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Using fuzzy proportional integral derivative for fig greenhouses on the Internet of Things

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ABSTRACT

The majority of people in the agricultural nation of Indonesia are farmers. Indonesia has created a variety of planting medium, including the use of greenhouses. For plant growers, greenhouses are one of the most promising planting medium because they may be able to address the problems caused by severe climate change. Technologies like automated watering systems, air temperature control, air humidity, and soil moisture make it simple to regulate the condition of a greenhouse. By using fuzzy proportional integral derivative (FPID) as artificial intelligence on the Internet of things (IoT) for greenhouses, this study focuses on figs. To ensure that the figs in the greenhouse are constantly in the best possible circumstances, the Tsukamoto technique is used to monitor the soil and air conditions. It is then combined with proportional integral derivative (PID) control to regulate the soil moisture, air temperature, and air humidity. The growth of figs in a greenhouse may be maximized by FPID on IoT as the soil and air conditions can be kept at optimal levels.

INTRODUCTION

The majority of people in the agricultural nation of Indonesia are farmers. A tropical temperature, large tracts of land, and fertile nature all encourage unrestricted cultivation. However, the agricultural sector's output has been severely deficient recently because of changes in harsh weather conditions that prevent plants from growing to their full potential. The agricultural sector is one of the most important for sustaining the national economy, but increasing productivity there will also have extraordinary benefits for public welfare, food sovereignty, and food production, as well as for building a nation that can produce the most food globally.

Cultivating uncommon fruits with potential commercial value, like figs, is one of the community's current economic strengthening initiatives. The hamlet of Karang Tempel, East Semarang, is home to the Semarang area's figs village. There, fig plants have been grown for four to five years. Figs are a fruit rich in oil, protein, and carbs. Because figs contain alkaline compounds that the body requires, they may be utilized for health purposes in addition to being a food source. Its active ingredient is similar to a cleaner that may be applied to exterior wounds [1].

Since figs are not native to Indonesia, a variety of planting medium have been created there to boost their output. One such method is the use of greenhouses, which take into account factors like humidity, temperature, sunshine, and water requirements. Issues that come up include

Since the treatment of figs in the greenhouse is still regulated traditionally, the temperature is unpredictable and the watering of plants, which sometimes receives less attention, all have an impact on the development of the plants.

According to the above description, this study will employ fuzzy proportional integral derivative (FPID) as artificial intelligence on the Internet of Things (IoT) to develop a control and monitoring system for fig plants in greenhouses [2]–[4]. The fuzzy Tsukamoto approach is used to monitor soil and air conditions. It is then combined with proportional integral derivative (PID) control to regulate soil moisture, air temperature, and air humidity, ensuring that the figs in the greenhouse are constantly in the best possible circumstances. The growth of figs in a greenhouse may be maximized by FPID on IoT as the soil and air conditions can be kept at optimal levels.

1. RESEARCH METHOD

1.1. Internet of things

IoT is a very promising technological development to optimize life based on smart sensors and smart equipment that works together through the internet network [5], [6]. Using computers in the future is able to dominate human work and defeat human computing capabilities such as controlling electronic equipment remotely using internet media, IoT allows users to manage and optimize electronics and electrical equipment that uses the internet. We can utilize the IoT system for monitoring and control of the greenhouse environment [5], [7]–[10]. This speculates that in the near future communication between computers and electronic equipment is able to exchange information between them thereby reducing human interaction. This will also increase the number of internet users with various internet facilities and services [6], [11]. Design of IoT system on greenhouse shown in Figure 1.

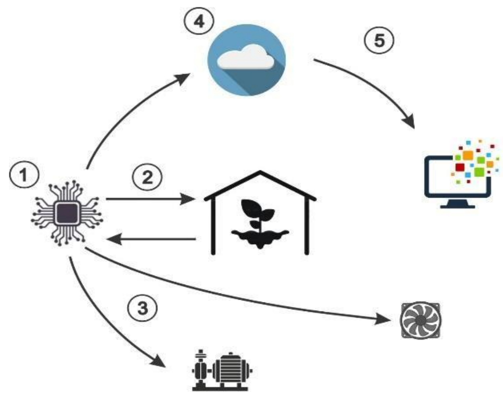


Figure 1. Design of IoT system on greenhouse

Description:

- Microcontroller has input and output, for input using DHT11 sensor and soil moisture sensor, both sensors are in greenhouse.
- From two sensors get data which is then sent to the microcontroller to be processed.
- After data is processed, data becomes the value of the output status determinant, the first output in the water pump to meet water needs and the second output is an air controller that serves to neutralize temperature and humidity of greenhouse.
- Data that has been processed in the microcontroller is also sent to the adafruit.io server in order to monitor the state of air temperature, humidity, and soil conditions in greenhouse.
- After sending to adafruit.io server, the server will display data on users using the website.

