STTS: IoT-based Smart Trash Tracking System for Dumpsters Monitoring using Web Technology

Padma Nyoman Crisnapat 1*, I Komang Agus Ady Aryanto 1, Made Satria Wibawa 1, I Nyoman Kusuma Wardana 1, Dedy Panji Agustino 2, Arkav Juliandri 3, Ann Margareth 3, Ricky Aurelius Nurtanto Diaz 1, Naser Jawas 1, I Made Sarjana 4

1 Computer System Department, STIKOM Bali, Denpasar-Bali, Indonesia
2 Information System Department, STIKOM Bali, Denpasar-Bali, Indonesia
3 PT XL Axiata Tbk, Jakarta, Indonesia
4 Electrical Engineering Department, Politeknik Negeri Bali, Badung-Bali, Indonesia

Abstract. Waste management is one of the main problems being faced by our society. The dumpsters that usually overflow prior to the scheduled cleaning time becomes the common problem as it might trigger other unwanted problems such as bad odor, clogged drains, and various diseases. To prevent such malicious effects, the IoT-based dumpster management system has been developed. This paper in turn aims to propose a smart monitoring system installed on a dumpster. The device will send signals to the web server. The verified signals from each dumpster announce the operators that the waste has to be cleaned. The system is accessible through the web interface and alternatively through the Android-based devices. It is expected that the developed system is able to provide an easier waste management system for society.

1. Introduction

A research published in 2015 by Jambeck revealed that Indonesia is ranked as the second largest waste contributor in the ocean after China. In every year, Indonesia contributes up to 187.2 million tons of waste while China reaches 262.9 million tons. Up to 83.4 million tons of waste are thrown away in the ocean by The Philippines as Indonesian’s neighboring country. The waste produced by society’s daily life is usually remained hidden from the public concern. This waste may be out to the river and then flows to the ocean.

One reason why people prefer to throw away the garbage into the river rather than into the dumpster is related to the dumpster location that is difficult to be reached. Besides, the overflowed dumpster is also another main reason. The overflowed dumpster may cause the bad odor - a condition avoided by people. Many dumpsters are placed on the banks of a river (see Figure 1). The location is selected solely because this location is owned by the local government. Most people refuse to donate their place for a landfill.

Based on Jembrana District Government’ data, in 2009 the population number in Jembrana-Bali reached 269,859 people. This figure increased by 19.42% in the end of December 2016 into 322,256 people. This increase in population has led to an increase in the level of urbanization. The demand for urban infrastructure particularly related to waste will increase, and therefore there will be a rapid and drastic change. Prior to the changes, an appropriate planning is required. The facility of TPS (Waste Disposal Site) in urban areas is closely related to the daily life of the inhabitants, so that the location planning should have a more serious attention.
To keep the environment clean and safe, an Internet of Things Technology (IoT) can be an alternative to be applied. The improved safety and quality of life can be achieved by systematically connecting the devices and other infrastructures around the city. The smart city paradigm can be built by involving all stakeholders to work together\textsuperscript{2-4}. System integrators, network operators, and technology providers are encouraged to work together with local government to reach the smart solutions. The Internet of Things (IoT) is a network of networks in which a massive number of objects, sensors, or devices are connected through the ICT infrastructure to provide the value-added services\textsuperscript{5}. The IoT connects people and things anytime, anywhere with anything and anyone, ideally using any path or network and any service. Over the last few years, the plethora of IoT solutions, products, and services make their way into the industry's marketplace\textsuperscript{6}. By 2020, 50 to 100 billion devices will be connected to the Internet\textsuperscript{7}. The use of IoT can make the efficient use of energy in managing and monitoring things\textsuperscript{8}.

Based upon the current condition, a \textit{Smart Trash Tracking System} (STTS) is proposed as an alternative solution. By implementing IoT Technology, each landfill or dumpster is equipped with a smart device. This device is able to detect the waste volume, whether in full, moderate, or in empty condition. The reflected dumpster condition is announced to the respective operators remotely by implementing the web-based technology. Moreover, to reduce the electric power consumption, a solar panel is implemented as an alternative power source. The proposed STSS is expected to enhance the quality of community service.

