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Design a Smart Waste Bin for Smart Waste Management

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***Abstract*—In this paper, we presented the smart waste-bin that can managed the waste in a smart city project. The system consist of sensors to measure the weight of waste and the level of waste inside the bin. The system also adapt with network environment, to manage all information from waste management. As the result we proposed a prototype of smart waste-bin that suitable for many kind of conventional waste-bin.**

Keywords—Smart City; Smart Waste-bin; Waste Management; Load Cell;

I. INTRODUCTION

A Smart City is a city development to manage multiple information and communication technology(ICT) in order to make a solution for any problem in the city. Smart city includes many information such as, local department information system, schools, libraries, transportation system, hospital, power plants, law, traffic system, waste management, and others city services. The goal of a smart city is to improve an efficiency of services and connect all information into one system. Nowadays, development of ICT especially internet of things (IoT) allow the city to be developed into a smart city.

The aforementioned concept is being realized through the use of real-time systems and sensors, where (a) data are collected from citizens and objects (things), then (b) processed in real-time and finally (c) the gathered information and related extracted knowledge are becoming the keys to tackling inefficiency [1].

In this context, waste management involves numerous waste bins that exhibit significant filling variations (over days and seasons or location) and diverse requirements for emptying, from sporadic (a few times within a week) to very frequent (several times a day). On the other hand, other waste forms (i.e. agricultural, biomedical, chemical, electronic, mineral, organic/inorganic, and radioactive, etc.) are characterized by specific collection points, uniform and predictable production, and equal, usually long, filling periods. The detection of the fill-level for urban solid-waste-bins presents many difficulties due to the various irregularities of the waste-bin filling process, such as the irregular shape and the variety of the included materials [2].

More challenges exist for the economical and energy efficient data aggregation from a large number of bins, as the harsh environmental conditions (e.g., humidity, temperature, and dust) can significantly affect the sensor measurement accuracy and reliability, while on the other hand these conditions constitute parameters that one should also take into account for a holistic waste management process [3].

II. PROPOSED DESIGN

The main concept of smart waste management is to handle all the waste in the city and monitoring all the process. Fig. 1 explains the proposed system environment.

To develop that environment, we proposed a design of a smart waste-bin. A smart waste-bin consists of a smart sensor and smart communication. Here is the detailed design system of a smart waste-bin:

A. General System

Our proposed smart waste-bin system can be adapted into general waste-bin and it consists of the sensing units, a bluetooth and GSM Module for data transmission, and a mobile application and web-based monitoring for interfacing and communication with the waste department for waste management. The general system of our proposed system is shown in Fig. 2 and the system flowchart is shown in Fig. 3.

The smart bin is composed of sensor node mounted on it for the data collection and transmission [4]. The sensors are divided into two path. One path is mounted with the bin cover and the other is in the bottom of the bin. The first path is level sensor to monitoring the level of waste-bin. The other path is smart load cell sensor to calculate the weight of waste.

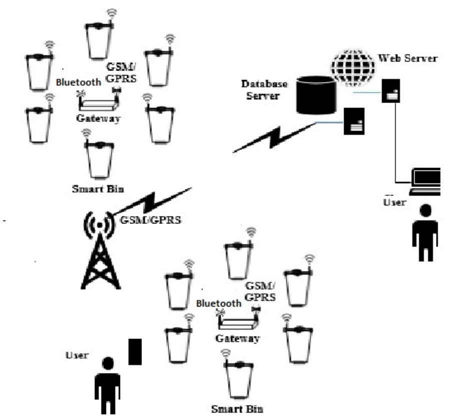

Fig. 1. Smart waste management environment.

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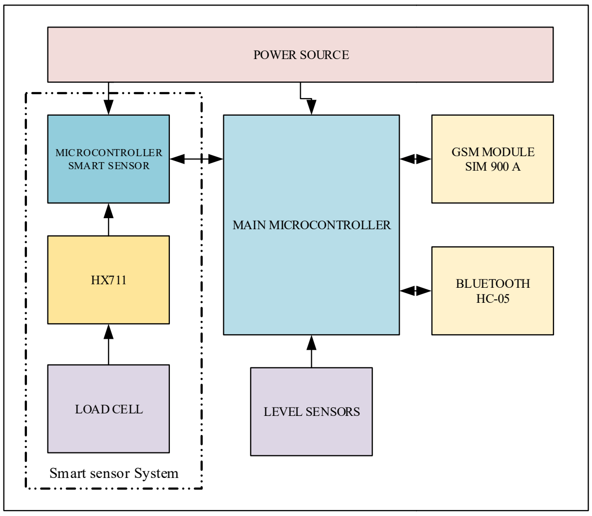

Fig. 2 General architecture of smart waste bin.

