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Abstract: The temperature and humidity of a plant are the main parameters that affect the amount of water it needs. The design of a control system that has non-linear inputs and with difficult transfer function equations requires a control system capable of making control decisions. This is because the control decisions issued by human logic have perfect control output in everything, both conventional and unconventional. Fuzzy Logic is a method of control system that can provide decisions that resemble human decisions. In this plant design process, the fuzzy logic control system development system is used by using the MCS51 microcontroller system in the DT51 Development Tools. This is intended for a design of water control plants in plants. This fuzzy control process is carried out by a microcontroller system with an additional interface which is an Analog Input Output add-on board for DT51, an LCD interface as a time display output, a temperature sensor and a soil moisture sensor as a fuzzy logic control input. From the results of experiments conducted, it shows that the fuzzy logic control system is easier to make the control system and more flexible in making its design by not requiring mathematical equations for the function of transfer over the plant, because the fuzzy system makes decisions from human logic placed on the knowledge base system fuzzy.

Index Terms: Fuzzy Logic, Water Plant, Control, Temperature sensor, humidity sensor, D51, microcontroller.

1. INTRODUCTION

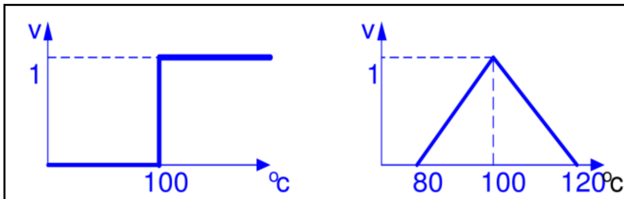
Watering plants is a job that is usually done every day, both for private plants at home, plants that exist in city parks and along sidewalks and plants that are made for cultivation. Watering these plants is one of the monotonous and routine work and usually this work is done manually by paying employees to do watering at certain times. This manual work usually experiences various problems when the work is done. One of the most serious problems is the problem of water quantity. How much water is needed by a plant that is treated so that the water used is not too much wasted, so that it becomes a Mubadzir. If this monitoring is not carried out, it can happen that the treated plants may experience excess or lack of water, resulting in plant death. Such monitoring cannot be completed with an ordinary control system, because the normal control system is regulated only when the water pump is started without taking into account the condition of the previous plant. Though the work faced can be more complex than that. The problem will be even more complex if the plant being treated is a plant that requires more specific treatment. For plants that need more intensive care, not everyone can do it, except for only those who have special expertise. Thus a special control system will be needed. In this case a fuzzy logic-based method will be applied which has 2 main parameters, namely air temperature [1], [2] and soil moisture. It is expected that this method can regulate the flow of water needed by the plant. Information base knowledge must come from an expert in the field of plants.

2 FUZZY LOGIC BASIC

Basic fuzzy theory [3] discusses the basic concepts of fuzzy sets, which include discussion of fuzzy sets, logical operations on fuzzy and laws on fuzzy sets.

2.1 Basic Concepts of Fuzzy Association

In classical set theory (Crisp) a variable has only two possibilities, being a member of a set or not being a member of a set. In this crisp set theory the boundaries between members and non-members are very clear. The temperature for water that is considered hot water is a temperature of 100ºC. If a water is heated to a temperature of 110ºc it means that the water is a member of hot water. Meanwhile, if the water is only 90ºc temperature means that the water is not a member of hot water or not hot water. In this case the classic set (crips) only has 2 possibilities that occur, namely the water is called hot if the temperature is equal to 100ºc or more and is called not hot water if the temperature is less than 100ºc. So that if the water temperature is only 99.9ºC then it is still not part of the hot water member. In the fuzzy set [4], [5] there are differences with the classical set. Fuzzy set [6]–[8] is an extension of classical set, so that in fuzzy set can have several possibilities, not just 2 possibilities as in classical set. The temperature for hot water is "around" 100ºc, so if a water is heated to reach 90ºc can be said to be a member of hot water, even water that is only 80ºc can be said to be a member of hot water temperature. If so to what extent is the "ambient" temperature for hot water members can be categorized as the temperature of hot water ?. Likewise, the moisture of a soil.



(a) Crips Association. (b) Fuzzy Association.

