Analysis of the Sw-420 Vibration Sensor Performance on Vibration Tools by using a Fuzzy Logic Method

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Abstract: Vibration sensor Sw-420 is one of the most widely used sensor modules because it is easy to learn and to install. This sensor is also compatible with Arduino Uno microcontroller board. This sensor has two types of output, namely digital output (0/1) and analog output (voltage). However, for specific purposes such as security and industry, more than just vibration detection is needed. The system used must be smart to distinguish vibrations due to errors / damage or just technical / accidental errors. The vibration received by the sensor must be classified properly. In this study, the fuzzy logic method as a decision support system to help determine the appropriate vibration classification was applied. The reason for using the fuzzy logic method was that it is flexible, easy to understand, and is able to produce values that are more specific than just 0 and 1 values according to the needs of the SW-420 vibration sensor. With the fuzzy logic method, it can be seen that the sensor can classify vibrations into 5 levels, very weak, weak, moderate, strong and very strong.

1 INTRODUCTION

Vibration is something that is often found in everyday life. When an object vibrates, it affects not only the object itself but also the objects around it. Apart from physical contact, a vibration can also be detected from the sound generated through the vibration. This happens because these vibrations create friction for the surrounding objects and the object itself. Through a vibration, information about what is happening with the object can be received so that humans can estimate the possibility of what is happening due to these vibrations.

The vibrations that occur will have different effects on different objects. A large tremor on the side of a cross-city road may not have a significant effect as it is common (many large capacity cars pass). But vibrations of that magnitude would be a big problem if they happened under a quiet house and away from the streets. Because it requires a system or a tool to classify the vibrations that occur in order to determine whether the vibration is a problem that needs to be resolved or not and how to solve it.

For many years, Fuzzy Logic has been considered as a control algorithm with The Fuzzy Logic Controller. This controller has been widely utilized for the active vibration control of engineering structures. The capability of using fuzzy control strategies in vibration control of civil engineering structures with active control systems was established by focusing on the seismic response of frame structures due to multiple earthquake records with an active mass driver system as a control device on the top story Azizi. M., Ejlali. R. G., Ghasemi. S. A. M., Talatahari. S. (2019).

Research by Julio Fajar Saputra, et al. (2018) show the advantages of using LoRa (Long Range) connections for wider distances. LoRa-based data communication testing uses LOS and NLOS scenarios, data emergence is measured using a web data center. The drawback is that it requires greater costs and more complex programming because it uses two microcontrollers, namely Arduino Uno and Raspberry Pi.

Widya Purnamasari and Romi Wijaya's (2017) research shows the advantages of using more than one sensor to increase security as well as a way to monitor which parts of the vibration are detected. This system is also equipped with a database that is useful for storing data and processing time. The drawback lies in the use of a PC for monitoring. PC is not a device that has high mobility so it will indirectly force users

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to stay around the PC to monitor the house. PC also requires a lot of power so it will require additional costs for electrical power in case of a power cut (difficult for users to monitor the system).

Poltak Sihombing, Jos Timanta Tarigan et al. (2019) presents a security system that offers better efficiency. It has the ability to identify when an intruder enters the warehouse and send reports to registered users via short message service (SMS). Information is based on vibration and infrared to detect intruders. They specifically use the Raspberry Pi as the system microcontroller because of its ease of use. In the test case, they implemented a security system built into the warehouse and observed the effectiveness of the system in detecting intruders. They test several possible methods of intruders to enter the warehouse and log system responses. The results show that the system has recorded the incident effectively and sent a report via SMS to registered users. The difference in average time between an intrusion event and a notification received by a user is 5 to 10 seconds.

In the research of Ikhwan El Akmal Pakpahan (2017) it has advantages, namely the monitoring process using a smartphone which can increase user mobility and minimize the possibility of users not hearing alarms sounding (alarms do not only come from bells but also from smartphones).

From this research, the author wants to develop the research of Ikhwan El Akmal Pakpahan by adding a fuzzy method so that the resulting system is better at monitoring existing vibrations as well as analyzing the fuzzy logic method on the SW-420.

2 METHODOLOGY

2.1 Research Methodology

In this study, the capabilities of the SW-420 vibration sensor with the fuzzy logic method so that the received vibrations can be classified into 5 parts, namely very weak, weak, moderate, strong, and very strong are developed. To aid in vibration classification, an algorithm for determining whether a received vibration is valid or accidental is constructed. This then becomes one of the 2 factors that determine the type of vibration classification received by the sensor.

