IOT-BASED REFRIGERATOR MONITORING SYSTEM

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Abstract. Refrigerators are very valuable asset of beverage distribution companies and also assets that are lent to customers for the business process of selling beverage products. Because of the slow response in complaining about damage of the refrigerator from customers, so that refrigerator monitoring system is a technology that creates practical solution for monitoring the refrigerator. Integrated sensors will send data for monitoring through the internet network provided temperature, light, electric current and also can help to decide the division of tasks for technicians who will repair automatically. With a refrigerator monitoring system that uses IoT in beverage distribution companies, hopefully that a monitoring system in the refrigerator is accurate and fast with notifications using email that directly approved by technicians, providing temperature information in the refrigerator, refrigerator lights, making the schedule of the automation system which is directly submitted to the technician so that the repair process is faster.

1. Introduction
The background of this research is considering the numbers of customer’s complains about the damage that happen in the refrigerators or the lamps of the refrigerators that are lent by PT. XYZ. Besides that, the slow fixing process because it is done only when customers report the issue caused the product selling and customer satisfaction are coming down.

Table 1. Top Five of Fixing Visits Duration after the Reports

| Data Problem                                | Total | Average Time Response (Hour) |
|---------------------------------------------|-------|------------------------------|
| Asset/Products are not cold                 | 19546 | 49.32321                     |
| Asset is totally off                        | 5889  | 163.7117                     |
| The lamps are off/broken                   | 5792  | 163.7117                     |
| Asset sounds noisy (not normal)             | 3073  | 313.7219                     |
| Electricity short circuit problem – OHS     | 2680  | 359.5036                     |

In this case study of PT.XYZ, refrigerator is the valuable company asset that is lent to customers for the business process of selling drinking products. From the data analysis above, it needs development or creating system using IoT that will support monitoring process toward refrigerator, so that it can be done quickly and accurately [1].

Now, communication technology has improved use of Internet of Thing (IoT). It is a technology that is able to connect all types of devices [2]. Internet of Things (IoT) offers various communication
designs for handling process, monitoring and setting by using internet communication [3]. One of the utilizations of IoT is Refrigerator monitoring or smart refrigerator.

2. Research Method
Collecting data method of this research is using literature study by studying literatures, research journals and other sources that are related with this research. Researcher did observation using field study which is a technique of collecting data by going to the place by observing the problems directly in the venue systematically, incidents, behavior, objects that can be seen and other things that are needed to support the research. Interview is a data collection technique that is done through face to face and asking – answering directly between data collector towards the data source. From the data collection which is obtained by PT XYZ, data that will be lent is data one year in Jakarta area.

Analysis that is used is qualitative data analysis. Qualitative data analysis is done by collecting, selecting, grouping and taking note the data that is obtained from the source and also giving code so that the data source still can be searched. Monitoring system planning using IoT based, the researcher does integration between software and hardware that can be applied; it is waterfall method.

This application that the researcher develops is an embedded program application for wemos, web service for applications from hardware to send data, console application for fuzzy logic and web – based to monitor dashboard and notification. Hardware planning that the researcher conducts are planning of prototype diagram block tool and electronic module which is used in creating refrigerator monitoring prototype using IoT based.

After implementation step is done, the next step is testing the system that purpose to the final system result that is implemented as the needs. The testing of refrigerator monitoring system with IoT based (case study: PT. XYZ), the researcher uses black box testing. The testing is done only by running or executing the unit as the expected process. In this testing step by using black box testing, the researcher will test the system function, login, control system, authentication process, monitoring system and application setting. The research steps are asking permission for conducting the research, observing the research objects, collecting data process, the analysis method that will be used and project implementation.

3. Results and Discussion

3.1. Application Design
The application designed in this study was developed using the C, C #, data-based programming language using mysql and sql server. In this research, developing an application for monitoring the refrigerator that reports damage to the refrigerator temperature, refrigerator lights and the current connected to the refrigerator [4][5].
Figure 1. Use Case Diagram (Technician).

