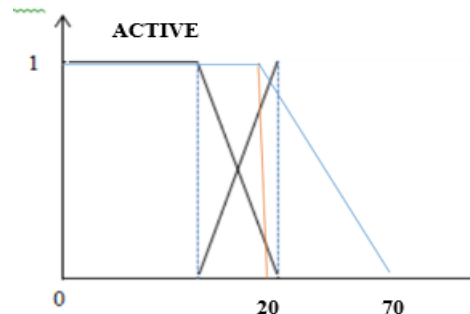
Fig 9. Valve Command's Fuzzy Membership Function

$$\mu\ active[x] = \begin{cases} 1 & x \leq 20 \\ 0 & x \geq 70 \end{cases}$$

Fuzzy Rule Base

Table 1. System's Fuzzy Rule Base

Temperature	Humidity	Valve Command
Cold	Wet	Non-Active
Cold	Normal	Non-Active
Cold	Dry	Active
Normal	Wet	Non-Active
Normal	Normal	Non-Active
Normal	Dry	Active
Hot	Wet	Non-Active
Hot	Normal	Active
Hot	Dry	Active

Result and Discussions

Fig 10. The Drip Irrigation System

Fig 11. System's Controller

DS18B20 Test Result

The sensor test is applied to determine the performance. The thermometer is used as the comparison for the sensor output results. Table 2 below shows the sensor test results.

Table 2. Temperature Sensor Test Results in Degrees Celsius

Test	Sensor	Thermometer	Difference
1	28	28	0
2	28	28	0
3	28	28	0
4	29	28	1
5	28	28	0
6	28	28	0
7	29	28	1
8	28	28	0
9	28	28	0
10	28	28	0

Soil Moisture Sensors Test Result

The sensor test is applied to determine the performance. Soil Moisture Detector is used as the comparison for the sensor output results and to determine the accuracy of sensors. Table 3 and Table 4 show the sensor's test results.

Table 3. Humidity Sensor 1 Test Result in RH%

Test	Sensor	Moisture Detector	Difference
1	93	86	6
2	89	76	13
3	89	74	15
4	80	73	7
5	73	65	8
6	60	52	8
7	53	44	9
8	49	35	14
9	38	24	14
10	23	21	2

Table 4. Humidity Sensor 2 Test Result in RH%

Test	Sensor	Moisture Detector	Difference
1	83	86	3
2	79	76	3
3	79	74	5
4	70	73	3
5	63	65	2
6	50	52	2
7	43	44	1
8	39	35	4
9	28	24	4
10	13	21	8

Overall System Test Result

Table 5. Overall System's Test Monitoring and Result

Test	Start Time (Minutes)	Finish Time (Minute)	Crop 1 Temperature ($°C$)	Crop 2 Temperature ($°C$)	Crop 1 Humidity (RH%)	Crop 2 Humidity (RH%)
1	0	5	28	28	74	73
2	5	10	28	28	74	73
3	10	15	28	28	74	73
4	15	20	28	28	74	73
5	20	25	28	28	74	73
6	25	30	28	28	74	73
7	30	35	27	27	62	61
8	35	40	27	27	62	60
9	40	45	27	27	62	59
10	45	50	27	27	62	59

Table 5 above shows the overall system test monitoring test and result for each Crop in the box. Each Crop 1 and Crop 2 has the same temperature value but a slight difference in humidity. Figure 12 and Figure 13 below show the result of monitoring in Android devices, while the following Table 6 shows the valve control monitoring status

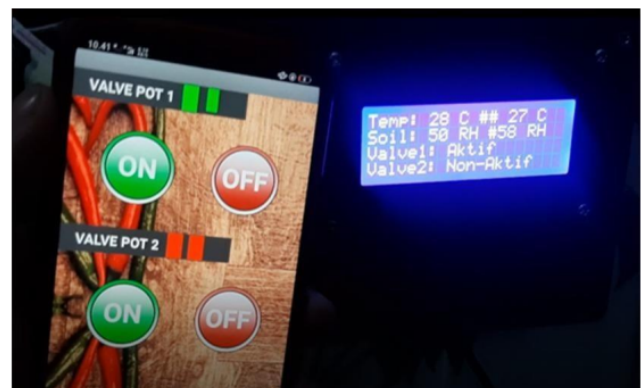Fig 12. System Monitoring Display for each Crop

Fig 13. Valve Control Monitoring Button

Table 6. Valve Control Status for Each Button

Test	Android Button	Solenoid Valve	Status
1	Valve 1 (ON)	Valve 1 Active	Match
2	Valve 1 (OFF)	Valve 1 Non-Active	Match
3	Valve 2 (ON)	Valve 2 Active	Match
4	Valve 2 (OFF)	Valve 2 Non-Active	Match

Conclusions

From the overall test, an Automatic drip irrigation system based on soil moisture level and plant temperature can be carried out using the fuzzy Mamdani method, where this method can determine when the solenoid valve is active or

non-active. However, it is limited that if the temperature level is too hot and the soil moisture level is classified as dry, the valve is active to water the crop with drip irrigation

The application of remote control for an automatic drip irrigation system on the crop is to use an android where there is a monitoring and control frame. The designed software can monitor sensor parameters and control valves freely.

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