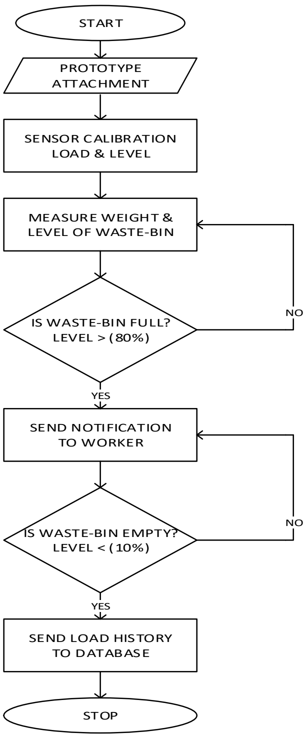

Fig. 3 Flowchart of prototype waste-bin.

B. Load Sensors

Load cell is a measuring device used to measure loads either directly or indirectly. Various types of load cells exist, these include: hydraulic load cells, pneumatic load cells and strain gauge load cells. In this paper, only the last type, namely the strain gauge load cells will be considered. This type of load cell is a transducer which converts a force into an electrical signal. This conversion is indirect and happens in two stages. Through a mechanical arrangement, the force being ensued deforms a strain gauge element. The strain gauge measures the deformation (strain) as an electrical signal, because the strain changes the effective electrical resistance of the wire [5].

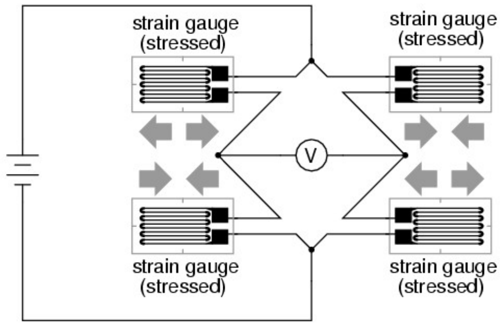

Fig. 4 Wheatstone for load cell.

Strain gauge load cells are the most commonly used in industry and research. These load cells are particularly stiff, have very good resonance values, and tend to have long life cycles in application. Strain gauge load cells work on the principle that the strain gauge deforms/stretches/contracts when the material of the load cells deforms appropriately. These values are extremely small and are relational to the stress and/or strain that the material load cell is undergoing at the time. The change in resistance of the strain gauge element provides an electrical measurable value change.

The strain gauge load cell usually consists of four strain gauge elements connected in a Wheatstone bridge (Fig. 4) configuration to measure the electric signal. Other measuring devices of the signal, but normally Wheatstone bridge is the one used due to simplicity availability and reliability.

Load Sensors was a four wire load sensor, with two excitation wires (power and ground) and two signal wires (positive and negative signal). The Wheatstone-Bridge circuit is integrated into the sensor. It had a rated loading of 750 kg and an accuracy grade of 0.02% full scale. For outdoor applications the load cell was also rated IP65, which guaranteed protection from dust and water jets. Because our system can attached into any waste-bin so we made the load cell can self-callibration depend on where it attached into waste-bin.

Load cells are very linear devices and therefore it is often possible to calibrate them by an easy and reliable method, that is the dead weight, noting that if the actual system capacity is small, it should be calibrated [6].

Load cells has a lot of benefit: low cost, ease of implementation, ability to detect large system non-linearity throughout the span. The only deficiency is their relatively low accuracy as they will not identify small to moderate slope errors. The procedure is as follows:

- Acquire zero point in system instrumentation.
- Apply partial deadweight and acquire/adjust a span point in the system load cell and record the output.
- Add more dead weight and repeat point 2 in the procedure
- Re-apply dead weight and observe change in measured value. It should be the same as the deadweight value
- Continue to add more dead weight to cover the whole span following the previous steps

C. Level Sensor

To measure the level of waste in the waste-bin we used ultrasonic sensor attached in the top side of waste-bin. The ultrasonic sensors are advantageous in providing ranging measurements independently of the contained objects, thus making possible the corresponding translation into fill level measurements. Moreover, ultrasonic sensors are most suitable to this application because they can be placed on the lid and thus avoiding harsh conditions (contact with waste, washing procedure etc.) of the main compartment. Finally, the chosen ultrasonic sensors can have a beam with a wide field of view and therefore the whole bin can be sensed with a limited number of sensors, thus reducing cabling and interconnection needs.

