Oyster Mushrooms Humidity Control Based On Fuzzy Logic
By Using Arduino ATmega238 Microcontroller

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Abstract. Control system becomes the most important factor in automation system. One of
control system method/models is fuzzy logic modeling. Fuzzy logic is a modern control system
that can produce decisions like human logic. Oyster Mushrooms cultivation is a business that
has many advantages such as, growth does not depend on weather and season, cultivation does
not require extensive land and special tools. However, business needs to be optimized so the
quantity and quality of production increases. One way to optimize the quantity and quality of
production is to keep the humidity in optimum conditions because humidity is an important
factor in the growth of Oyster mushrooms. So far to keep humidity, entrepreneurs use the
traditional way that is sprayed with water granules to the Oyster mushrooms, but this is not
optimal because humidity can not be maintained at all times. In addition, entrepreneurs must
pay for spraying services. The solution to the problem is create an automatic humidity
regulator with a Fuzzy logic control system.

1. Introduction

Oysters mushroom are a type of mushroom that is most increasingly in demand among other types of
mushroom. Along with the increasing awareness of Indonesian people for health, oyster mushrooms
are selected as daily food menu by the people because of high fiber and vitamin content and free of
cholesterol so it can be a substitute source of animal protein. In terms of cultivation, compared with
other mushrooms, oyster mushrooms are the most easy to cultivate mushrooms, the most tolerant
mushroom / weather resistance (can grow in various seasons), most productively, can grow in a
variety of media, which is large, and can be built with little capital. Optimum oyster mushrooms grow
in the temperature range 28-30°C and humidity 80-90%. So for temperature parameters, Indonesia as a
tropical country with a average temperature 25-32°C is very suitable for cultivated oyster mushrooms,
but for humidity must still be controlled to be fulfilled optimum moisture.

The demand for oyster mushroom in Bandung area is about 7-10 ton/day while its production only
reach 2-3 ton/day, in Jakarta area of oyster mushroom demand about 15 ton/day whereas supply from
karawang only reach 3 ton/day so that cultivation of oyster mushroom needs to be improved. The
mushroom cultivation business has a good prospect. Mushroom business is medium easy because it is
not limited by season and with small capital can start this business, therefore many businessmen who
glance at this sector. Not only experienced businessmen, not even a few of the students were involved
in opening a mushroom business, whether they still in a college or a new graduate.
Because of the tight competition, it is necessary to have optimization in this business so that it can excel to produce maximum product. One of the things that can be optimized is in terms of cultivation. One important factor in cultivation of mushrooms is humidity in the mushroom house. Right humidity value will make the optimal growth of mushrooms. Unfortunately, many farmers are not focus to optimize the humidity in mushrooms house. Although not dominant, but one of the causes of crop failure or bad harvest is due to the bad humidity. Farmers usually make the mushroom house humid by spraying the soil with water only in the morning and afternoon, then the humidity level is not measured whether it is appropriate or not, it certainly can still be optimized again. Many farmers are busy so they have to pay workers to spray water. The effect of bad humidity is time to harvest longer, the frequency of harvest each medium is decreases and mushroom can die. Therefore we need a way to keep humidity of the mushroom house at the optimal value and can be real time monitoring.

Today’s automation technology has begun in the agricultural sector. Lots of electronics equipment that began in applied to raise agricultural production. Currently the automation technology is very sophisticated, easy to make, easy to apply and the cost to realize it is not too expensive. To make the automation system, needed some main equipment such as sensor, controller and actuator. Sensors works to detect changes in physical symptoms being in control. The controller works to process the results of sensor readings which will then result in a decision to make the physical symptoms that being in control as expected. The actuator acts as a tool that receives commands from the controller to change the physical symptoms that being in control. The Examples of physical symptoms that being in control are temperature, flow, pressure, level, humidity, and others. The realization of automation technology has been widely applied to the agricultural sector.