2. Experimental

Figure 1 shows the STSS main idea. A device composed by a microcontroller, an ultrasonic sensor, a GPRS module and a power supply device was installed on a dumpster.
The installed sensor was controlled by a microcontroller and the collected data would be sent to the server (cloud) through the internet connection. Main processes such as reading and delivering the data would be controlled by a microcontroller. The stored data in the server would be used as the information accessible by the user. In this case, the user is the operator on duty.

![Figure 3. The hardware layout](image)

Figure 3 shows the hardware layout. As shown in the top view, an ultrasonic sensor was placed in the middle of the device. A microcontroller is the main part that controlled all processes (reading the data from sensor, sending data to server, or accessing GPRS module). To powering all parts, 1300mAh-battery cells were used. These batteries were charged by the solar panels.

![Figure 4. The installed device on the dumpster](image)
3. Result and Discussion

The workflow begins by collecting the data from the sensors. Then, the system prepares the communication service with web server through the internet protocols. The communication process is provided by the GPRS module which is installed on the microcontroller board. By implementing wireless communication, the system can be integrated with other networks. The HTTP (Hypertext Transfer Protocol) is used as data transfer protocol. It defines how the data will be sent from client to server (and vice versa) when the web server should do their duties, and when the results will send back to the web browser. Therefore, each object will send and receive the data through the web server. The collected data is stored on the database in which they will be processed to obtain the percentage amount of waste. The final result will be displayed on the web interface. Some modern frameworks such as JavaScript and CSS are implemented to build the interface. These frameworks are designed to provide the device compatibility, regardless the monitor’s size. Figure 4 presents the software scheme.

The main hardware used in this research is Arduino Leonardo board equipped with an Atmel ATmega32u4 microcontroller featured by 14 digital I/O pins. These pins were composed by seven PWM outputs, two Serial in-Out pins, and the rest was used as standard digital I/O pins. Moreover, this board was featured by 6 analog I/O pins, which were useful for reading the data from any analog sensors. The communication system was provided by GPRS SIM 800L board. The board supported the quad band GSM/GPRS network. The data could be sent by using GPRS or SMS method. The GPRS and Leonardo board were connected to each other through UART protocol.

The ultrasonic sensor was based on sound wave concept. The sensor would detect the received sound wave, reflected by a particular surface. The time travel of the sound wave was then calculated to find the distance between the sensor and the target surface. Figure 5 presents the Hardware Architecture.

![Figure 5. The software schematic](image1)

![Figure 6. Hardware architecture](image2)
Figure 7. Web Based Monitoring System

Figure 6 presents the web interface. The interface displayed the dumpster conditions in a real-time. The interface was designed in the form of block-by-block, each of which was equipped by a module’s identity for the easiness of monitoring process. Every calculation related to the dumpster condition would be displayed by progress bar along with their respective value. The level of waste was displayed by two different colors (green, yellow and red). For examples,

1. if the waste level was below 50, then the graph was displayed in green color, stating that the dumpster was empty
2. if the waste level was above 50 but below 70, then the graph was displayed in yellow color, stating that the dumpster was moderately full
3. the last, if the waste level was above 75, then the graph was displayed in red color, stating that the dumpster was full

After sensor and program have been integrated, the next stage was system evaluation. This evaluation was divided into three parts: evaluation of device, software, and system. The evaluation results are shown in Table 1-3. Based on the evaluation that has been done, all functionality was found running as planned.

| No | Examination scenario | Expected target | Result |
|----|----------------------|-----------------|--------|
| 1  | Device condition just after started | Connected to the internet automatically | On target |
| 2  | Opening the serial port for observing the collected data from the sensors | Serial monitor can display the sensor data | On target |
| 3  | Opening the database for observing the sending data through internet protocol. | The data on database changes according to the received data | On target |