2.2 Research Design

In this study, the fuzzy logic method as a decision support system to divide the classification of vibrations received by the sw-420 vibration sensor based on two variables (namely the average value of analog data and the total data filled with vibration values from the 15 data slots provided) was applied. The following is the research design process:

1. Analyze the maximum value of analog data input that can be received by the sw-420 vibration sensor.
2. Adjust and adjust the sensitivity of the sensor to received vibrations.
3. Applying the fuzzy logic method to the Arduino Uno microcontroller connected to the sensor.
4. Analyze the results obtained by the vibration sensor after adding the fuzzy logic method as a decision support system.

2.3 Research Stages

The stages of the research to be carried out can be seen in Figure 1.

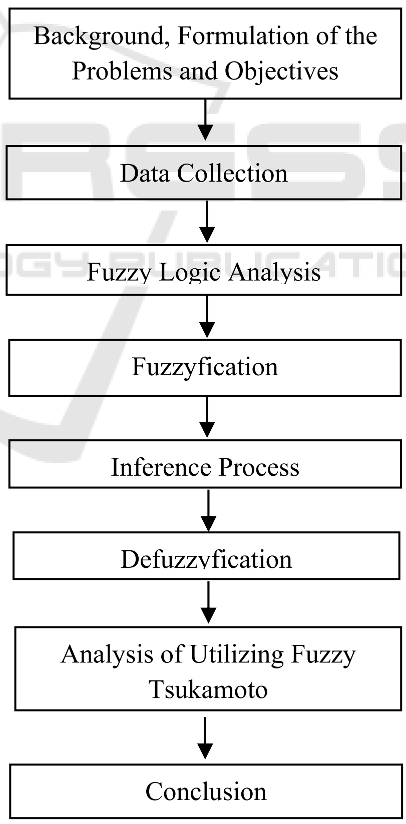

Figure 1: Research Stages.

The stages of the research to be carried out can be seen in Figure 1. Figure 1 is the stage carried out in the research: the first stage was to determine the background of the reasons for conducting the research, formulate some things that have been done and make the goals to be achieved. Furthermore, the data were collected to be processed using fuzzy logic with the Tsukamoto method. The second stage was fuzzification and performs an inference process from the data that has been obtained for testing using the applied Tsukamoto method. In the last stage, test results and conclusions are obtained.

2.4 System Design

In system design, the system that has been designed will be described and explained including the steps that must be taken so that the system runs as desired, starting from sensor detection, sending data from the sensor to the microcontroller to the output after being classified by the fuzzy logic method.

The Arduino Uno vibration sensor and microcontroller communicate using a jumper cable on the specified port. Meanwhile, to display the results of vibration classification with fuzzy logic as a decision support system, Arduino Uno was connected to a laptop / PC. Furthermore, the Arduino IDE application results of vibration classification can be seen on the serial monitor.

The following are the stages of system design being developed:

1. Initially, the Sw-420 vibration sensor data was received by the Arduino Uno Microcontroller.
2. The data was classified into several parts, such as analog data with a value of more than 10 will be entered and processed in the variable "content data". When the total sensor data received has reached 15 data, the results of the average value are accommodated in the "analog data" variable.
3. After the required data is sufficient, the next step was to determine the degree of membership, namely determining whether the data is included in a certain membership or not.
4. The next step was to calculate the predicate of the rule in the form of calculations performed to determine the predicate of the received data rule.
5. Defuzzification was the process of converting data from fuzzy data to real data.
6. The final step was to display the results of the data classification from the vibration sensor.

2.5 Flowchart

The steps of the program process can be seen in Figure 2.