1.2. Cloud computing

A simple understanding of cloud computing is computing happens on the internet. The internet is generally visualized as cloud, so the term “cloud computing” for computing is processed through the Internet. Users can access database resources via internet from anywhere, as long as they need. In addition, databases in the cloud are very dynamic and can be scaled. cloud systems to enable data-based services and overcome the challenges of complexity and resource demands for online, offline data processing, storage, and analysis [10]–[13]. The best example of cloud computing is Google Apps where any application can be accessed

using a browser and can be used on thousands of computers via internet [14]. Concept of cloud computing shown in Figure 2.

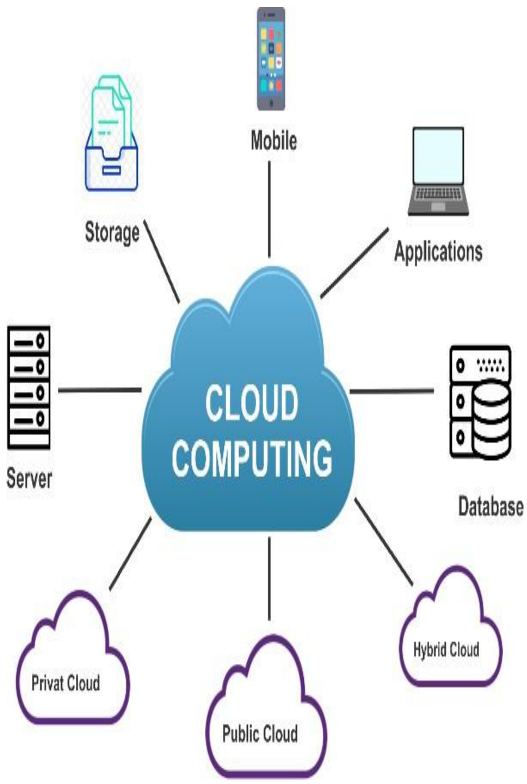


Figure 2. Concept of cloud computing

1.3. MQTT protocol

The message queuing telemetry transport (MQTT) protocol is a simple, lightweight publish/subscribe communication protocol designed for devices with limited capabilities. MQTT has the ability to be able to support an IoT device. MQTT in principle has an information exchange center between subscriber and publisher namely MQTT broker. Publisher is sending data such as sensors while the subscriber is sending data such as humans [6], [12]. Concept of MQTT shown in Figure 3.

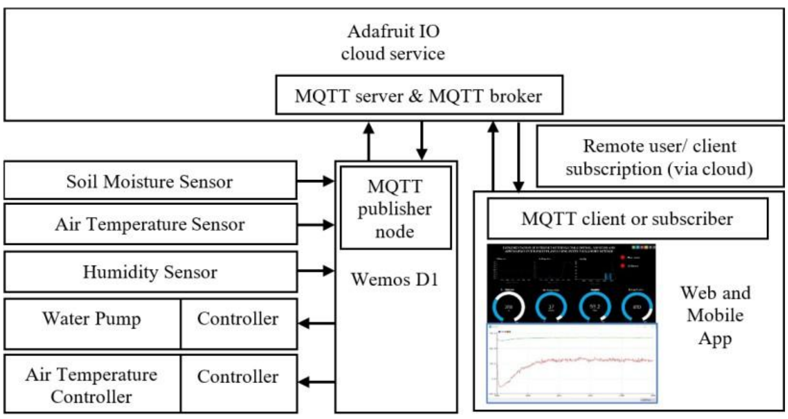


Figure 3. MQTT concept

There are MQTT Clients and MQTT brokers or can also be called MQTT servers. When the MQTT client wants to broadcast or publish some information to the MQTT broker, the client needs to make a connection with the MQTT broker. The client asks the broker to connect, then the broker sends a connection request notification to the client after a connection is made between the client and the MQTT broker. Clients can send or publish information to brokers [15], [16]. The MQTT protocol is divided into several features namely:

a. Publish and subscribe provide one to many messaging.
b. Has three levels of qualities of service (QoS): “At most once”, messages will be sent using the best TCP/IP network. Message missing or duplication is likely to occur “at least once”, the message will be delivered even though duplication can occur. “Exactly once”, the message can arrive exactly once.
c. Uses TCP/IP connections for basic connections.

