Design of Waste Transportation Management System Using Fuzzy Logic Algorithm Based on Internet of Things

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Abstract. Garbage is one of the environmental problems faced by society in general. The process of managing and transporting waste that is carried out on a scheduled basis by officers is still not optimal in management. The process of transporting this model is considered ineffective because the volume of waste in the available trash cans is unpredictable. This study aims to apply Internet of Things (IoT) technology in a waste transportation system by applying the Mamdani Fuzzy logic algorithm. The system created serves to draw the best decisions in uncertain problems, namely to determine the condition of the volume of waste by calculating the input parameters based on the distance of the sensor to the object of waste and the time of landfilling. The system development method used in this research is using the Rational Unified Process (RUP) method. The stages in this study include inception, elaboration, construction, and transition. The results of this study are a prototype of a waste transportation management system in the form of a mobile web-based application. Based on the results of tests that have been carried out on the prototype, namely two trash bins, the results show that the system can work well by providing information on the results of measuring the level of waste from the proximity sensor installed in both bins and the results of data processing based on the time parameter can be displayed on the application in the form of notifications. waste transportation decisions that can be made by the cleaning staff.

Keywords: Algorithm; Internet of Thing; Fuzzy; RUP; garbage.

1 Introduction

Inadequate and inefficient waste management systems cause severe environmental problems. In most cities, overflowing trash cans give off a bad smell and make the environment unhygienic, and can cause various kinds of diseases. [1] In research [2] the development of a smart green environment from a waste monitoring system by measuring the level of waste in real-time. Internet of Things monitoring has been used in smart bin designs by connecting them to the Internet of Things.

Research [3] develops practical real-time applications in designing and building prototypes to open and close trash bins automatically to detect human intervention who wants to dispose of their garbage. The depth of the trash in the trash is measured using an ultrasonic sensor and the weight of the trash can with the trash is measured from the load cell [4].

The accumulation of garbage can not only cause unpleasant odors, it can also cause various kinds of diseases. Good waste management is expected to create a cleaner and more

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comfortable environment for its residents. So to overcome one of the problems that arise, it is necessary to create a waste monitoring system that can be monitored in real-time. Research [5] developed a monitoring system for trash bins using the HC-SR04 sensor to detect garbage loads and detect the distance of humans throwing garbage. The results of testing the maximum and minimum distances from the sensor reached an average of 143cm and 0cm. The determination of the action to clean the trash can is determined using the fuzzy logic method with 100% accuracy in determining the action.

This study aims to develop a waste management system based on the level of waste height using an ultrasonic sensor. The system is made to provide notifications to officers through applications that have been installed on smartphone devices. Notifications on the application are the result of data processing from sensor readings using fuzzy logic algorithms. This system can assist officers in scheduling waste transportation according to the condition of the waste level.

2 Methodology

The block diagram of the system design developed in this study is shown in Figure 1. The trash can is equipped with an ultrasonic sensor to measure the level of the waste height. This sensor is connected directly to the ESP8266 microcontroller module. The data sent by the sensor will be sent to the internet via the Wi-Fi module.