From the technician use case diagram image above, the process is described as follows:

Technicians can directly access the IoT-based refrigerator monitoring system application to see a list of refrigerators that will be processed for repair. After seeing the details of the request by the technician, the technician will take a process action by pressing the process, completed, or reject button.

The technician will receive a notification from an email regarding a ticket request from a damaged refrigerator. The technician will click the link from the email to see the details of the request to perform the process action, namely by pressing the process, completed, or reject button.

Figure 2. Use Case Diagram (Customer).

From the customer use case diagram above, the process is described as follows:

The customer will receive an automatic notification to an email containing the ticket number, then the customer will track the process via the link in the email. In addition to using email, subscribers can perform tracking from the web provided for tracking from the ticket number in the email.

The hardware design that the authors do includes designing a block diagram of the prototype tool, and the electronic module used in making IoT-based refrigerator monitoring prototypes.
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Variables are used to detect issues in the refrigerator. The light conditions on the refrigerator lamp consist of three conditions: Normal (X1), Faint (X2) and Off (X3).

**Table 2. The of Variable Range of refrigerator’s light Condition**

| Variable | Range      |
|----------|------------|
| Normal   | More than 56 ohm |
| Faint    | 11-58 ohm  |
| Off      | 0-10 ohm   |

The table above is sourced from research conducted with technicians at PT. Xyz, namely the variable conditions to determine the condition of the refrigerator lamp which consists of normal, dim and dead variables, for the variable value using Ohm units. The threshold value above is from the variable category and the value range is obtained from the technician at the research site.

The condition of the cooling temperature gauge in the refrigerator consists of three conditions Cold (X4), Less Cold (X5) and Off (X6).

**Table 3. Table of Variable Range of Refrigerator’s Temperature**

| Variable   | Range     |
|------------|-----------|
| Cold       | 0-11 Celcius |
| Less Cold  | 9-21 Celcius |
| Off        | More than 19 Celcius |

The table above is sourced from research conducted with team technicians at PT. Xyz, namely the variables to determine the temperature conditions of the refrigerator consisting of cold, less cold and dead variables, for the variable value using Celsius units. The threshold value above is from the variable category and the value range is obtained from the technician at the research site.
The condition of the electric current meter in the refrigerator consists of three conditions Normal (X7), Not Normal (X8) and Off (X9).

**Table 4. Table of Variable Range of Electric Current**

| Variable | Range          |
|----------|----------------|
| Normal   | 99-121 watt    |
| Not Normal | More than > 191 watt |
| Off      | Less than 99 watt |

The table above is sourced from research conducted with technicians at PT. Xyz, namely the variable to determine the condition of the refrigerator electric current which consists of normal, abnormal and dead variables, for the variable value using watts. The threshold value above is from the variable category and the value range is obtained from the technician at the research site.

3.2. Manual Fuzzy Logic Calculation Process

The following is a manual calculation for the process of determining whether the refrigerator is damaged or not damaged. The first process is to create a matrix of refrigerator conditions, process rules, calculations and results.

If the condition is damaged and the value of cold temperature, normal light and normal current is given a value of 0 because the following conditions are not damaged and if the temperature is not cold enough, the temperature is off, the light is dim, the light is off, the current is not normal and the current is off then the value is 1 because this condition is the result is broken.

If the condition is not damaged and the value of cold temperature, normal light and normal current is given a value of 1 because the following conditions are not damaged and if the temperature is not cold enough, the temperature is off, the light is dim, the light is off, the current is not normal and the current is off then the value is 0 because of this condition the result is damaged.