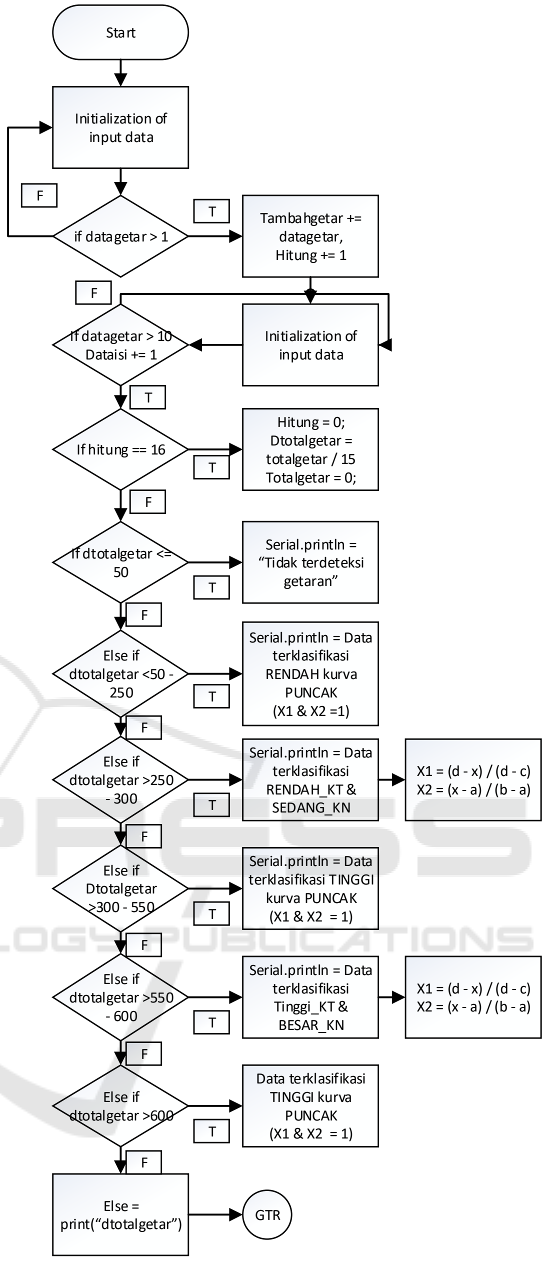

Figure 2: Flowchart.

2.6 Arduino Uno

Arduino Uno, an open-source platform, accounts for the data acquisition hardware in our toolbox. Different types of connection ports, including digital input/output, PWM output, UART TTL (5V) serial communication, and analog input, make the Arduino Uno board powerful and cost-effective hardware for data collection purposes. The Arduino Uno board has an Atmel ATmega328 microcontroller which can be programmed in C/C++ language through an integrated development environment (IDE). Regulated 5 V and 3.3 V outputs can be obtained from the Arduino board to provide the supply voltage for particular sensors. The Arduino Uno supports 6 analog input pins that read data in the range of 0–5V with the resolution of 10 bits (Karami. M., McMorrow. G. V., Wang. L., 2018).

2.7 Vibration Sensor

A vibration sensor is a sensor that can measure the vibration of an object whose data will be processed for experimental purposes or used to anticipate a possible danger. It has measurement accuracy and increasing the sensitivity range. One type of vibration sensor is the SW-420 sensor (Deviana. H, Amin. M. M., Sandy R., et al., 2019).

2.8 SW-420 Vibration Sensor

In this study the SW-420 series was used as a research variable. SW-420 is a vibration sensor that can detect vibrations from various angles. When the sensor does not receive vibrations, the electronic components of the sensor will function as a switch and will be closed. Meanwhile, when the sensor receives a vibration / shock, the switch will open and close at the transfer rate following the vibration (Siahaan. A.O, 2017).

This module features an adjustable potentiometer, a vibration sensor, and an LM393 comparator chip to give an adjustable digital output based on the amount of vibration. The potentiometer can be adjusted to both increase and decrease the sensitivity to the desired amount (Jagdale. S. B., Sali. M. R., Kulkarni. S. D. et al., 2019).

Image of the SW-420 vibration sensor can be seen in Figure 3:

Figure 3: SW-420 vibration sensor.

This circuit receives vibrations through a metal buoy inside the sensor. It also has 2 types of output, namely: digital output (based on values 0 and 1) and analog output (value is in the form of received voltage).

Table 1: SW-420 sensor specification.

No	Specification	Information
1	Voltage used	3,3V DC – 5V DC
2	Output	Digital (0 and 1) Analog
3	Sensor size	3,2 cm x 1,4 cm
4	Detection distance	760 nm – 1100 nm
5	Detection angle	60 degree
6	Signal	15mA

2.9 Software Implementation on the Sensor

Arduino Uno programming can be operated using the Arduino IDE. If Arduino can be likened to a brain, then Arduino IDE is the mindset. Through this application, we can adjust the Arduino Uno according to the user's wishes. However, there are several steps that we must do before we can use the program based on what is written in it. The first step is writing the program, then compiling the program and uploading the program to Arduino Uno using the provided USB cable.