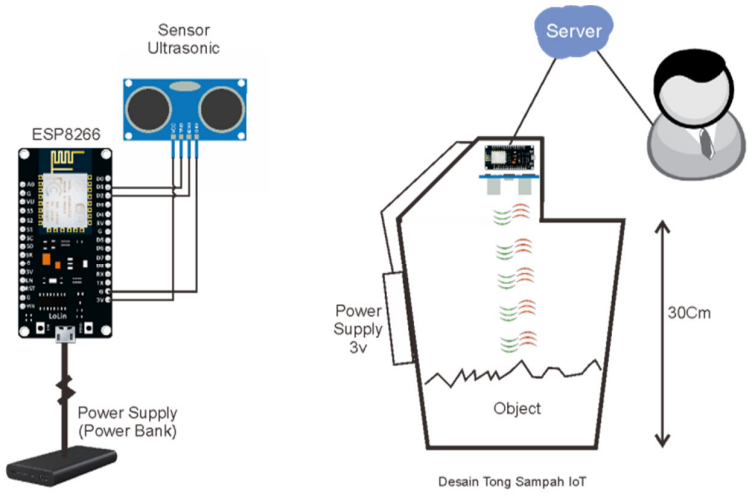
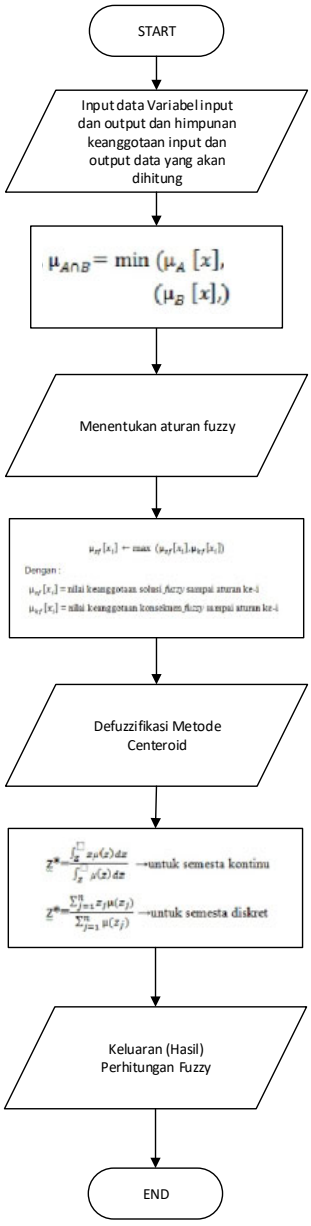


Figure 1. System Block Diagram

In this research, the solution method used is the Fuzzy Mamdani Algorithm. This algorithm is also known as the MIN - MAX method. This method was introduced by Ebrahim Mamdani in 1975.

To solve this research problem, the flowchart of the fuzzy mamdani algorithm is as follows:


START
Input data Variabel input dan output dan himpunan keanggotaan input dan output data yang akan dihitung
$\mu_{A\cap B} = \min(\mu_A[x], (\mu_B[x],)$
Menentukan aturan fuzzy
$\mu_{sf}[x_i] \leftarrow \max(\mu_{sf}[x_i], \mu_{kf}[x_i])$
Dengan :
$\mu_{sf}[x_i]$ = nilai keanggotaan solusi_fuzzy sampai aturan ke-i
$\mu_{kf}[x_i]$ = nilai keanggotaan konsekuen_fuzzy sampai aturan ke-i
Defuzzifikasi Metode Centeroid
$Z^* = \frac{\int_z^{\square} z\mu(z)dz}{\int_z^{\square} \mu(z)dz}$ →untuk semesta kontinu
$Z^* = \frac{\sum_{j=1}^{n} z_j \mu(z_j)}{\sum_{j=1}^{n} \mu(z_j)}$ →untuk semesta diskret
Keluaran (Hasil) Perhitungan Fuzzy
END

3 Result and Discussion

In this section, the results of the research will be discussed which include system design, system implementation, and testing of the system that has been developed. The automatic waste transportation system developed in this study was made in the form of a prototype, the system was designed to be able to provide notifications automatically. waste transportation that can be carried out/works automatically, based on the information on the height of the filled/full trash can. Broadly speaking, this system consists of two parts, namely software/application / system and a trash can that has been installed with ultrasonic sensors.

The system development method used is the Rational Unified Process (RUP). The RUP software development process is described in 2 dimensions, namely the horizontal dimension and the vertical dimension. The horizontal dimension represents the time and stages of development, while the vertical dimension represents the workflow at each stage that needs to be done. RUP stages are Inception, Elaboration, Construction, Transition.

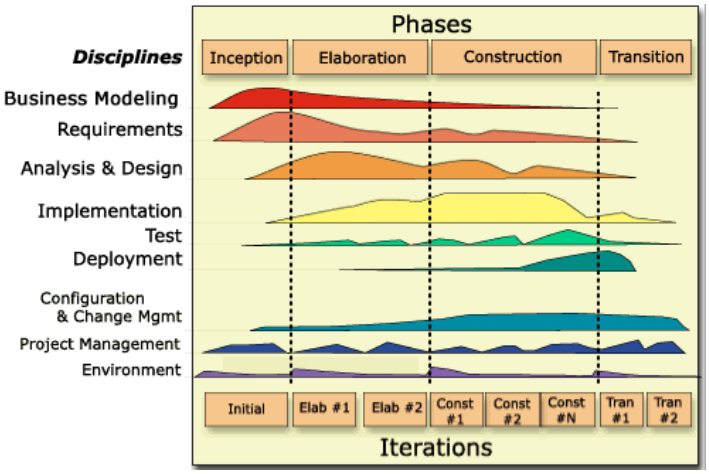


Figure 2. Tahapan *Rational Unified Process* (RUP)