***Fig. 1**. Graph of membership functions of the Crips and Fuzzy set.*

For this problem the fuzzy set [9]–[13] distinguishes the temperature of the hot water member by using its membership value, ie from the membership value of "0" to the membership value of "1". The value or degree of membership can be expressed as a membership function. The membership function within the crips set (Figure 2.a) and the fuzzy set membership function (Figure 2.b) [11], [14], [15] can be described as follows. The set in fuzzy logic uses 3 parameters to form a membership in the set. The parameters used to form the fuzzy logic set are:

a. Linguistic variables Variables used in fuzzy logic to replace quantitative variables used in crisp logic. Linguistic variables have values expressed in words, for example for linguistic variables 'air temperature' will have values in the form of linguistic values such as: Heat (P), Very Hot (SP), Somewhat Hot (AP) and No Heat (TP).

b. Degree of membership Degree of membership, i.e. values contained in linguistic variables mapped to intervals [0,1]. This mapping value is referred to as membership value or degree of membership.

c. Membership function. Mapping relationships on linguistic values and membership values (from 0 to 1) are drawn into the function graph so that a function is obtained. This function is called a membership function in the fuzzy set.

3 FUZZY BASIC STRUCTURE OF THE SYSTEM

In the basic structure of a control system in fuzzy logic control, there are four main components or parts that are very important. Figure 3 shows the basic structure of the fuzzy logic control controller, which consists of Fuzzification, Knowledge Base, Inference and Defuzzification.

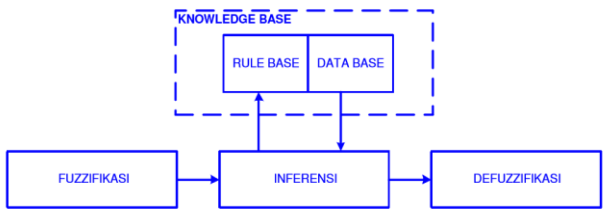


Fig. 2. *Basic Structure of Fuzzy Logic Control Controller.*

3.1 Knowledge Base

Knowledge base has an important function in controlling fuzzy logic because all processes: fuzzification, inference and defuzzification work based on the knowledge that is in the knowledge base. Knowledge base is divided into two, namely the data base and the rule base. The Data Base contains important definitions of fuzzy parameters such as fuzzy sets with membership functions that have been defined for each existing linguistic variable. The establishment of a data base includes defining the universe, determining the number of linguistic values used for each linguistic variable, and forming a membership function. The rule base contains fuzzy control rules that are run to achieve control objectives. Each control rule in the form of implications and conditional statements IF - THEN. The existing IF - THEN rules are grouped and arranged in the form of Fuzzy Associative Memory (FAM). This FAM is a matrix that states the input-output in accordance with IF-THEN rules on the basis of existing rules. The matrix form of the FAM will be discussed later. The rules that have been made must be able to overcome all input combinations that may occur, and must be able to produce the appropriate control signal so that control objectives are achieved. Therefore, the formation of this rule base is very important.

3.2 Inference Inference

Inference Inference is the process of transformation from an input in the fuzzy domain to an output (control signal) in the fuzzy domain [16]–[18]. The transformation process in the inference section requires fuzzy rules contained in the rule base. The inference block uses reasoning techniques to select the rule bases and rules from the knowledge base block. The reasoning technique used is the MAX-MIN reasoning technique which functions as a decision-making logic. Figure 3 shows the inference process with the MAX-MIN reasoning method using air temperature input and soil moisture input. The initial step in the MAX-MIN reasoning process is the reading of the values entered from the sensor, namely: the air temperature sensor and the soil humidity sensor as well as the placement of these inputs on the membership chart for the air temperature sensor (X0 = temperature sensor) and the soil humidity sensor membership chart (Y0 = sensor humidity). The next step after obtaining the results of the placement of values X0 and Y0, the selection process is carried out by taking the minimum value from the input graphs X0 and Y0. After obtaining the results of the minimum value selection, MAX-MIN reasoning selects back by taking the maximum value to get the final result in the form of inference output in the fuzzy domain.

- X 0 = Input air temperature (input 1).
- Y 0 = Input of soil moisture (input 2).
- μA = Air temperature membership function.