Image of the implementation on the sensor can be seen in Figure 4:

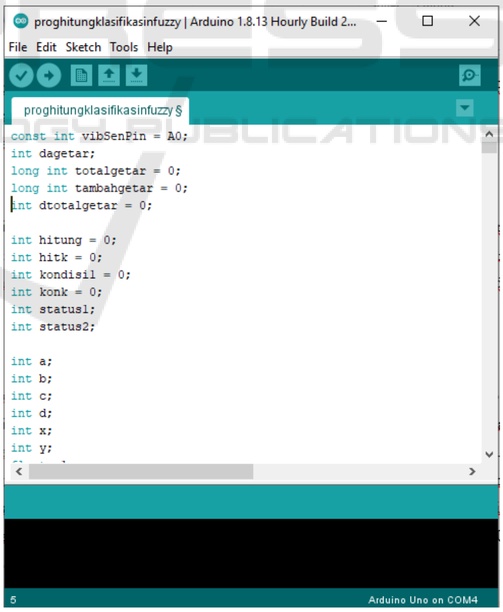

Figure 4: Arduino IDE application.

2.10 Testing Instrument

Data obtained through the SW-420 vibration sensor will be processed in a microcontroller using fuzzy logic methods. Thus the received vibration classification degree will be generated. Furthermore, based on the results of data processing on fuzzy logic classification of vibration levels is obtained.

Figure 9 shows the appearance of the application using the built fuzzy inference system. In the application display, the SW-420 sensor automatically sends data to the Arduino Uno microcontroller when it detects a vibration. Figure 5 shows the application test display.

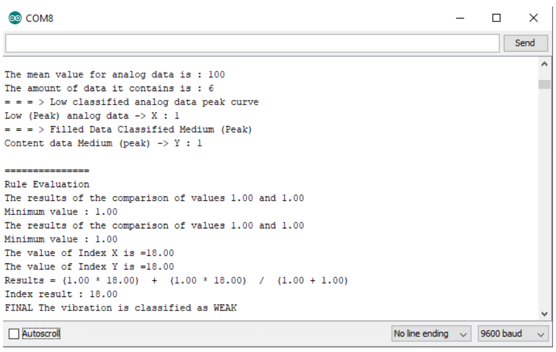

Figure 5: Display of Application Testing.

2.11.1 Input Variable Data Analog

The analog data variable provides information about the average value received from the fifteen incoming data from the SW-420 vibration sensor to the Arduino Uno microcontroller. This data is used to determine the number of detected vibration values so that it can facilitate the classification to determine the degree of vibration detected. The input data can be seen in Figure 6:

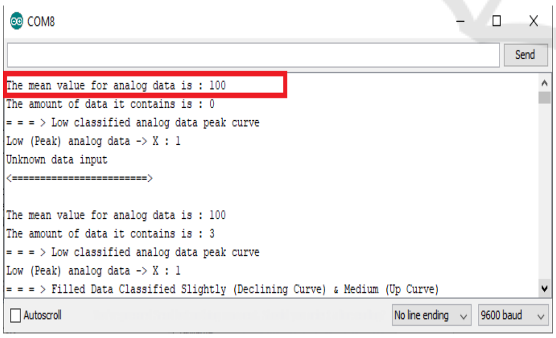

Figure 6: Display of Analog Data Variable Input.

2.11.2 Input for Content Data Variable

The data content variable is a variable that functions to accommodate the amount of data received from the SW-420 vibration sensor. Therefore, every fifteen data entry can be determined how many values contain vibration values and what values do not detect these vibrations. This makes classifications for determining vibration levels easier to create. The display of the data content variables can be seen in Figure 7.

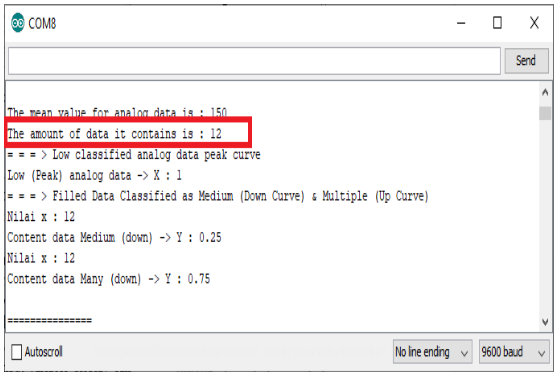

Figure 7: Display of Filled Data Variable Input.