Table 2. Software Evaluation

| No | Examination scenario | Expected target | Result |
|----|----------------------|-----------------|--------|
| 1  | Accessing web for the first time | Login page will be displayed | On target |
| 2  | Accessing the web interface on the dashboard page | Data panel will display the information about the percentage of the dumpster capacity | On target |
| 3  | Opening the CV page and choosing the data personal menu | Displaying the admin’s CV page | On target |
| 4  | At the CV page, choosing the button to change the CV | Displaying the page for changing the CV and then the admin changes his/her identity | On target |
| 5  | Choose to change password for admin | Displaying the page for changing | On target |
and change the account password the password and then the admin
deciding the new password

6 Choosing the operator menu Displaying all lists of the
operator data On target

7 Choosing the add operator menu Displaying the page for adding
the operator data. Admin can change the new data. On target

8 Admin chooses and changes the The operator’s data will be
operator identity displayed in detail and then the
admin can change the operator
data. On target

9 Admin chooses menu for changing Changing operator’s password
the operator’s password and decides successfully On target
which operator will be changed.

10 Choosing menu for deciding the Displaying the list of dumpster’s
dumpster’s location data On target
11 Choosing dumpster’s location menu The dumpster data is stored on
and inserting the new dumpster’s data the database. On the dashboard
page it will be automatically
displaying the dumpster capacity

12 Choosing and changing the Displaying the dumpster’s data. On target
dumpster’s data Admin can change those data.

13 Deleting the dumpster’s data The data is erasable On target

14 Deleting the operator’s data The data removed from database On target

| Table 3. System Evaluation |
|----------------------------|
| No | Examination scenario | Expected target | Result |
|----|-----------------------|-----------------|--------|
| 1  | Waste level below 50% | Progress bar on interface is green. | On target |
| 2  | Waste level above 50% and below 75% | Progress bar on interface is orange | On target |
| 3  | Waste level above 75% and below or equal to 100% | Progress bar on interface is red | On target |

In this study using 20Wp polycrystalline solar panels and batteries with 12V 12Ah capacity. In the experiment, the battery is fully charged with a voltage of approximately 12V so that the controller automatically adjusts the energy consumption to the battery when the solar panels in a state that does not produce energy that is at night. This controller circuit is tasked as disconnecting and charging to the battery. If the voltage in the battery drops then the controller will fill it with solar panel as its power. This charging process takes place when there is sunlight, if the voltage drops at night then the controller will automatically disconnect the supply of electrical energy. Conversely after the charging takes place and the battery voltage has risen, then the controller will disconnect the charging process.

GPRS SIM800L module is used with supported voltage regulator to get 4.2V. For testing the data transmission by this module into the sensor using the HTTP protocol. If the data submitted by this Module is already stored in the database with a pre-configured web service then the data submission process has been successful. The Transfer / Receiver data process is also affected by the provider card used as well as the signal conditions. Test has been done by sending 42 characters repeatedly, and the result that there is delay for an average of 3 seconds.

The ultrasonic sensor accuracy testing process is seen based on the ratio of values obtained by the sensor to the manual measurement using ruler. Intake of data on sensor every 1 (one) minute for one data. There is difference between sensor measurement result and ruler as much as 3.87% error percentage. Comparation table is shown in table 4.
4. Conclusion and Future Work

From the research a number of conclusions can be drawn as follows:

1. This research can be a media for announcing the waste level in the dumpster. This system is composed by a microcontroller and GPRS module.
2. Communication system implementing by a web server is accessible remotely. The system can be also accessible using any devices with a different monitor’s size.
3. Based on the module’s identity, the collected sensor data can be stored on the database
4. The dumpster’s condition can be categorized into empty, moderate and full.
5. The communication system between the device and the web server process is implemented by HTTP:// protocol in duplex mode.
6. The next project will be focused on the security testing for the network and also using a more accurate sensor and GPRS Module.

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