1.4. Fuzzy Tsukamoto

Fuzzy logic is a branch of computer science that studies the value of truth that has a lot of value [6], [17]. It is different from the truth value in classical logic which is 0 (false) or 1 (true). Fuzzy logic has a real truth value in the interval [0,1]. Fuzzy logic was first developed by Lotfi A. Zadeh, an Iranian American scientist from the University of California at Berkeley. However, fuzzy logic was more developed by Japanese practitioners. Design of triangle curve shown in Figure 4.

In the fuzzy Tsukamoto method, each consequence of IF-THEN rules must be presented with a fuzzy set with a monotonous membership function. Tsukamoto's fuzzy logic was chosen because it gives an output of sharp individual rules [18]–[20]. As a result, the output of the inference results from each rule is given explicitly (crisp) based on α-predicate (fire strength), then the final result is obtained using a weighted average. Stages of how fuzzy Tsukamoto works:

a. Fuzzification

The process of converting system inputs that have explicit values into linguistic variables uses membership functions stored in the knowledge base.

b. Formation of a fuzzy knowledge base (Rule in the form of IF-THEN).
c. Inference engine

Process of converting fuzzy input into fuzzy output by following the rules (IF-THEN Rules) that have been set on fuzzy knowledge.

d. Aggregation

There are often cases where there is more than one rule. This means that the results of the implication are worth more than one. Therefore, we need to combine all the results of these results into one single fuzzy set. The aggregation method used here is the MIN method.

e. Defuzzification

Process for converting fuzzy output obtained from an inference engine into an explicit value using the membership function that is in accordance with when Fuzzification was performed. With calculations:

– Weighted average method.

$$* = \frac{\int (\ ).\ \ -}{\int (\ )} \tag{2}$$

– Center of area method

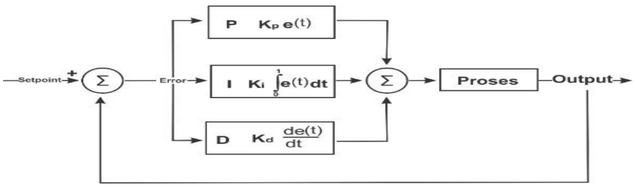
$$* = \frac{\sum \ \ *}{\sum} \tag{3}$$

1.5. Proportional integral derivative control

Proportional integral derivative (PID) control is a control system that has long been used in industry or the military. 90% of industrial equipment already uses PID control because it is easy and simple to use. The use of this PID aims to stabilize the output speed in the form of a water pump and air controller [4], [21]–[24]. The advantages of using PID controls are:

- If using a relay can only control Output with active and inactive status only.
- However, if using PID control, the status control is not active and no longer active, but with a slow, normal, and fast status.

Using the PID control can be used separately or together and not use any of the



P, I or D components [25], [26] shown in Figure 5.

Figure 5. PID control diagram

PID control is the combined result of three forms of control, namely Proportional, Integral and Derivative control

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Description: 0

u(t) = control signal K = strengthening
e(t) = error signal obtained from the difference between the Output signal value minus setpoint signal. Kp = Proportional parameters
Ki = Integral parameters Kd = Derivative parameters

The main parameters of the PID controller are proportional strengthening of Kp, integral time Ti, and derivative time Td. The equation is an equation in time value (t), so that equation is converted by using a first-order differential finite. The detailed explanation of PID is:

- Proportional control

Proportional control has an output that is proportional to the error signal (the difference between the intended value and actual value, error). Changes in input will affect output by its multiplying constant. The proportional control equation is formulated as:

( ) = ( ) (5)

Description:
Kp = Proportional parameters
e = error
u = is an output of values relative to time (*t*)

- Integral control

Integral control has a function to eliminate the steady-state error to zero. If a plan does not have an integrator element (1/s), the proportional controller cannot be able to guarantee that system output will be exactly according to desired response, so an integral controller is needed. The integral control equation is formulated as:

( ) = $\int_0$ ( )

Description:
Ki = Integral parameters
e = error
u = is an output of values relative to time (*t*)

(6)

- Derivative control

Output value of derivative is differential, derivative control using speed of error signal changes as a control parameter. If there is no change in error signal, output of derivative control will not change. The derivative control equation is formulated as:

( ) = _ ( ) (7)

Description:
Kd = Proportional parameters
e = error
u = is an output of values relative to time (*t*)

2. RESULTS AND ANALYSIS

Implementation is the stage carried out to implement a system that has been built in accordance with the system design. The following is an interface display of the IoT system on the greenhouse that has been developed based on the web shown in Figure 6.

