EXHAUST FAN SPEED CONTROLLER USING FUZZY LOGIC CONTROLLER

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Abstract. Fuzzy logic is a reasoning method for solving linguistic problems that cannot be solved mathematically. The application of fuzzy logic from our development program regarding the development of exhaust fans with fuzzy logic controllers to regulate air flow velocity in accordance with air conditions in a room. Using a gas sensor and a temperature sensor will create a number of conditions to then be treated in a fuzzy logic system using the Mamdani method. The process that occurs in the Mamdani fuzzy includes four stages including the process of calculating the fuzzy set (fuzzification), the application of the implication function, the composition of the rules to the last stage, the defuzzification process. The inter elements of the mamdani fuzzy process are interconnected in the sense that the order determined by fuzzy mamdani cannot be removed or replaced by another. Development that has been done related to the exhaust fan uses two sensors namely the temperature sensor and gas sensor. Used as a detector for the amount of harmful gas in a room so that it activates the exhaust fan to eliminate it at a speed consistent with the gas content in the room. Also used to measure the temperature of the room and then activate the exhaust fan so that the room can be inhabited comfortably. Fuzzy logic controller system is used to adjust the rotational speed of the exhaust fan.

Keywords: air flow regulator; exhaust fan; fuzzy logic; fire; mamdani.

1. Introduction

As time goes by, the greenhouse effect increases due to the depletion of the ozone layer due to human actions. The increasing greenhouse effect causes prolonged global warming. In addition, the spread of air pollution in the world began to experience very rapid development. Along with global warming, the spread of pollution began to spread until it entered community housing [1].

At present, air temperature due to global warming is uncertain [2]. In Indonesia, the temperature had reached 40.6°C on August 16th, 1997. Driven by air pollution which began to get into the housing complex, it made the housing feel very stuffy and wearn’t. Some cities in Indonesia have even been diagnosed as being in an unhealthy area even for the condition of their own homes.
Therefore technology is needed to at least provide a supply of fresh air to occupied homes such as the installation of exhaust fans [3],[4],[5]. Exhaust fan is a fan that serves to provide refreshment and help remove harmful gases in our room.

Automatic mode is needed in the use of exhaust fans. Automatic mode will make it easier for users because the use of exhaust fans will function in accordance with conditions in the field [6] [7] [8]. Worried, if not automatically, when have been traveling and want to rest comfortably, but the condition of the house is not comfortable to be inhabited by reason of being too hot and too much pollution in the room. As a result we have to wait for a few minutes to condition the temperature and the level of air pollution in the room so that the house becomes even more feasible.

Installation of fuzzy logic controller on motor control can improve the quality and quality of the tool [9], [10]. Why is that? Because by using fuzzy logic controller, the exhaust fan speed can be adjusted according to the conditions in the room so that its use is more friendly and the budget in use is lower.

2. Research Method

2.1 Exhaust Fan Design

The development we made was a fan mounted on a panel box made of acrylic with a thickness of 3 mm. Inside the box contains a series of electronics consisting of Arduino which is connected to a gas sensor and temperature sensor. The specifications of the components used to make this tool can be seen in Table 1.

| Components      | Spesification                        |
|-----------------|--------------------------------------|
| Power Supply    | DC 12V                               |
| Actuator        | Fan with Connector 4 Pin             |
| Sensor          | DHT11 (temperature sensor)           |
|                 | MQ-5 (gas sensor)                    |
| Connector       | Male to male                         |
|                 | Male to female                       |
|                 | Female to female                     |
| Project board   | Mini project board                   |
| Body frame      | Acrylic with thin of 3 mm            |
| Body Size       | 20 cm x 20 cm x 10 cm                |

Both sensors are used to receive input. DHT11 sensor functions to receive input in the form of room temperature while MQ-5 sensor is used to receive input in the form of the amount of CO2 gas in a room.