3.1. Mamdani Fuzzy Algorithm

The Mamdani method is often also known as the MIN - MAX method. This method was introduced by Ebrahim Mamdani in 1975. To get the output, it takes 4 stages, including:

3.2. Fuzzy Set Formation

The first stage of the Mamdani Fuzzy Method procedure is the formation of a fuzzy set or also known as fuzzification. For the calculation of the function on the fuzzification as follows:

a. Persamaan fungsi segitiga :

$$\mu[x] = \begin{cases} 0; & x \le a \text{ atau } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(c-b); & b \le x \le c \end{cases}$$

b. Persamaan fungsi trapesium :

$$\mu[x]= \begin{cases} 0; & x \le a \text{ atau } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ 1; & b \le x \le c \\ (d-x)/(d-c); & c \le x \le d \end{cases}$$

Sensor Distance Parameters are divided into three parts, namely Low, Medium and High. The value range of the sensor distance parameter is between 0-30 in centimeters. The degree of membership of the sensor distance parameter is shown in Figure 3.

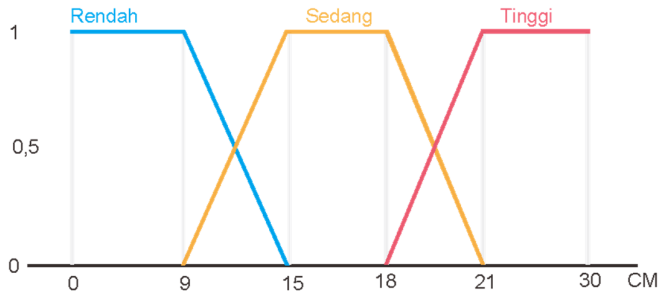


Figure 3. Membership Degrees Proximity Sensor

The fuzzification sensor distance parameter is calculated based on the graph. The following is the equation for the sensor distance parameter in the following equation.

$$\mu\text{Rendah}\,[x] = \begin{cases} 1 & ; x \le 9 \\ \dfrac{15-x}{6} & ; 9 \le x \le 15 \\ 0 & ; x \ge 15 \end{cases}$$

$$\mu\text{Sedang}\,[x] = \begin{cases} & ; 15 \ge x \le\ 18 \\ \dfrac{1}{x-9} & ; 9 \le x \le 15 \\ \dfrac{21-x}{3} & ; 18 \le x \le 21 \end{cases}$$

$$\mu\text{Tinggi}[x] = \begin{cases} 0; x \le 18 \\ x-18 \\ \dfrac{}{3} \\ 1; x \ge 21 \end{cases} \quad 18 \le x \le 21$$

Parameter Waktu dibagi menjadi tiga bagian yaitu Cepat, Sedang dan Lama. Rentang nilai dari parameter waktu yaitu antara 0–72 dalam satuan Jam. Berikut adalah derajat keanggotaan dari parameter waktu pada gambar 4

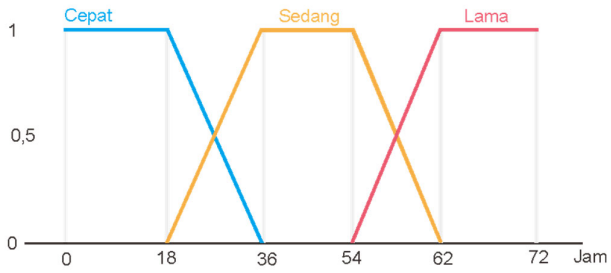


Figure 4. Membership Degree Time

The fuzzification time parameter is calculated based on the graph. Here is the equation for the time parameter.

