Solid Waste Management And Collection System In Metro Manila With Dijkstra Algorithm And Internet Of Things

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Abstract: Solid Waste is one of the major problems of the Philippine government due to rapid growth of population. People are dumping waste on streets, open drainage and even rivers. Waste management is one of the solutions that tends to provide programs and to create mechanisms, encouragements and funds that hold responsibilities in implementing ordinances and laws of local government units. Thus, this research focuses on the development and application of a waste management system which segregates biodegradable and non-biodegradable wastes, measures the level of waste inside the container and helps the waste collector to find the shortest path of a nearest waste container; straight to the waste land fill using the Internet of Things (IoT) and mobile application. With the proposed system, the waste monitoring, collection and disposal are improved, especially in collection. Because of Global Positioning System (GPS) and Dijkstra Algorithm, the system provides an alternative direction to ease collecting wastes from different houses going to sanitary landfills. Through wireless network topology, the level of waste container can be monitored and can give signal to waste collectors. Furthermore, the record of collected data and household location are also used to identify locations or communities that has produced more solid wastes and can be used for future research.

Index Terms: Solid Waste Management, Global Positioning System, Dijkstra Algorithm, Shortest Path, Solid Waste, Internet of Things, Cloud Technology.

1 INTRODUCTION

Philippines is one of the developing Asian country and is the 12th largest country in the world today. It is evident that this country is very aggressive in terms of economic growth that it resulted in the manufacture and use of different products. This leads to generation of different wastes. The consequences of economic growth are the causes of climate change and environmental degradation [1]. Solid wastes are one of the major problems because of the rapid growth of population. People are dumping waste on streets, open drainage and even rivers. Because of this, the Philippine government created the Republic Act 9003 or the Ecological Solid Waste Management (SWM) Act of 2000 that mandates and provide framework for solid waste management [2]. This law provides solid waste management programs, creates mechanisms and incentives, acts providing drawbacks, allotment of funds, and other purpose that is connected to waste management [3] and the local government unit holds its responsibility in the implementation of the said law. The law mandates that the special waste collection, like health waste and non-recyclable materials is the responsibility of the local government while the separation and solid waste collection are conducted at the barangay level [4]. Some local government also created municipal and city ordinance for solid waste management, conducted different campaigns, trainings and seminars in SWM and recycling [5]. But according to studies, local government units mostly in metro manila are still struggle in the execution of solid waste management. Legislation strategies and policies, technical knowledge, lack of awareness and use of advance technology should be addressed [4].

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It is estimated that 0.7 kg per person per day more than 8,000 tons of garbage in metro manila is generated per day. It is also stated in the study that the household is the major cause of waste (74%) and 95% of the solid waste in the household can turn in to compost or be recycled or reused [6]. Only 85% is the maximum collection rate are recorded in metro manila and uncollected garbage is either dumped anywhere. Most of the local government units do not comply on City and/or Municipality Recovery Facilities – facilities that solid waste can transfer, compost or recycle – mandated on the RA 9003 [1]. It is said on the law that the cluster of barangay should have recovery facilities but more than 8,500 barangays in the Philippines used these and 56% national average of these barangays are in metro manila area. It is also revealed that weakness of industries in recycling and high cost of transporting recyclable materials are major limiting factors in solid waste management [7]. Poor solid waste management process may lead to danger in human health, environment and human resources like flooding, attraction of different insects and rodents and water contamination [8]. Non-communicable diseases, infection transmission and physical and emotional effects are the major impacts on human health. Improper solid waste management can cause pollution, and pollutants from the dumpsites can increase the respiratory diseases and the cost of disposal [9]. Schools are also instructed to follow the RA 9003, Part 6, Rule 21, Section 2. It is stated that the Commission on Higher Education (CHED) and the Department of Education (DepEd) mandated schools to teach students on the ecological solid waste management to take action and actively engage students in all level, teachers, parents, school community, school personnel and administrators in the management process and include it in the student's curriculum. Also, the National Waste Management Commission (NWMC) together with the Department of Environment and Natural Resources (DENR) headed a project that enhance the ability of the students in solid management through training programs among private educational institution [4]. However, according to research, the universities produce most of biodegradable waste (ranked 2) and recyclable materials (ranked 1) than the other producers of waste [10]. Although, some universities integrate these problem in innovating and inventing different systems in solving solid waste. There are huge number of advance technologies and methodologies that are being used in solid waste management like composition of waste fraction, landfilling with biogas recovery, different thermal processes, anaerobic digestions and others [11]. But these are all technologies that are used in the dumpsites and the process of segregation and collection of solid waste from different houses are still in manual process. There are already waste containers in every establishment, municipalities and barangays that segregate biodegradable and non-biodegradable but it can be improve by using sensors and technologies that would segregate wastes into its categories like plastic bottles, papers, cans and the likes. The local government mandates each barangay to schedule the collection of wastes but sometimes it is not well implemented and have delays due to small number of garbage collector trucks. The main purpose of the research is to design, construct and implement a new system of segregation, collection and management of solid waste using Internet of Things. To create a new system of collection of waste using Global Positioning System and Dijkstra Algorithm that could monitor the different trash containers located on different houses connected to the system through sensors and microprocessor.