**Table 5. Table of Rule Conditions**

| Number | Conditions          |
|--------|---------------------|
| 1.     | IF SD – CN – AN THEN TR |
| 2.     | IF SD – CN – ATN THEN R |
| 3.     | IF SD – CM – AM THEN R |
| 4.     | IF SD – CR – AN THEN R |
| 5.     | IF SD – CR – ATN THEN R |
| 6.     | IF SD – CR – AM THEN R |
| 7.     | IF SD – CM – AN THEN R |
| 8.     | IF SD – CM – ATN THEN R |
| 9.     | IF SD – CM – AM THEN R |
| 10.    | IF SKD – CN – AN THEN R |
| 11.    | IF SKD – CN – ATN THEN R |
| 12.    | IF SKD – CN – AM THEN R |
| 13.    | IF SKD – CR – AN THEN R |
| 14.    | IF SKD – CR – ATN THEN R |
| 15.    | IF SKD – CR – AM THEN R |
| 16.    | IF SKD – CM – AN THEN R |
| 17.    | IF SKD – CM – ATN THEN R |
| 18.    | IF SKD – CM – AM THEN R |
| 19.    | IF SM – CN – AN THEN R |
The table above is the table determining the rules from the combinations in the matrix, namely from the following combinations there are 27 rules.

Information:
- SD is Cold Temperature.
- SKD is Less Cold Temperature.
- BC is Dead Temperature.
- CN is Normal Light.
- CR is Low Light.
- CM is Off Light.
- AN is the Dead Current.
- ATN is Abnormal Current.
- AM is the Dead Current.
- TR is Undamaged.
- R is Damage.

If the refrigerator temperature is 2 Celsius and the refrigerator light is 70 Ohm and the current is 100 Watt.

\[
\mu[x] = \begin{cases} 
0; & x \leq a \\
1; & b \leq x \leq c \\
 \frac{(d-x) / (d-c)}{c \leq x \leq d} 
\end{cases}
\]

(1)

\[
\text{COG} = \frac{\int_a^b \mu_A(x) x \, dx}{\int_a^b \mu_A(x) \, dx}
\]

(2)

Here are the minimum values for a broken rule:
0, 0.01098901098901099, 0.9, 0, 0.01098901098901099, 0, 0, 0.9, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

Here are the minimum values for an undamaged rule:
0.6818181818181818

Take the max value from the list of values for the broken condition: 0.9
Take the max value from the list of values for the undamaged condition: 0.6818181818181818

Calculate with the method of finding the center of gravity, the formula is as follows

\[
\text{COG} = \frac{\int_0^b \mu_A(x) x \, dx}{\int_0^b \mu_A(x) \, dx}
\]

(3)

\[
\text{COG} = \frac{0.1+0.2+0.3+0.4+0.5 \times \text{MaxA}}{\text{MaxA} 	imes 5} + \frac{(0.6+0.7+0.8+0.9+1) \times \text{MaxB}}{\text{MaxB} 	imes 5}
\]

(4)

Calculation of the formula above:
Result formula: \[(0.1 + 0.2 + 0.3 + 0.4 + 0.5) \times 0.9) + ((0.6 + 0.7 + 0.8 + 0.9 + 1) \times 0.6818181818181818) / (0.9 \times 5) + (0.6818181818181818 \times 5)\]
Result formula = \[4.077272727272726 / 7.99090909090908 = 0.5155172413793103\]

![Figure 4. Fuzzy sets for broken and not broken variable.](image)

Image of fuzzy set for damaged and undamaged variables, In the Figure above it can be seen that:
Value 0.1,0.2,0.3,0.4,0.5 including the set Damaged.
Values above> 0.5 include the Undamaged set.
From the above calculations, the value is 0.5155172413793103 if 0.5155172413793103 is entered into the graph, the result is the condition is not damaged

4. Conclusion
The use of the Fuzzy Logic Sugeno method in this research is expected to detect damage to the refrigerator from the data obtained from the temperature, light and current sensors. With the creation of this system, it is expected to be able to monitor the refrigerator accurately and quickly using IoT.

References
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