We used HC-SR04 for sensing the level of waste. This sensor provides 2cm to 400cm of non-contact measurement functionality with a ranging accuracy that can reach up to 3mm. Each HC-SR04 module includes an ultrasonic transmitter, a receiver and a control circuit.

D. Microcontroller

A microcontroller will be programmed in such a way that it would control the power from being wasted. Microprocessor will allow the voltage to flow across sensors after a certain period of time. Monitoring the bin at every interval will lead to waste to energy through sensors. Thus, the sensors will be activated only after certain intervals of time. The output of Bluetooth and GSM is also controlled by microcontroller.

An ultrasonic sensors as level sensor will be installed at top portion of the bin. Along with it there will be load cells for pressure measurement purpose. Ultrasonic sensors will be interfaced with ultrasonic signal conditioning chip. Whereas the signal from array of 4 load cells will be given to Analog to Digital Converter. Microcontroller will receive inputs. It will perform signal processing as per signal processing algorithms. With the help of an electronic switch and timing circuit in microcontroller the voltage of battery of sensors will be controlled. Microcontroller will communicate to GSM modem through UART. GSM modem will send the data to the municipality head office. So they will get data and notification before their periodic interval visit of picking up dustbin.

E. Waste Management

- GSM Module: A GSM module is used to communicate with server. It will send priodically the information of waste weight and bin capacity. When waste-bin is full it will send directly notification for worker to pick the waste.
- Bluetooth: Bluetooth is attached for short range communication. It is used by the worker for maintenance should there is system fault. It also communicates with the application to get the data if GSM modul have a problem. A bluetooth connect trough a mobile application and share information about the weight of waste in waste-bin.
- Mobile Applicaton: For efficient waste management, a mobile application is also made to help worker picking and managing the waste bin. The notification sent from GSM module also came up in mobile application. So it can make the handle of a fully waste-bin faster.We used app inventor to develop a mobile application running in android platform. Fig. 5 shows the interface of the mobile application.
- Web-based Monitoring: Web-based monitoring is the place that all data from all waste-bin is managed. It will show the graphic daily, weekly, monthly, and yearly about the number of waste in all the city. Development of the website use code igniter, while php and mysql are used for the database [7].

III. Results

A prototype of smart waste-bin is made consists of devices as explained in previous sections. Fig. 7 shows the picture inside of prototype.

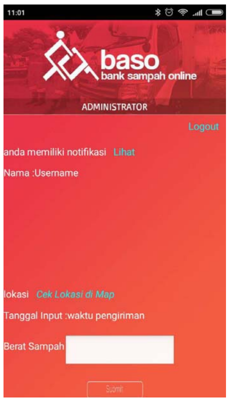

Fig. 5 Mobile application of waste-management.

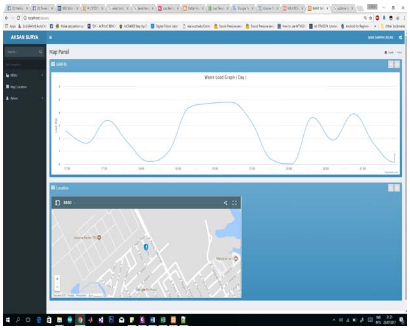

Fig. 6 Web services interface.

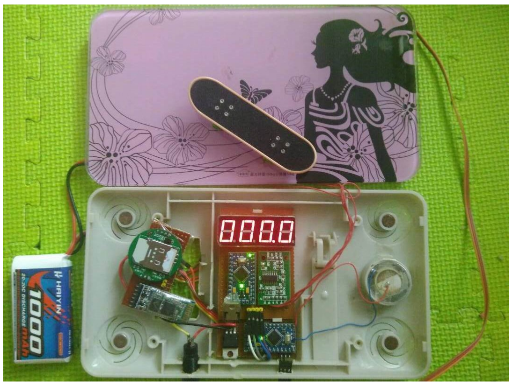

Fig. 7 Prototype of smart waste-bin.

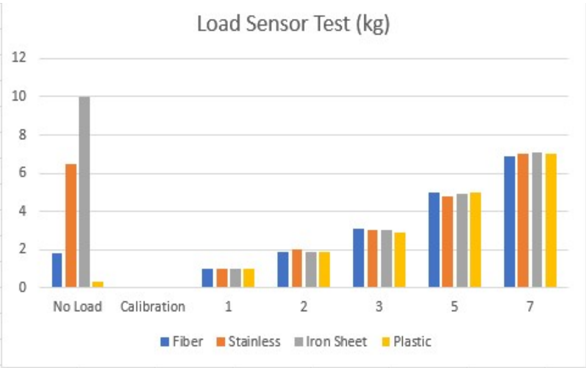

Fig. 8 Load sensor test result.