2 METHODOLOGY

The researchers proposed a prototype that were able to collect and segregate solid waste materials into four categories: plastic bottles, papers, cans and biodegradable wastes. It has mobile application that monitors the different garbage container and notify the garbage collector that there is waste container that is available for waste collections. The system then gives shortest path on how garbage collector truck and the person that collects the garbage can reach the house in shortest time. It is integrated to any scheduled garbage collection process of every barangay whether it is collected through house to house process, designated garbage container or both.

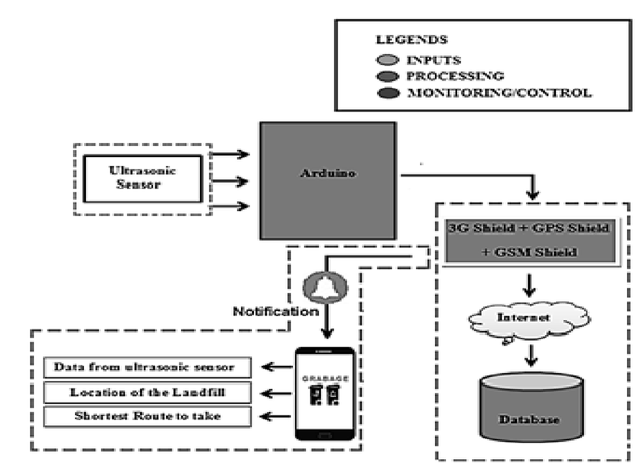

Fig. 1. Conceptual Framework

Fig. 1 shows the system flowchart and the main operation of the system. The ultrasonic sensor, Arduino microcontroller and the different shields used for Internet of Things (IoT) are the hardware components meant for the main operation of the system. The ultrasonic sensor is responsible for monitoring the level of waste, different shields are responsible for obtaining the global positioning system of a particular garbage container, and sends it to cloud database and to sends information using mobile application. The weight of the solid waste was saved in the database and can be used to manage and analyze the results.

2.1 Hardware Development

The hardware components that were used for identifying recyclable waste materials are consist of Infrared (IR) sensor, Light Dependent Resistor (LDR) and Servo motor. The IR sensor and LDR are responsible for sensing the cleanliness of plastic bottle and the rotation of the Servo motor depends on the cleanliness of the plastic bottle. Another LDR and a Servo motor are responsible for restricting any material to enters the paper bin. Weight sensor were used to measure the weight of the solid waste materials. It is located at the bottom part of the container. The researchers used descriptive research method to describe the results of the functionality of the system from hardware, software and integration of both using the Internet of Things. The heart and the brain of the system was the Arduino UNO which is responsible for the communication of each component.

2.2 Software Development

For the software side of the system, the researchers used Wireless Fidelity (WiFi) a wireless network technology to transfer data to the single-board microcomputer which is a Raspberry Pi. Python is used for the application-level gateway. It is a high programming language that can be collaborates with Raspberry PI, and MongoDB. This open source software that is connected to Raspberry Pi will be used to create different programmable instructions. The data uploaded in Raspberry Pi is stored and collected using a MongoDB database. This database system is compatible for python and systems with hardware integration. It is also easy to use since its data is contained in a flexible environment where its data structures can be altered progressively. Web application is used to display the data collected from data mining including the status of the prototype and the water surrounds it will be program using HTML and CSS. The data from different parameters attached to prototypes are used to: know the location of garbage container that are always full of garbage, the weight of the biodegradable wastes and the time it takes to collect the garbage. The researchers used responsive web application to support the use of mobile devices and smart phones. The system is connected to the MySQL database which served as the server database to store information gathered in the prototype. The shortest path on the map of the mobile application came from the Dijkstra Algorithm. This algorithm can solve shortest path problems in the process of organization, management and production. It can also be used in generating global optimum solutions for ship routes and save fuel [12]. Dijkstra Algorithm is used in modern map systems like google map and other routing application that which we explore and made it shortest route to advanced guide from Point A to Point B [13]. The distance of the destination from the location of the waste collector truck can be computed by equation (1):

$$\text{distance} = [(x_2 - x_1)^2+[(y_2 - y_1)^2+[(z_2 - z_1)^2]^{1/2} \quad (1)$$

where the coordinates of the location given by the global positioning system is represented by x, y and z.