The working principle of this tool is very simple. Starting with temperature data and the amount of gas in the inbox going to Arduino. The data is then processed in accordance with the program that has been created to produce a fan speed that has been set speed.
2.2 Fuzzy logic controller design

FLC is an approach to computing based on “degrees of truth” rather than the usual “true or false” (1 or 0) Boolean logic on which the modern computer is based. In this study using the fuzzy mamdani method. The Mamdani fuzzy method is often known as the max-min method, which was first made by Abraham Mamdani in 1975. This method is often used because it is more easily understood by the human mind itself. A Mamdani Fuzzy Inference System (Mamdani-FIS) is a paradigm in soft computing which provides a means of approximate reasoning. A Mamdani-FIS is capable of handling computing with knowledge uncertainty and measurements imprecision effectively. It performs a non-linear mapping from an input space to an output space by deriving conclusions from a set of fuzzy if-then rules and known facts. Fuzzy system workflow if displayed using matlab it will look like in Figure 1.

![Figure 1. Fuzzy Logic Controller](image)

The first step that must be implemented is the initialization process. This process is used to determine the magnitude of the distribution of fuzzy numbers and how the range for each fuzzy class. In the fuzzy logic controller, the membership function input and output and the rules table is used to get the output controller and system input. Membership function is a curve that determines how the values of fuzzy variables in a Certain regions are mapped to membership values between 0 and 1. The temperature sensor will be divided into 5 parts namely very cold, cold, medium, hot and very hot. The fuzzy arrangement sequence for the temperature sensor can be seen in the following Figure 2.

![Figure 2. Fuzzy Temperature](image)

In the picture above, it can be concluded that the fuzzy temperature classification is as follows.

- Very Cold : [-5.0 15 20]
- Cold : [15 20 25]
- Medium : [20 25 30]
- Hot : [25 30 35]
- Very Hot : [30 35 50 55]
For fuzzy gas can be seen in the Figure 3.

**Figure 3. Fuzzy Gas**

In the picture above, it can be concluded that the fuzzy gas classification is as follows.

- **Very Less**: [-100 0 100 200]
- **Less**: [100 200 300]
- **Medium**: [200 300 400]
- **Many**: [200 300 400]
- **Very Much**: [400 500 600 700]

For output which is the rotating speed of the exhaust fan is classified as shown in Figure 4.

**Figure 4. Fuzzy Speed Rotating**

In the picture above, it can be concluded that the fuzzy Speed Rotating is as follows.

- **Snail**: [-50 0 50 100]
- **Slow**: [50 100 150]
- **Medium**: [100 150 200]
- **Fast**: [150 200 250]
- **Very Fast**: [200 250 300 350]

In the Mamdani method, both input variables and output variables are divided into one more fuzzy set. In this experiment using fuzzy set as many as 5 conditions on 2 input variables and 1 output variable. For the first input variable ie gas consists of 5 fuzzy sets that are very less, less, medium, many and very much. If it is written with a membership function it will get the following results.
Table 2. The Fuzzification of Gas Condition

| Condition | Value | Requirement |
|-----------|-------|-------------|
| Very Less | \( \frac{200 - x}{100} \) | \( X \leq 100 \) |
|           | \( 0 \) | \( 100 < X < 200 \) |
|           | \( 0 \) | \( X \geq 200 \) |
|           | \( 0 \) | \( X < 100 \) or \( X < \frac{300}{x} \) |
| Less      | \( \frac{x - 100}{300 - x} \) | \( X \leq 200 \) |
|           | \( \frac{100}{100} \) | \( 200 < X < 300 \) |
|           | \( 1 \) | \( X = 200 \) |
|           | \( 0 \) | \( X < 200 \) or \( X < \frac{400}{x} \) |
| Medium    | \( \frac{x - 200}{400 - x} \) | \( 200 < X < 300 \) |
|           | \( \frac{100}{100} \) | \( 300 < X < 400 \) |
|           | \( 1 \) | \( X = 300 \) |
|           | \( 0 \) | \( X < 300 \) or \( X < \frac{500}{x} \) |
| Many      | \( \frac{x - 300}{500 - x} \) | \( 300 < X < 400 \) |
|           | \( \frac{100}{100} \) | \( 400 < X < 500 \) |
|           | \( 1 \) | \( X = 400 \) |
|           | \( 0 \) | \( X \leq 400 \) |
| Very much | \( \frac{X - 400}{100} \) | \( 400 < X < 500 \) |
|           | \( 1 \) | \( X \geq 500 \) |

For the second input, a temperature sensor is used to detect the room temperature. Temperature is defined as 5 conditions including very cold, cold, moderate, hot and very hot with the following membership functions.