$$\mu\text{Cepat}\,[x] = \begin{cases} 1; x \leq 18 \\ \dfrac{36 - x}{18}\ 18 \leq x \leq 36 \\ 0; x \geq 36 \end{cases}$$

$$\mu\text{Sedang}[x] = \begin{cases} ; x \leq 18 \\ 0 \\ \dfrac{x - 18}{18}\ ; 18 \leq x \leq 36 \\ \dfrac{62 - x}{8}\ ; 54 \leq x \leq 62 \\ 1\ ; 36 \leq x \leq 54 \end{cases}$$

$$\mu\text{Lama}[x] = \begin{cases} 0; x \leq 54 \\ \dfrac{x - 54}{8}\ 54 \leq x \leq 62 \\ 1; x \geq 62 \end{cases}$$

After obtaining the input and output variables, the next step is to determine the application of the implication function, the implication function used is.

$$\mu_{A \cap B} = \min\,(\mu_A\,[x], (\mu_B\,[x])$$

Berikut adalah aturan yang dibentuk :

[R1] If (Jarak Sensor is Tinggi) and (Waktu is Cepat) then (Pengangkutan is Tidak Angkut).

[R2] If (Jarak Sensor is Tinggi) and (Waktu is Sedang) then (Pengangkutan is Tidak Angkut).

[R3] If (Jarak Sensor is Tinggi) and (Waktu is Lama) then (Pengangkutan is Tidak Angkut).

[R4] If (Jarak Sensor is Sedang) and (Waktu is Cepat) then (Pengangkutan is Tidak Angkut).

[R5] If (Jarak Sensor is Sedang) and (Waktu is Sedang) then (Pengangkutan is Tidak Angkut).

[R6] If (Jarak Sensor is Sedang) and (Waktu is Lama) then (Pengangkutan is Angkut).

[R7] If (Jarak Sensor is Rendah) and (Waktu is Cepat) then (Pengangkutan is Angkut).

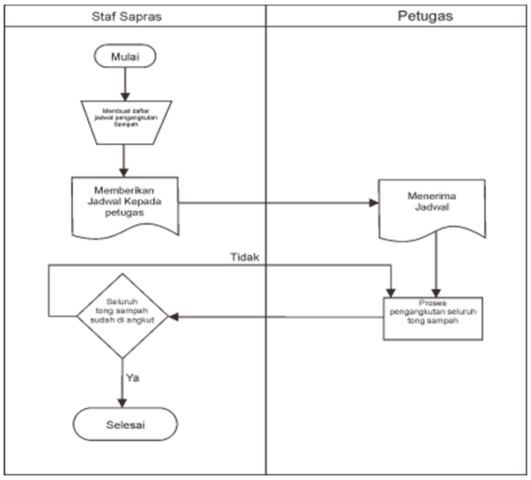
[R8] If (Jarak Sensor is Rendah) and (Waktu is Sedang) then (Pengangkutan is Angkut).

[R9] If (Jarak Sensor is Rendah) and (Waktu is Lama) then (Pengangkutan is Angkut).

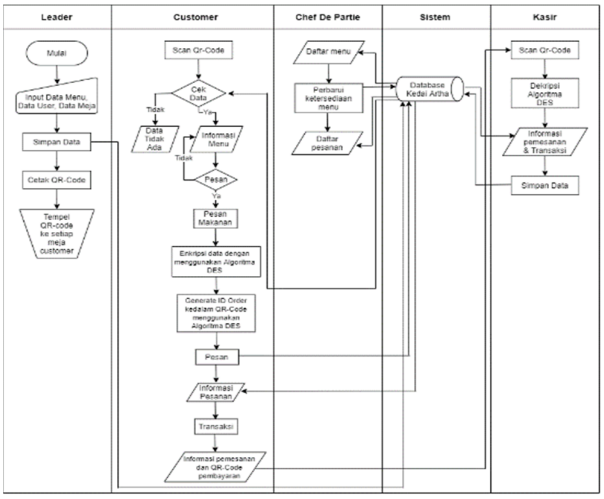
After obtaining the results of the implication function, the next step is to determine the composition of each rule and method used in performing fuzzy system inference. There are 3 methods used in performing fuzzy system inference, namely max, additive and probabilistic OR (probor).

a) System Design

The initial stage for the design is the analysis of the current system. (Figure 2). The next stage, the researcher makes a proposed system design that will be developed. The results of the system design to be made are shown in Figure 5.