With the modern technology, humidity settings can be automatically. The Created device can spray water mist when humidity is lower than set point, and can turn on fan when humidity is higher than set point. So the humidity can be maintained all the time and mushrooms house not need to maintained every time so that the mushrooms can grow optimally. Then the cost is only for the procurement of equipment once and the cost of electricity is relatively low because the electricity consumption of the device is small. Compared to the costs that must be paid to pay the wages of workers, the cost for this device is cheaper. Moreover, for the super busy businessmen or students who run the business while still able to run other activities because mushroom house will always be monitored by this device, it means that in mushroom cultivation will be more optimal and efficient in terms of time and cost.

1.1. Cultivation of Oyster Mushrooms

Oyster mushrooms (Pleurotus ostreatus) is a food mushrooms from the Basidiomycota group and belongs to Homobasidiomycetes class with the general characteristics of the white fruit body to the beige and the semicircular hood is similar to the oyster shell with the middle part is slightly concave. Oyster mushrooms are still one relative with Pleurotus eryngii and often known as King Oyster Mushroom.

The oyster mushrooms body has a sideways grove (Latin: pleurotus) and oyster-shaped (ostreatus) so that the oyster mushrooms has the binomial name Pleurotus ostreatus. The hood part of the mushrooms changes color from black, gray, brown, to white, with an almost slippery surface, a 5-20 cm diameter with a smoothly curved edge hood slightly curved. In addition, oyster mushrooms also have a rod-shaped spore 8-11 × 3-4μm and white miselia that can grow quickly.

In the wild, oyster mushrooms can be found almost throughout the year in the cool mountainous forests. The fruit body looks stacked on the surface of decayed tree trunks or stems of tree trunks that have been felled because the oyster mushrooms is one type of wood mushrooms. For that, when it wants to cultivate this mushrooms, the substrate must be made to consider the natural habitat.
Common media used to breed oyster mushrooms is sawdust wood which is waste from sawmill. In the cultivation of oyster mushrooms one of the parameters that determine the quantity and quality of the harvest is the temperature and humidity. Fruit body optimum grows in the temperature range 26-28 °C, while the growth of mycelium at 28-30 °C, air humidity 80-90%. For temperature parameters, Indonesia as a tropical country with an average temperature are 25-32°C already fits with the growing temperature needs of oyster mushrooms so there is no need for temperature control, but for humidity levels still have to be controlled because many factors can affect the humidity level.

1.2. Humidity
Humidity is the concentration of vapor in the air. These concentration figures can be expressed in absolute humidity, certain humidity or relative humidity. The tools for measuring humidity are called hygrometers. A humidistat is used to regulate humidity levels in a building with a dehumidifier. Vapor pressure in the air is associated with temperature changes. The concentration of water in the air at sea level can reach 3% at 30 °C (86 °F), and not exceed 0.5% at 0 °C.

The absolute humidity is the content of air vapor (the unit with the volume of vapor or the pressure) per unit volume. The relative humidity compares the air vapor content with the saturation state or to the air capacity to accommodate vapor. The air capacity to accommodate the air vapor (in saturation state) is determined by the temperature of the air. The vapor pressure deficit is the difference between the saturated vapor pressure and actual vapor pressure. Each assumption of air humidity has certain meanings and functions with closed problems.

All vapor in the air starts from evaporation. Evaporation is a change of water from the liquid state to the gas. In the evaporation process is necessary heat, while the condensation is released heat. As is known, evaporation can not only occur in the open water table only, it can also occur directly from the soil and more than the plants.

The humidity of the air in a confined space can be adjusted as desired. This air humidity setting is built on the principle of the equal potential of water between air and solution or with certain solid materials. If into a closed chamber, then the water of the solution will evaporate until there is a balance between water potential in air and the water potential of the solution.