We tested some of parameters that indicate the prototype of smart waste-bin works well and addapt in a real enviroment.

1. *Load Sensor*: Load sensor is tested using brass weight set with four different kind of conventional waste-bin that usually used in the road and public place. First is, fiber waste-bin 60L, stainless waste-bin 40L, iron sheet waste-bin 45 90L, and plastic waste-bin 30L. Fig. 8 shows the result of load sensor using brass weight set as the dummy load. In Fig. 8, we can calculate that each waste-bin have an error percentage of measurement. Fiber have an error 2,0%, stainless 0,8%, iron sheet 1,7%, and plastic 1,7%. The maximum error observed is approximately 5%, which is considered to be significantly low, taking into account that the accurate volume value of a waste-bin's contents does not provide more information to a designated authority than the fill level status approximation does. A few experiments with uniform placement of the cardboard boxes have also been performed in order to verify sensors and measurements accuracy, which concluded to a less than 3% error.

2. *Level Sensor*: Level sensor is also tested by using four kind of convectional waste-bin. Fiber 120cm, stainless 60cm, iron sheet 50cm, and plastic 30cm. Level sensor using hcsr-04 is produce the distance of an object in front of sensor. This means the more waste in the bin the closer object in front of sensor. To test the level sensor, we use meter roll to manually measure the level of waste. In the program, we set level sensor as percentage level waste in waste-bin Fig. 9 shows the result of leveling sensor in different waste-bin.

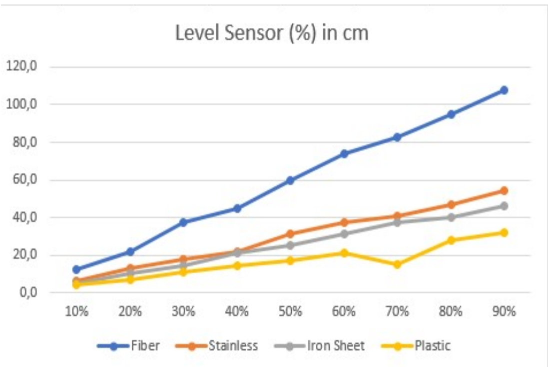

Fig. 9 Level sensor test result.

In Fig. 9 we can see that both of ping sensor and manually measurement using meter roll have less error percentage. The average of error percentage of level sensor is 3-5%. It means that the sensor can measure the waste level in the bin.

3. *Network Communication*: We conducted experiments to evaluate the response performance of network communication using GSM Communication that connect all the node into web services as shown in Fig. 1. The experiments are aimed to determine the response time between waste-bin as a node and web services. We use four different kind of network GSM provider and 3-time monitoring condition. Morning, noon, and night. The result that shown in figure 10 describes the average of response time of network communication is 60-100 seconds. That is quite fast if we compare for the time range to get data in hour or day. So, the system has a quick response to monitor the condition of waste-bin.

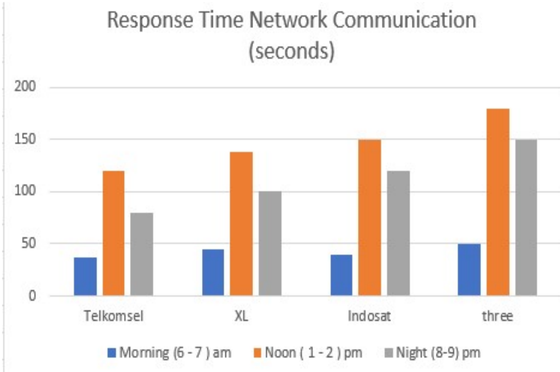

Fig. 10 Response time network communication.

IV. Conclusion

Through this paper we intend to propose a technological process for waste management system. We started from smart waste-bin. By using network environment, the real time accurate data from the implemented system could be used for the efficient solid waste management system. The system can collect accurate data on real time which can be used further as an input to a management system. With load cell calibration approach, it simplify the calibration process so it can be attached to commonly used waste-bin without changed or modification. The level sensors also can be attached to common waste-bin. So the protoype is suitable for using in conventional waste management infrastructure.

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