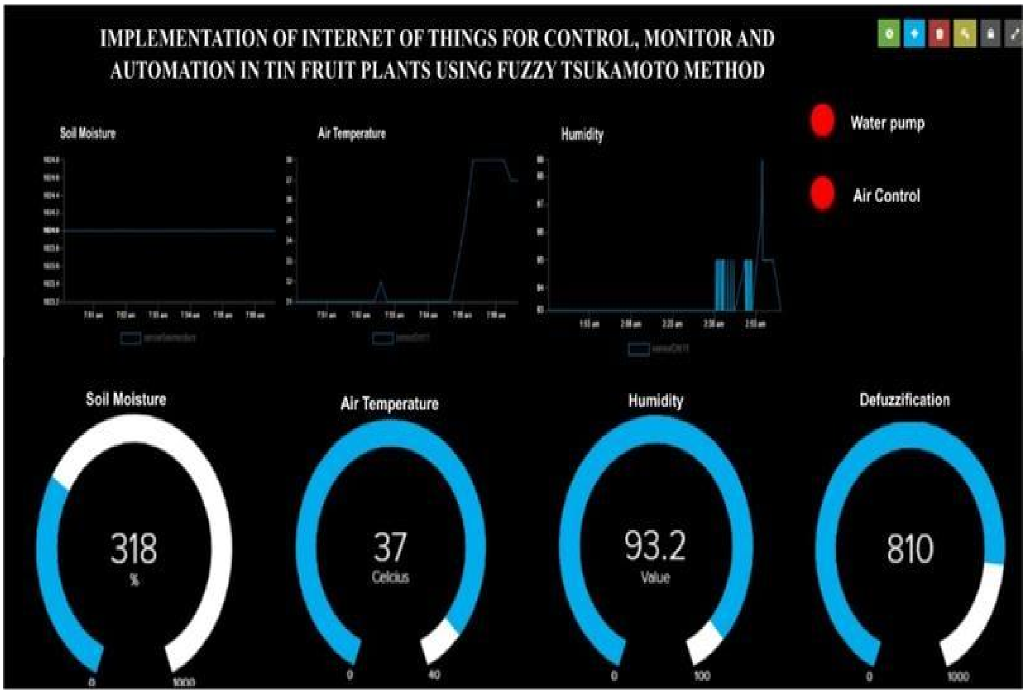

Figure 6. IoT data monitor dashboard on the greenhouse

Information displayed by the Adafruit IO dashboard to monitor data from IoT in the greenhouse. Data displayed in system are soil moisture, air temperature, humidity, water pump status, air controller status, and defuzzification value from calculation results that have been made. The value of humidity and air temperature obtained from DHT11 sensor and soil moisture values obtained from soil moisture sensor. Three input variables will be input from the fuzzy process. To get the defuzzification value of three variables will be processed on the rule base and inference engine. As a result of defuzzification of the pump into a setpoint value for PID control, PID control is used to control the speed of the water pump and the air controller to keep it stable so that the speed suddenly increases or decreases dramatically, as a pump speed test without using PID and using PID is shown in Figures 7 and 8.

In Figure 7 the pump speed that does not use PID control so that to adjust pump speed it still looks rough in an increasing and decreasing position. Very different if you use a PID control as shown in Figure 8. In Figure 8 is the pump speed using PID control. PID tuning using a trial-error method with the simulation conditions used values of Kp = 2, Kd = 0.03, Ki = 0.2 with t = 0.10s and the setpoint of the results of defuzzification will produce 370 that are close to the setpoint number.