Level humidity in a place depends on several factors as follows:

1. Temperature
2. Air pressure
3. Wind movement
4. Quantity and Quality of Irradiation
5. Vegetation and so on
6. The availability of water at somewhere

In oyster mushrooms cultivation there are several techniques for raising humidity, such as spraying water mist using spray, soaking the soil (if the foundation of the house), and wetting the fabric wall (if the wall is a cloth). To reduce the humidity can be done by sucking the moist air from the house so that the air inside the house to dry.

1.3. Water Mist
In this research, the technique used to increase humidity is by spraying water mist. Spraying water mist is spraying that produces spraying water in the form of very small granules, it can be done by compressing water and air so that when sprayed, the water becomes fragmented by the air impulse.
with a special spray and nozzle. In contrast to spraying or flushing water with a hose without air compression, the water will not be in the form of small grains.

1.4. Exhaust
Humidity level can be depends of the amount vapor in air and air movement. These things can be utilized to manipulate the humidity levels in mushrooms house. To decreases the amount of vapor is using exhaust fan. Fan will move the vapor from inside mushrooms house to outside and also make the air movement so the humidity will be decreases.

1.5. Fuzzy Logic Controller
Fuzzy logic controller is logic control that use fuzzy set to collect membership. In the fuzzy set theory, membership of an element in the set is expressed by the membership values whose value 0-1. Fuzzy logic controller use three step, that is fuzzyfication, rule base, and defuzzyfication. Fuzzyfication is a process of changing input from the firm form (crisp) into a linguistic variable (fuzzy) which is usually presented in the form of fuzzy sets with a membership function respectively. Rule base is a rule created to determine the output that occurs. The Fuzzy Rules Base is a collection of IF-THEN rules based on expert knowledge. Defuzzyfication is the process of converting from fuzzy quantities to firm form (crisp) back.

Fuzzy logic is an enhancement of Boolean logic confronting the concept of partial truth. When classical logic states that anything can be expressed in binary terms (0 or 1, black or white, yes or no), fuzzy logic replaces Boolean truths with truth levels. Fuzzy logic allows membership values between 0 and 1, gray and black and white levels, and in linguistic form, uncertain concepts such as "a little", "tolerable", and "very". This logic is related to the fuzzy set and probability theory.

2. Research Methodology

This research used control system with fuzzy logic modeling. The control system has four parts: input, controller, control system modeling, and Output. Control system block diagram of this device can be seen in Figure 1.

![Figure 1. Block Diagram of Fuzzy Logic Control System](image)

Set point is the optimal point/value of a system desired to achieve. In this study set point is the most optimal humidity value for the fungus to grow maximal, the most optimum humidity value is 80% - 90% so set point is determined 80% -90%. Sensor in the control system serves to get the controlled variable value so the system can correct if there is a non-conformity of the controlled variable with the set point. In this research, the controlled variable is humidity, so this device use humidity sensor. The humidity sensor plays a role in reading the humidity change which will then be compared with the set
point. The results of the comparison between sensor readings and set points are error values (difference). Sensors placed in 30cm x 50cm mushroom house to detect humidity change. The humidity control ranges is from 80% to 90%. The sensors reading the actual humidity then sent to the controller to be compared with specified humidity set point.

Controller is a device that can decide and produce an action to eliminate errors. This device used Arduino ATMega328 as controller. To be able to make error corrections, the controller requires a formula/modeling. This research used fuzzy logic modeling. When the sensor and set point are compared then there is an error, the error value will be sent to the controller to be processed by fuzzy modeling. After the controller is finished processing, then the controller will generate output value and then sent to the actuator/final device.

Actuators are tools that can change physical quantities. In this device there are 2 final devices or actuator, that is spray and exhaust fan. Spray serves to increase the percentage of humidity by spraying water mist into the mushroom house. Exhaust fan serves to reduce the percentage of humidity by sucking the water mist inside the mushroom house and throw it outside the house. After the actuator works, the sensor continuously reads the humidity change and then sends it to the controller to compare and process it to produce the output and then sent it to the actuator and the actuator is working again, the cycle is repeated continuously so that humidity is always maintained. Fuzzy logic control system plays a role to produce decisions or manipulated variables. Input system is error and d_error, then output consists of 2 pieces of element that is spray and fan.