Gambar 2. Flowmap Sistem Berjalan



Gambar 3. Flowmap Sistem Usulan

Metode perancangan atau pemodelan perangkat lunak yang digunakan dalam penelitian ini yaitu Unified Modeling Process (UML).

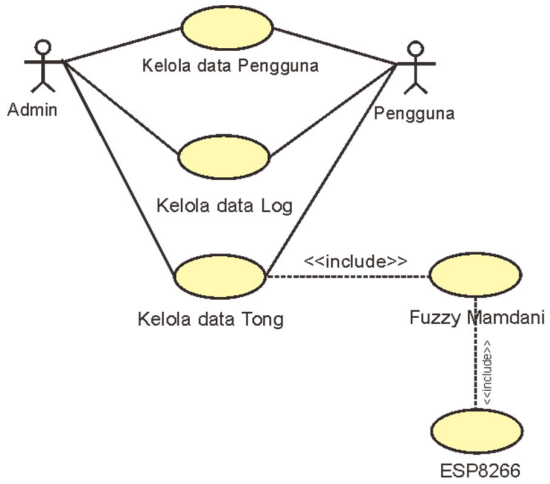


Figure 5. Use Case Diagram

b) System Implementation

The next stage of the research is testing the system interface, namely applications developed on smart phones and desktops. The display of the developed application is shown in Figure 6.

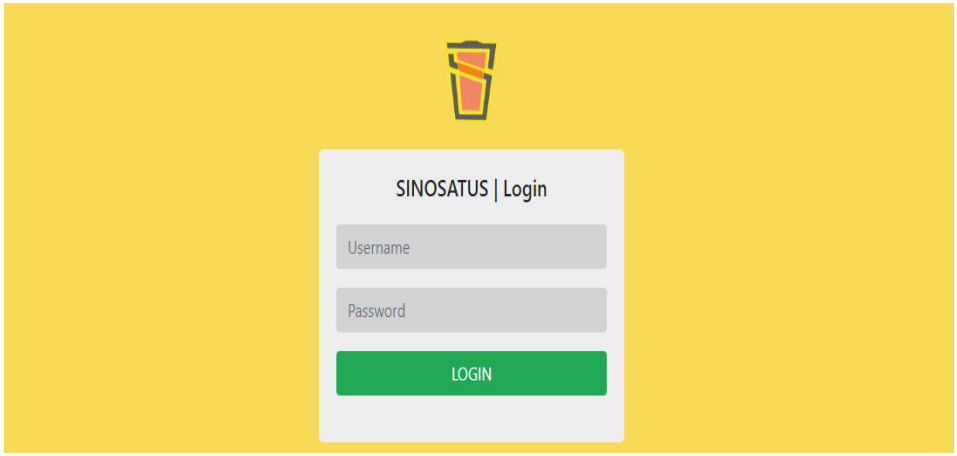


Figure 6. Aplication Login Page

Figure 6 is the login page for admins and officers. To be able to login the user must enter a username and password.