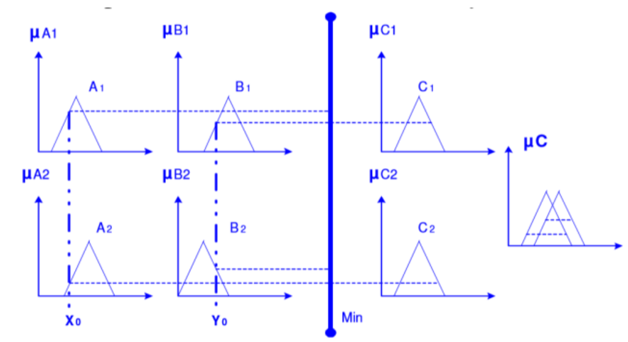


Fig. 3. *Inference Process with the MaxMin method..*

- μB = Moisture membership function.
- μC = Timer membership function.
- A = linguistic value of air temperature (input 1).
- B = linguistic value of humidity (input 2).
- C = timer (output) linguistic value.

4 SYSTEM DESIGN & ANALYSIS

Will be discussed about the design and manufacture of plant water control systems analysis based on fuzzy logic control systems and devices outside of the fuzzy system that are used as an additional circuit in the simulation and design of plant water control systems. The discussion is divided into several sections, namely: Designing a fuzzy logic control system that will explain the creation of the fuzzy membership function for air temperature and soil moisture sensors in fuzzification, the creation of rules and FAM at the knowledge base, and the creation of a fuzzy membership function for defuzzification as the output of the fuzzy logic control system. Discussion of microcontroller [19], sensors, LCDs, electronic switches and pumps as outputs from the system, and discussion of additional circuits for testing of water plant simulation systems on these plants. Block diagram of the watering system in plants based on fuzzy logic control can be seen in the following figure 4.

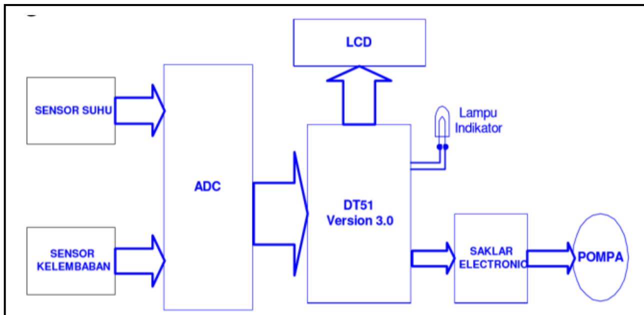


Fig. 4*. Block diagram of an automatic watering system.*

a. Fuzzy Logic Control system design Fuzzy logic control has four main parts in making the basic structure of a fuzzy control system, namely: Fuzzification, Knowledge Base, Inference and Defuzzification.

• Fuzzification In this plant water control system there are two input inputs that will be fuzzified to the fuzzy set and become a fuzzy membership function. Figures 9 and 10 below are fuzzification of the input inputs released by the air temperature and soil humidity sensor circuit. Five linguistic values for the temperature sensor output are chosen: Cold (D), Cool (S), Normal (N), Warm (H) and Hot (P) as shown in Figure 6.

- Cold = 10 0C - 25 0C. - Cool = 20 0C - 30 0C. - Normal = 25 0C - 35 0C. - Warm = 30 0C - 40 0C. - Heat = 35 0C - 50 0C.

- Dry = 0% - 40%. - Normal = 25% - 75% - Wet = 60% - 100%. As for the output from the soil moisture sensor using three linguistic values to define the state of the soil in plants, namely Dry (K), Normal (N) and Wet (B).

• Knowledge Base For automatic watering systems on these plants, use several rules that are likely to occur in the plants to be controlled. In making this rule or statement, it actually has no limits in numbers, the more rules are made the more precise and detailed the working tools are designed. Table 4.1 below is the statement rules on the automatic watering system using a 15 system rule fuzzy logic control.

Rule-statement statements are grouped into a matrix called Fuzzy Associative Memory (FAM). This Fuzzy Associative Memory matrix has a size of n x m, with n = the number of air temperature input membership and m = the number of soil moisture input membership. The shape of the Fuzzy Associative Memory (FAM) matrix.