![Figure 2. Block Diagram of Oyster Mushrooms Humidity Control](image)

As seen in the block diagram of Oyster Mushrooms Humidity Control in figure 2, this devices using Arduino Nano ATMega328 microcontroller as controller. Arduino Nano ATMega328 was chosen because it is the most efficient and effective controller for mushroom cultivation automation applications. The superiority of Arduino Nano ATMega328 is have input and output port according to the requirement to be applied. In addition, Arduino ATMega328 has good processing capabilities, low prices and available on the market.
This device use SHT11 Industrial Class humidity sensor, the sensor is reliable enough to detect humidity changes, industrial grade sensors are selected because the sensor is durable and not easily damaged, this humidity sensor will contribute to produce the value to be processed into 2 inputs (variable error & variable change error) by the controller. In addition to sensors, on the input is also used a button that serves to make changes to settings such as set point, etc.

This device used spray & fan as the final element to manipulate the humidity, spray is used to increase humidity because spray will increase water content, and to decrease humidity is use exhaust fan for decreasing water vapor. On the output side is also used LCD as the interface device with the user. Method of modeling/control system is a method or formula or algorithm that will make the three elements (sensors, controllers and actuators) work optimally to produce control on physical symptoms to be controlled. In this research, the modeling method or control system used is Fuzzy Logic.

The concept of fuzzy logic was first introduced by Professor Lofti A of Zadeh University of California Berkeley in 1965. Fuzzy logic is used to monitor nonlinear systems that are difficult to handle mathematically. Fuzzy logic is chosen because Fuzzy Logic goes like the logic of human thinking, so it can produce the right decision as it should. Fuzzy logic has a working step starting from fuzzyfication, rule base, and defuzzyfication.

2.1. Fuzzyfication
Fuzzyfication is a process of changing input from the firm form (crisp) into a linguistic variable (fuzzy) which is usually presented in the form of fuzzy sets with a membership function respectively. In this research fuzzyfication process 2 input variables (error, d_error) obtained from processing the value of the humidity sensor. Error and d_error each have 3 membership function (MF) i.e. Error is negative, error is 0 and error is positive. The error value obtained from the reading value of the humidity sensor is reduced by the set point value. Error variables are made of measurement ranges ranging from -3 to 3. This value can be from the humidity sensor reading which results in an error value when compared with the set point.

Set point specified is 4 (humidity 80%). For an error change (d_error) is made a range of from -6 to 6. The value of this error change is obtained from the calculation of the difference of the present error value subtract with the previous error value. Membership function of error variable can be seen in figure 3 and membership function of d_error variable can be seen in figure 4.

![Figure 3. Membership Function of error Variable](image-url)
Figure 4. Membership Function of d_error Variable

An example of fuzzification on error, if the value of humidity sensor reading is 2.5 then it can find the error value use this formula:

\[
\text{error value} = \text{set point} - \text{sensor reading value} \\
= 4 - 2.5 = 1.5 
\]  

(1)

Once the error value is known, it can be seen that the error value is included into any member.

Figure 5. Example Membership Function of error Variable

Based on the figure 5 can be seen that the error value of 1.5 members enter ErrorZero with membership degree of X1 and ErrorPos with membership degree of X2. Here's how to find X1 and X2:

\[
X1 = \frac{c-x}{c-b} = \frac{2-1.5}{2-0} = \frac{0.5}{2} = 0.25 
\]

(2)

\[
X2 = \frac{x-b}{c-b} = \frac{1.5-0}{2-0} = \frac{1.5}{2} = 0.75 
\]

(3)

This fuzzyfication process resulted in the error value of 1.5 being a member of the ErrorZero set with a membership value of 0.25 and a member of ErrorPos with a membership value of 0.75.