Table 3. The Fuzzification of Temperature

| Condition | Value | Requirements |
|-----------|-------|--------------|
| Very Cold | \( \frac{20 - x}{5} \) | \( X \leq 15 \) |
|           | \( 0 \) | \( 15 < X < 20 \) |
|           | \( 0 \) | \( X \geq 20 \) |
|           | \( 0 \) | \( X < 15 \) or \( X < \frac{25}{x} \) |
| Cold      | \( \frac{x - 15}{5} \) | \( X = 20 \) |
|           | \( \frac{25 - x}{5} \) | \( 20 < X < 25 \) |
|           | \( 1 \) | \( X = 20 \) |
| Medium    | \( 0 \) | \( X < 20 \) or \( X < \frac{30}{x} \) |
As well as the case with the output in the form of time the Exhaust Fan is defined to be 5 conditions in accordance with the rotating speed of spinning among them being snails, slow, medium, fast and very fast which can be seen based on the membership function as following results.

| Table 4. The Fuzzification of Rotating Speed |
|---------------------------------------------|
| Condition  | Value  | Requirements |
| Snails     | $1 - x/50$ | $50 < X < 100$ |
|            | $0/50$    | $X \geq 100$  |
|            | $0/50$    | $X < 50$ or $X < 150$ |
| Slow       | $x - 50/50$ | $50 < X < 100$ |
|            | $100 - x/50$ | $100 < X < 150$ |
|            | $0/50$    | $X = 100$     |
|            | $0/50$    | $X < 100$ or $X < 200$ |
| Medium     | $x - 100/50$ | $100 < X < 150$ |
|            | $200 - x/50$ | $150 < X < 200$ |
|            | $1/50$    | $X = 150$     |
|            | $0/50$    | $X < 150$ or $X < 250$ |
| Fast       | $x - 150/50$ | $150 < X < 200$ |
|            | $250 - x/50$ | $200 < X < 250$ |
|            | $1/50$    | $X = 250$     |
|            | $0/50$    | $X \leq 200$  |
| Very Fast  | $x - 200/50$ | $200 < X < 250$ |
|            | $1/50$    | $X \geq 250$  |
The second stage of the Mamdani Fuzzy Method procedure is the application of the rule evaluation. The rules of the fuzzy system are a formulation of the mapping from a given input set to an output set. The rule evaluation is a logical structure consisting of a collection of premises and one conclusion. The rule evaluation is useful for knowing the relationship between premises and conclusions. The form of this function implication is by the statement IF x is A THEN y is B, where x and y are scalar, and A and B are fuzzy sets.

In this experiment, Table 5 was used to map the implications of the fuzzy logic controller function.

**Table 5. Rule Evaluation**

| Gas and Temperature to Rotating speed | Gas        |
|--------------------------------------|------------|
|                                      | VL  | L  | M  | Ma | VM |
| VC                                  | Sn  | Sn | Sn | Sn | Sn |
| C                                   | Sn  | Sl | Sl | Sl | Sl |
| M                                   | Sn  | Sl | M  | M  | M  |
| H                                   | Sn  | Sl | M  | F  | F  |
| VH                                  | Sn  | Sl | M  | F  | VF |