2.11.3 Identify Set Value

Before using the fuzzy logic method, determining the value of the data to be processed must be calculated first by determining the value of each set. The image of the analog data set input value is shown in Figure 8.

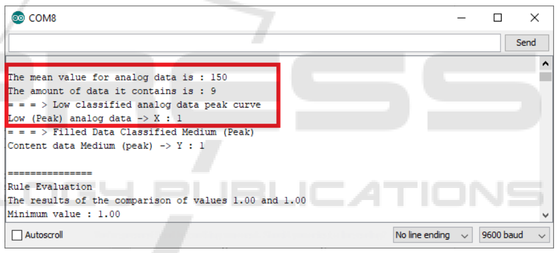

Figure 8: Value of Analog Data Set.

Data from the SW-420 vibration sensor will automatically enter the microcontroller and pass through the Arduino IDE software in the Serial Monitor section. We can see the incoming data directly when one by one the data is processed and calculated until the required amount of data is reached. Then the program will determine the average value of the data. Based on this data, the value is then determined into which category set.

2.11.4 Final Classification

The final step is taken to convert the fuzzy data into easy-to-understand data, in this case it means displaying the final classification of vibrations that have been received and processed by the Arduino Uno microcontroller. The classification results can be in the form of very weak, weak, moderate, strong, and very strong vibration statements. Figure 9 shows a display of final vibration classification results.

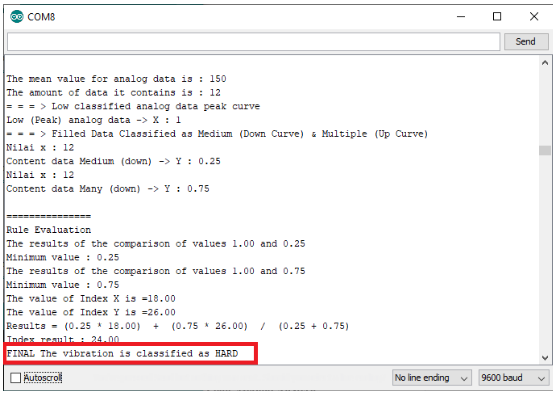

Figure 9: Final Classification.

2.11.5 Fuzzy Logic Method Analysis

In calculating fuzzification manually, 251 analog input data and 7 content data can be taken as an example.

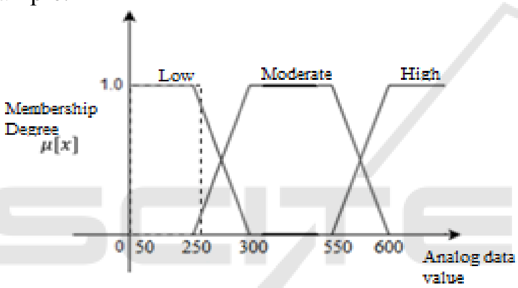

Figure 10: Analog Data Membership.

As shown in Figure 11, the analog data value 251 is included in the low (lower curve) and medium (upper curve) set. The membership degree value can be written as follows:

Low set (down curve)

$\mu\ [x] = 0;\ x \leq a \text{ or } x \geq d$

$(x-a) / (b-a);\ a < x \leq b$

$1;\ b < x \leq c$

$(d-x) / (d-c);\ c < x < d$

$\mu\ [x] = (d-x) / (d-c);\ c < x < d$

$= (300-251) / (300-250);$

$= 49 / 50$

$= 0{,}98$

Moderate set (up curve)

$\mu\ [x] = 0;\ x \leq a \text{ or } x \geq d$

$(x-a) / (b-a);\ a < x \leq b$

$1;\ b < x \leq c$

$(d-x) / (d-c);\ c < x < d$

$\mu\ [x] = (x-a) / (b-a);\ a < x \leq b$

$= (251-250) / (300-250);$

$= 1 / 50$

$= 0{,}02$

Thus the set of μ analog data values obtained is (0.98, 0.02, 0) or μ low [251] = 0.98, μ is medium [251] = 0.02.

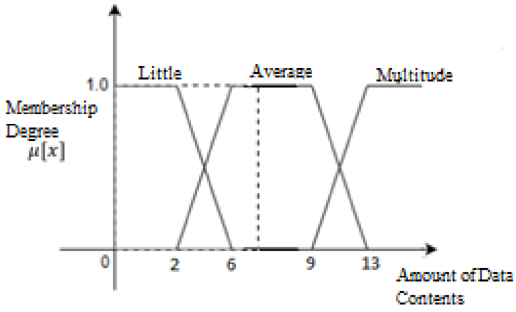

Figure 11: Content Data Membership.