Fuzzyfication of error change is the calculation of current error and previous error, here is the fuzzyfication example of error change. If the first sensor reading is 2, and the second sensor reading value is 1. The second sensor value reflects the current state (n) and the first reading becomes the previous reading condition (n-1). First look for the error value for each sensor reading.

\[
\text{error}(n-1) = \text{set point} - \text{sensor value(n-1)} \\
= 4 - 2 = 2 
\]

(4)
error(n) = Set point – sensor value(n) 
= 4 – 1 = 3

(5)

If the values of current errors and previous errors have known, it can be searched for the value of error changes.

change of error = error – previous error 
= error(n) – error(n – 1) 
= 3 – 2 = 1

(6)

Figure 6. Example Membership Function of d_error Variable

Based on Figure 6 it can be seen that the value of error change 1 entry member DerrorZero with membership degree of X1 and DerrorPos with membership degree of X2. Here are the calculations to get X1 and X2.

\[
X1 = \frac{c-x}{c-b} = \frac{4-1}{4-0} = \frac{3}{4} = 0.75
\]

(7)

\[
X2 = \frac{x-b}{c-b} = \frac{1-0}{4-0} = \frac{1}{4} = 0.25
\]

(8)

This fuzzyfication process results in the value of error 1 being a member of the DerrorZero set with a membership value of 0.75 and a member of DerrorPos with a membership value of 0.25. Membership function of spray variable can be seen in figure 7 and membership function of fan variable fan can be seen in figure 8.

Figure 7. Membership Function of Spray Variable
2.2. Rule Base
Rule base is a rule created to determine the output that occurs. The Fuzzy Rules Base is a collection of IF-THEN rules based on expert knowledge. The method used in the determination of the Fuzzy rule base is to use the trial and error method. The logic of decision making is prepared by writing the rules that connect the input and output of the Fuzzy system. This rule is expressed in the sentence: 'if <input> then <output>'. The rules base accrued in this device as shown in table 1.

Table 1. Set Rules

| d_error | ErrorNeg | ErrorZero | ErrorPos |
|---------|----------|-----------|----------|
| ErrorNeg | Long Spray (R1) | Short Spray (R2) | Idle (R3) |
| ErrorZero | Short Spray (R4) | Idle (R5) | Short Fan (R6) |
| ErrorPos | Idle (R7) | Short Fan (R8) | Long Fan (R9) |

Here is an example of a rule using IF ELSE that refers to table 1.

R1
IF error ErrorNeg AND d_error DerrorNeg THAN Working Long Spray

R2
IF error ErrorNeg AND d_error DerrorZero THAN Working Short Spray

R3
IF error ErrorNeg AND d_error DerrorPos THAN Idle

R4
IF error ErrorZero AND d_error DerrorNeg THAN Working Short Spray
R5
IF error ErrorZero AND d_error DerrorZero THAN Idle

R6
IF error ErrorZero AND d_error DerrorPos THAN Working Short Fan

R7
IF error ErrorPos AND d_error DerrorNeg THAN Idle

R8
IF error ErrorPos AND d_error DerrorZero THAN Working Short Fan

R9
IF error ErrorPos AND d_error DerrorPos THAN Working Long Fan

2.3. Defuzzyfication
Defuzzyfication is the process of converting from fuzzy quantities to firm form (crisp) back. There are many defuzzyfications method such as AI (adaptive integration), COA (center area), COG (center of gravity), MOM (maximum center), etc. This research uses defuzzyfication with COG method. Center Of Gravity (COG) or commonly known by the centroid method is a defuzzyfication method for obtaining crpis value use calculate center of gravity from the aggregation area or the result of total moments with total area. From the example in this journal, the selected rule base is R8 (Short Fan), in the membership function of output fan (figure 8) can be seen short fan area, so position of COG is in that area and can be find the right position by use COG formula. Calculation result will get the output value of crpis in the form of time that will determine how long the actuator will work.