Based on the table can be translated into applications function implications become:
1) IF (Gas IS Very Less) AND (Temperature IS Very Cold) THEN (Exhaust Fan Rotate IS Snail).
2) IF (Gas IS Very Less) AND (Temperature IS Cold) THEN (Exhaust fan rotate IS Snail).
3) IF (Gas IS Very Less) AND (Temperature IS Medium) THEN (Exhaust fan rotates IS Snail).
4) IF (Gas IS Very Less) AND (Temperature IS Hot) THEN (Exhaust fan rotates IS Snail).
5) IF (Gas IS Very Less) AND (Temperature IS Very Hot) THEN (Exhaust fan rotate IS Snail).
6) IF (Gas IS Less) AND (Temperature IS Very Cold) THEN (Exhaust fan rotates IS Snail).
7) IF (Gas IS Less) AND (Temperature IS Cold) THEN (Exhaust fan rotate IS Slow).
8) IF (Gas IS Less) AND (Temperature IS Medium) THEN (Exhaust fan rotates is Slow).
9) IF (Gas IS Less) AND (Temperature IS Hot) THEN (Exhaust fan rotate IS Slow).
10) IF (Gas IS Less) AND (Temperature IS Very Hot) THEN (Exhaust fan rotate IS Slow).
11) IF (Gas IS Medium) AND (Temperature IS Very Cold) THEN (Exhaust fan rotates IS Snail).
12) IF (Gas IS Medium) AND (Temperature IS Cold) THEN (Exhaust fan rotates IS Snail).
13) IF (Gas IS Medium) AND (Temperature IS Medium) THEN (Exhaust fan rotate IS Medium).
14) IF (Gas IS Medium) AND (Temperature IS Hot) THEN (Exhaust fan IS Medium).
15) IF (Gas IS Medium) AND (Temperature IS Very Hot) THEN (Exhaust fan rotate IS Medium).
16) IF (Gas IS many) AND (Temperature IS Very Cold) THEN (Exhaust fan rotate IS Snail).
17) IF (Gas IS Many) AND (Temperature IS Cold) THEN (Exhaust fan rotate IS Slow).
18) IF (Gas IS Many) AND (Temperature IS Medium) THEN (Exhaust fan IS Medium).
19) IF (Gas IS Many) AND (Temperature IS Hot) THEN (Exhaust fan rotate IS Fast).
20) IF (Gas IS Many) AND (Temperature IS Very Hot) THEN (Exhaust fan rotate IS Fast).
21) IF (Gas IS Very Much) AND (Temperature IS Very Cold) THEN (Exhaust fan rotates IS Snail).
22) IF (Gas IS Very Much) AND (Temperature IS Cold) THEN (Exhaust fan IS Slow).
23) IF (Gas IS Very Much) AND (Temperature IS Medium) THEN (Exhaust fan rotate IS Medium).
24) \( \text{IF (Gas IS Very Much) AND (Temperature IS Hot) THEN (Exhaust fan rotate IS Fast).} \)

25) \( \text{IF (Gas IS Very Much) AND (Temperature IS Very Hot) THEN (Exhaust fan rotate IS Very Fast).} \)

The process of determining the central point of a fuzzy area is carried out using the formulation:

\[
Z^* = \frac{\int Z \mu(z)z \, dz}{\int Z \mu(z) \, dz}
\]

by stating the result of defuzzification / focal point of the fuzzy region, \( \mu(z) \) represents the value of membership, and \( \int Z \mu(z)z \, dz \) represents the moment for all regions resulting from the composition of the rules.

3. Results and Analysis

The area for each rule composition result can be obtained by finding the area based on the shape of each rule composition result area, or can also use integrals, namely \( \int Z \mu(z)z \, dz \). The value of the value is the result of the defuzzification process, this value is the result of the final decision, and is adjusted to the linguistic variable of the fuzzy set that has been determined in the initial process, namely the formation of the fuzzy set. Based on the tools used, Figures 5 and 6 present the performances of the system.

![Figure 5. Input Motor](image)

![Figure 6. Observation Data](image)
By using a program created using a minimal system for example the amount of gas is very much but the temperature is very cold, the system will rotate the fan with a snail or very slow conditions. The calculation results will be very slowly by the formula in accordance with the agreed temperature. Select it will determine the classification and rotation of the motor. Suppose the temperature shows 12 degrees Celsius with very cold degrees. The amount of gas shows 521 with very many classifications. The system will take 12 degrees Celsius which will be processed fuzzy value then multiplied by the fuzzy results for a very fast motor rotation. Then the results of the multiplication will be classified according to the output size determined by the system.

4. Conclusions

Based on the experiments that have been carried out it can be seen the use of fuzzy logic controller (FLC) so that it is complex in everyday life until we can use it on various components of life. Based on experiments, the use of fuzzy on the exhaust fan is useful to help determine the number of these tools. Not only to adjust the actual in the room. The application of FLC is also applied by using the additions caused by the use of exhaust fans that exceed the requirements.

5. References

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