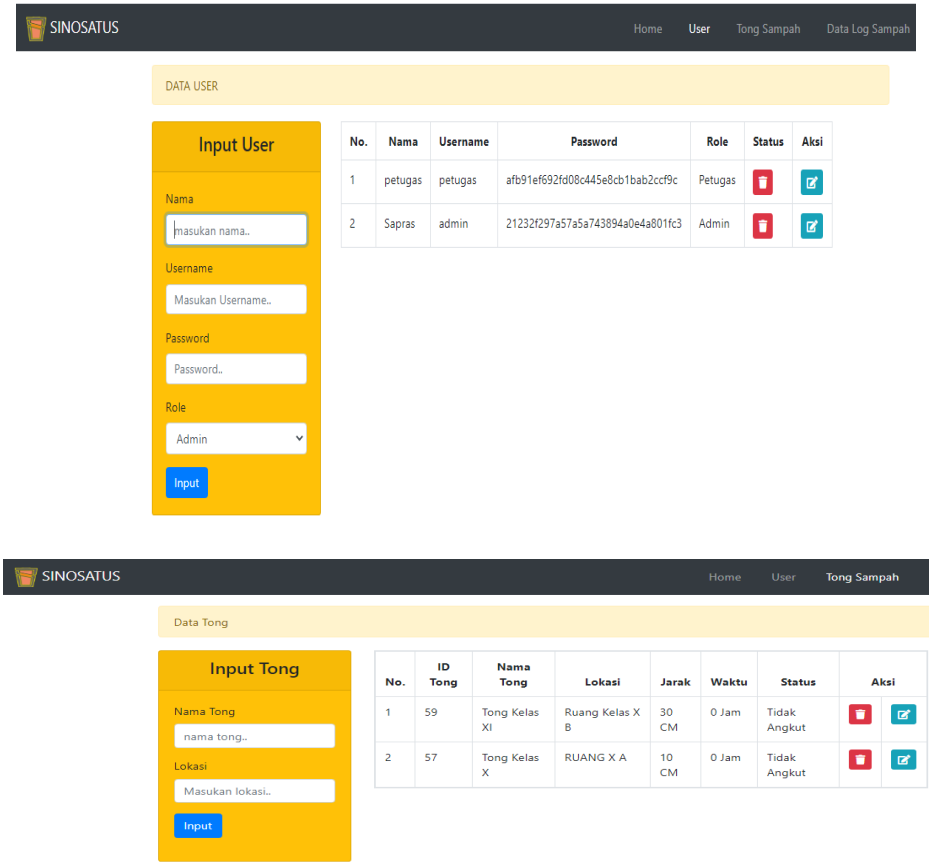


Figure 7. Dasboard website

On the detail menu page, the admin can monitor the level of the trash can in each room.

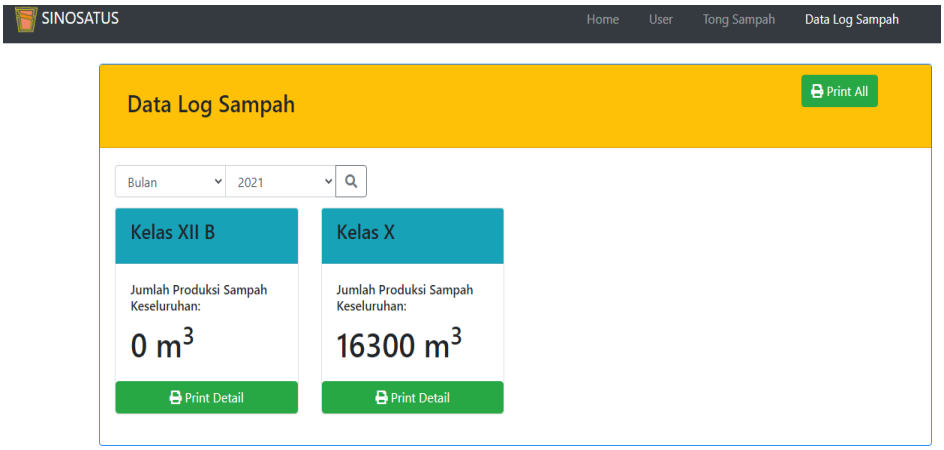


Figure 8. Data Log

Figure 9 shows the prototype design of the trash can that was developed consisting of an integrated sensor and a microcontroller as a data processing center. The next testing process is to determine the performance of the system made, the authors make a prototype, namely a trash can that has been fitted with an ultrasonic sensor. The ultrasonic sensor functions to read objects in the trash, which is used to measure the height of the trash level in the trash can.

Gambar 9. Trash can prototype.

As previously mentioned, this study develops a waste transportation system by applying fuzzy logic algorithms for decision making in collecting waste in the form of notifications on the application.

4 Conclusion

This research produces a prototype of an android-based garbage transportation system by applying a fuzzy algorithm. The prototype was developed using an ultrasonic sensor module to detect the level of waste in the trash can. Based on the test results, the system can work well according to the design. Information on the condition of the height of the waste level can be displayed on a smartphone device in real-time. Officers receive notification of waste transportation status. If the trash can is full, the system will automatically notify the officer, for further transportation.

The development of a waste transportation system is expected to be a solution to the problem of managing waste that accumulates which can cause unfavorable conditions for the surrounding environment. So that this system can be developed to assist sanitation officers in monitoring the condition of the trash.

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