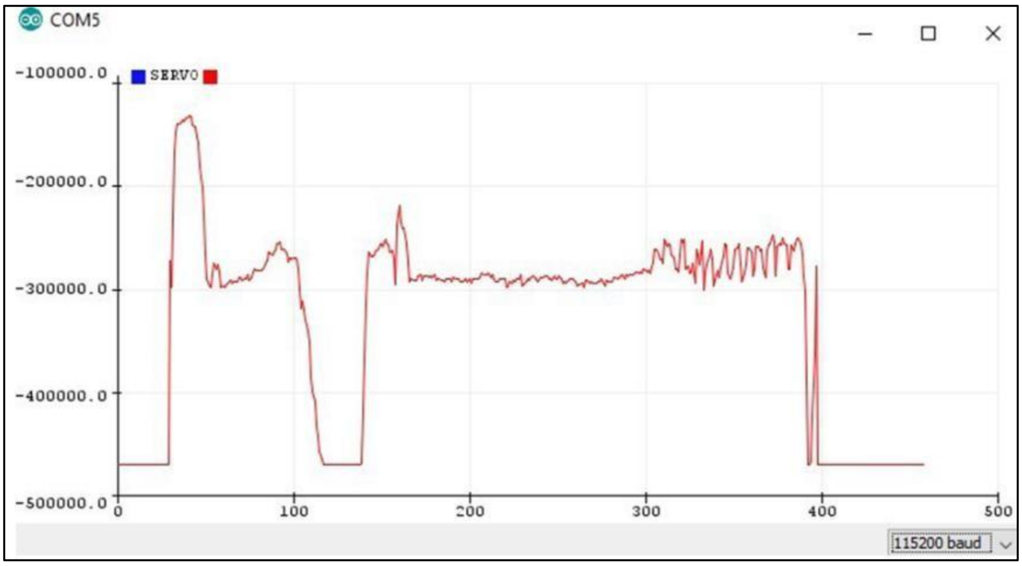

Figure 7. Without using PID control

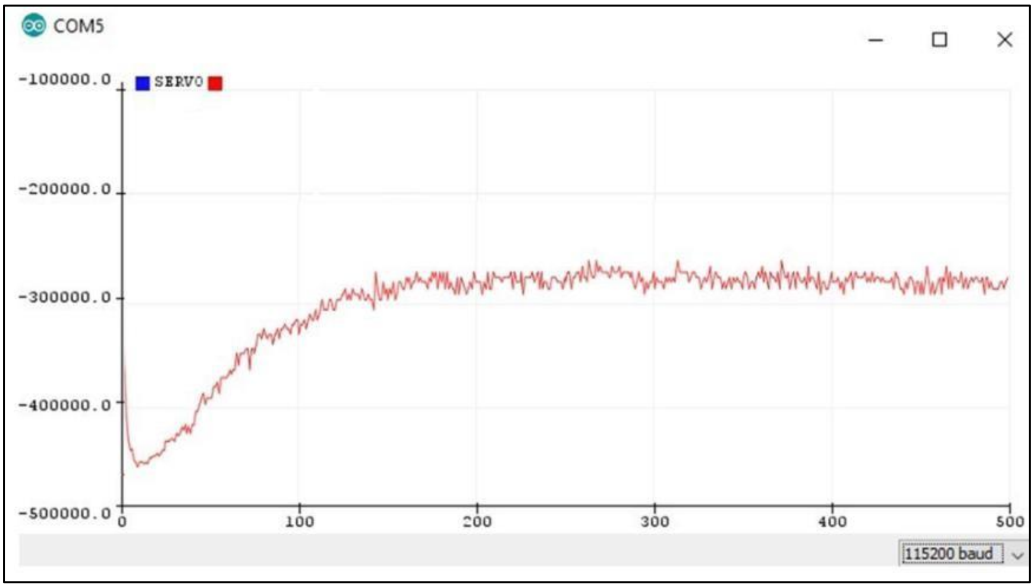

Figure 8. Using PID control

For calculations in the program is:

Error = setpoint – input
Error1 = *Error+Error_* previous
Error2 = *Error* – *Error_* previous
P = KP x *Error*
I = KI x *Error1*
D = KD x *Error2*
*Error_* previous = *Error*
PID = P + I + D

From the real-time data the PID calculation gets the results shown in Table 1. The table shows the data from the control PID calculation with values of Kp = 1.0, Ki = 0.5, and Kd = 0.2 with t (time) = 0.100/s and the setpoint of the defuzzification results.

Table 1. Results of PID control calculations

No	Time	P	I	D	Error	Output
1	15:51:51.477	111.00	95.00	6.40	111.00	212
2	15:51:51.579	159.00	135.00	9.60	159.00	303
3	15:51:51.579	155.00	157.00	-0.80	155.00	311
4	15:51:52.762	227.00	195.00	12.80	227.00	434

3. CONCLUSION

The system that was created to apply FPID on the Internet of Things and put in the greenhouse has performed as planned. IoT allows for real-time monitoring of soil and air conditions, as well as real-time irrigation according on crop demands. The growth of figs in a greenhouse may be optimized by using FPID as artificial intelligence to IoT placed in the greenhouse because suitable soil and air conditions can be maintained.

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