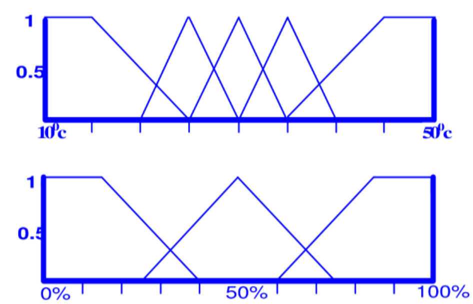


Fig. 5*. The membership function of the temperature sensor and humidity sensor.*

The division of the two parameters is arranged as follows: - C = Fast. - SB = Wait a minute. - AS = A little while. - SD = Medium. - ALM = Somewhat decent. - LM = Not bad. - L = Long time.

• Inference Furthermore, the Fuzzy Associative Memory matrix of the rules of the statement above is used as a knowledge base or knowledge base for the process in the inference block. In this inference block, MAX-MIN reasoning is used to get the output in the fuzzy domain. The results of the process of inference using MAX-MIN reasoning can be seen in the attachment sheet.

• Defuzzification In this defuzzification process there is also a graph of the membership function to determine the limits of the desired fuzzy output. Seven linguistic values are chosen to determine the condition of the timer as shown in Figure 6.

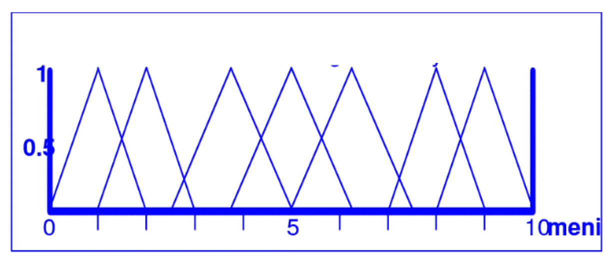


Fig. 6*. FAM plant watering system and fuzzy (time) output membership function.*

5 SENSOR

In addition to using the Analog Digital Converter (ADC) as a tool to convert analog quantities to digital quantities, simulating a watering system on this plant also requires a series of

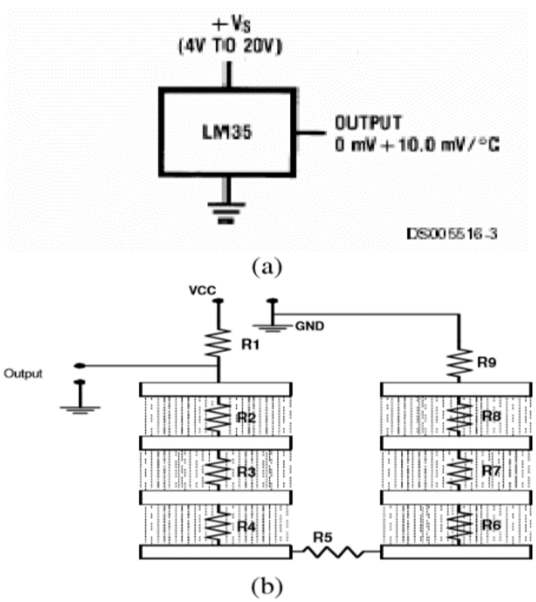


***Fig. 6**. a) LM35 Temperature Sensor and b) Schematic of the soil humidity sensor circuit.*

sensors that function to detect and determine the conditions that occur in plants that will control, both for the condition of the soil and the temperature conditions of the plant. For this simulation two sensors are used to detect it, namely the air temperature sensor and the soil moisture sensor. Figure 8a shows the main components of the temperature sensor (LM35). LM35DZ temperature sensor has a temperature range between 0-100 degrees Celsius with an increase of 10 mV for each degree Celsius, for example: at 0 degrees Celsius the voltage is 0 mV while at a temperature of 30 degrees Celsius the voltage is 30 mV or 0.3 V. For the sensor soil moisture uses several resistor components which are arranged and connected in such a way as to form an electronic circuit that can detect moisture in the soil. Figure 7 above shows a circuit scheme of soil moisture sensors.

6 CONCLUSION

From the test results and analysis of the application of the fuzzy logic controller in the Park water control system, several conclusions can be obtained as follows. For the application of the fuzzy logic control system does not require a mathematical model and optimum non-linear control because the decisions issued only use human logic. Linguistic variables, membership degrees and membership functions are the forming parameters for the fuzzy logic set members. The steps to create a fuzzy logic control system consist of: fuzzification, knowledge base, inference and defuzzification. Knowledge base is compiled based on the experience of an expert operator in their field. For a specific and precise watering system in accordance with the characteristics of the plant to be watered, requires more diverse input sensors.

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