3. Result of Research and Discussion
Fuzzy logic sent output to the actuator so actuators work in such a way as to keep humidity mushrooms house. This device keep the mushroom humidity at 80% -90%, although in the hot day, as well as the cold night, the mushroom house humidity is always maintained between 80% -90% because the spray will work to increase moisture when moisture descending below the set point, and the exhaust fan will work when the humidity exceeds the set point. This device keep the optimal humidity of mushroom house, so baglog mushrooms stored in the mushroom house grow maximum. Every mushroom growing out of the baglog is always full and the mushrooms grow many times until the baglog runs out. It indicates that the moisture in the mushroom house is always optimal. Device performance is viewed from the output that generated by the controller for the actuator at a certain humidity state. Results/output of fuzzy logic can be seen in table 2.

| No. | Input | Output | Time Value (s) |
|-----|-------|--------|---------------|
| 1   | 65    | LS     | ±146          |
| 2   | 66    | LS     | ±144          |
| No. | Input Hum Value (%) | Operation Time | Output Time Value (s) |
|-----|---------------------|----------------|----------------------|
|    |                     |                |                      |
| 3   | 67                  | LS             | ±142                 |
| 4   | 68                  | LS             | ±140                 |
| 5   | 69                  | LS             | ±138                 |
| 6   | 70                  | MS             | ±135                 |
| 7   | 71                  | MS             | ±130                 |
| 8   | 72                  | MS             | ±125                 |
| 9   | 73                  | MS             | ±115                 |
| 10  | 74                  | MS             | ±105                 |
| 11  | 75                  | SS             | ±95                  |
| 12  | 76                  | SS             | ±80                  |
| 13  | 77                  | SS             | ±65                  |
| 14  | 78                  | SS             | ±45                  |
| 15  | 79                  | SS             | ±25                  |
| 16  | 80                  | I              | 0                    |
| 17  | 81                  | I              | 0                    |
| 18  | 82                  | I              | 0                    |
| 19  | 83                  | I              | 0                    |
| 20  | 84                  | I              | 0                    |
| 21  | 85                  | I              | 0                    |
| 22  | 86                  | I              | 0                    |
| 23  | 87                  | I              | 0                    |

Fuzzy logic output is sent to the actuator so that actuators work in such a way as to keep humidity mushrooms house. The tool is made to keep the mushroom humidity at set point 80% -90%, although
in the hot day, as well as the cold night, the mushroom house moisture is always maintained between 80% -90% because the spray will work to increase moisture when moisture descending below the set point, so the exhaust fan will work when the humidity exceeds the set point. That because this device keep the humidity of mushroom house optimal, baglog mushrooms stored in the mushroom house grow maximum. Every mushroom growing out of the baglog is always full and the mushrooms grow many times until the baglog runs out. It indicates that the moisture in the mushroom house is always optimal.

In this research only humidity parameters are controlled, for temperature parameters are not controlled, it is because the average temperature in Indonesia is 25-32°C, according to the needs of the optimal temperature of oyster mushrooms are 28-30°C. Temperature changes in Indonesia are not extreme and rarely occur, unlike non-tropical countries that often occurs extreme changes in air temperature. In addition to the above facts, the authors conducted a survey to the oyster mushroom farmers in Sleman, Yogyakarta, the farmers said that the parameters they monitored are only humidity, for the temperature is not monitored because the temperature in the place of oyster mushroom cultivation is always in the optimal conditions for mushrooms, The temperature changes extremely is very rare so that the temperature parameter is not monitored and does not require control.

4. Conclusion

Prototype of oyster mushroom humidity control system based on fuzzy logic by using arduino ATMega349 microcontroller can be developed well using one humidity sensor and two outputs (spray and exhaust fan). Water mist spray working well to increase the oyster mushroom house humidity. Exhaust fan also effective to decrease humidity when humidity in mushrooms house upper than set point. The system has been able to work properly in accordance with the desired system, the system has been able to maintain the required moisture of oyster mushrooms to grow optimally.

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