It can be seen in Figure 12 that the value of 7 is on a medium curve (peak), so the degree value can be written as follows:

$\mu\ [y] = 0;\ x \leq a \text{ or } x \geq d$

$(x-a) / (b-a);\ a < x \leq b$

$1;\ b < x \leq c$

$(d-x) / (d-c);\ c < x < d$

Since the value 7 is at the vertex of the moderate set, the formula is that x is less than b and x is less than c, so the y value is 1.

$\mu\ [x] = 1\ ;\ b < x \leq c$

$\mu\ [x] = 1.$

So the set of μ is obtained (0,1,0). After the μ of the two inputs is obtained, the next step is entering into rule evaluation with the minimum comparison method. The minimum comparison is obtained as follows:

$\mu\ (x \cap y)\ (1) = \min\ [\mu\ x\ [\text{Low}] \cap \mu\ y\ [\text{Moderate}]]$

$= \min\ (0{,}98\ ;\ 1)$

$= 0{,}98\ (\text{Low})$

$\mu\ (x \cap y)\ (2) = \min\ [\mu\ x\ [\text{Moderate}] \cap \mu\ y\ [\text{Sedang}]]$

$= \min\ (0{,}02\ ;\ 1)$

$= 0{,}02\ (\text{Low})$

3 RESULTS AND DISCUSSIONS

After the minimum comparison implications have been obtained, the final step is defuzification using the center of single-ton method.

Table 2: Rule Evaluation Fuzzy.

Amount of Data Content \ Analog Data Value	Little (0)	Average (1)	Multitude (0)
Low (0,98)	Average (0)	Multitude (0.98)	Multitude (0)
Moderate (0,02)	Little (0)	Little (0.02)	Multitude (0)
High (0)	Little (0)	Slight (0)	Average (0)

decision index = (0.98x8) + (0.02x18) / (0.98+0.02)
= (7.84 + 0.36) / (1)
= (8.2 / 1)
= 8.2 (Measly)

From the results of the theory that has been done, and is referred to in the vibration level classification table, the vibration level status is said to be in the very small category.

Following are the results of testing the vibration level with digital data without using the fuzzy logic method:

Table 3: Test Results with Vibration Level Digital Data Without Fuzzy Logic Method.

Sensor condition	Information
0	No vibration detected
1	Vibration Detected

Based on the data obtained above, it can be concluded that by using digital input data, the data that can be generated by the sensor is only the presence or absence of a detected vibration and does not at all describe and produce a large level of vibration received by the sensor.

Following are the results of testing the vibration level with analog data without using the fuzzy logic method:

Table 4: Vibration Level Test Results with Analog Data Without Fuzzy Logic Method.

Data Mean Value	Classification Results
0-299	Very weak
300-349	Weak
350-599	Medium
600-649	Stromg
650-700	Very strong

Based on the research that has been carried out to build an algorithm with the support of the fuzzy logic method, the data generated by the SW-420 vibration sensor can produce a better classification than without the fuzzy logic method. By adding the input data used as the determining variable for vibration classification, it can be said that digital and analog data can be utilized properly with maximum work. Previously, digital data was only able to receive binary data, namely 0 and 1, which were received by the sensor so that the sensor could only produce 2 classifications, namely vibration detection and vibration detection without vibration magnitude classification. Whereas the previous analog data was able to receive a vibration level with values ranging from 0-> 700. However, classification by only utilizing a range of vibration values has drawbacks such as a difference of 1 certain value in a condition can affect the results of the classification of vibrations which are considered unfair. For example 1-99 is a small vibration and 100-200 is a moderate vibration. The distance between 99 and 100 is only 1 but even so the vibration will result in a different classification, this is considered ineffective and can cause countermeasures error depending on the type of vibration sensor system applied. With the fuzzy logic method, the vibration classification can be done better and reduce the risk of data errors, so that the cause and effect that will be carried out from the vibration will be more targeted and effective.

4 CONCLUSIONS

Based on the research that has been done, several conclusions are described as follows:

- Fuzzy logic method can be used for classification needs of data taken from the SW-420 vibration sensor using the Arduino Uno microcontroller.

- The use of delay on the sensor can result in data not being successfully received because the sensor may detect data while it is still in the delay process.
- With the fuzzy logic method, the resulting data will be more accurate and can take into account the many variables that determine the results of a data.

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