3 RESULTS

The innovation in monitoring, managing and transporting of the collected wastes was the main concern of the research. The different hardware components used were meant for monitoring the weight of the recyclable wastes, cleanliness of the environment and to separate the different wastes to its category. The monitoring, location and possible routes in collecting the garbage were seen in the mobile application of the system. Clean plastic bottles were only accepted in the garbage container and it will be reject if it is unclean to also promote discipline to the users. It separates three categories of wastes: clean plastic bottles, unruffled papers and biodegradable wastes. In this section, the researchers presented and discussed the different results of the average response of the sensors, its limits and the accuracy in giving results to the users. It also discussed the results of testing to identify the area that produced largest amount of solid wastes in the designated barangays.

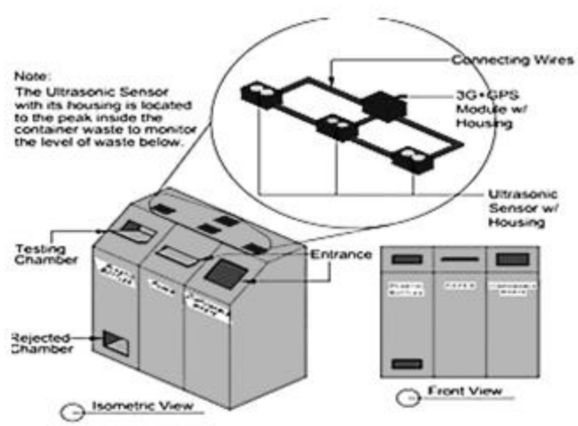

Fig. 2. Physical Output of the Waste Container

Fig. 2 represents the physical model of the garbage container. The model is divided into three containers; one for the disposable wastes and two for recyclable wastes materials specifically plastic bottles and unruffled papers. Each division of container is monitored by an ultrasonic sensor that is responsible for detecting the level of wastes on each container. When it reaches the programed threshold, the system the sends notification through mobile application. The plastic bottles are placed to the testing chamber to test whether the bottle is clean or does not have anything inside. If there is, there is a reject bottle chamber. For the papers, a space is provided by inserting the unruffled paper and shred. The researchers summarize the different results of the performance of each sensors and devices to identify the average response, limits and accuracy.

TABLE 1

SUMMARY OF RESULTS OF DIFFERENT SENSORS, MOTORS AND GPS WITH AVERAGE RESPONSE, LIMITS AND ACCURACY

	Average Response	Limits	Accuracy
Ultrasonic Sensor	0.81 second to respond	10 inches to respond	95.65%
LDR Sensor	29.8 ohms	5 sheets	89.54%
IR Sensor	0.75 cm	1.4 cm	90.32%
Weight Sensor	6.8 kg	20kg	87.43%
GPS	4.8 seconds		96.56%
Servo Motor	2.4 seconds	180 degrees	98.29%

Table 1 shows the different sensors, motors and Global System Positioning response used in the system and its corresponding average response in different unit, its module limits and accuracy in giving results. The ultrasonic sensors were tested for 20 testing and the average response rate of detection is 0.81 seconds with limits a distance of ten (10) inches before the sensor perform detection of waste with an accuracy result of 95.65%. The Light Dependent Resistor (LDR) sensor were used to detect sheets of paper inside the feeder with an accuracy of 89.54% having a sensitivity 29.8-ohm resistance with a limit of 5 sheets of paper due to the limited number of sheets that can be inserted in the machine. The Infrared (IR) sensor were used to identify if the plastic bottle is clean or not. The average distance that the IR sensor of the system responded was 0.75cm. It means that the plastic bottle should be in the range of the said distance before the sensor responded with an accuracy rate of 0.9. The weight sensor of the waste container has average weight of 6.8 kg when the waste materials reached the average height when the ultrasonic sensor reacts, each container has a weight limit of 20kg per container. The global positioning system had the average response of forty-eight (48) seconds once the other sensors give feedback to the mobile application that the container is already full. These results showed that the different modules were all integrated and gave very good result in managing the solid waste materials and giving direction to the mobile application. The next result discusses the mobile application results in giving directions to each houses that has waste container and connected to the mobile application. The improved Dijkstra Algorithm [13] was used in the system. It has a wide range application such as mapping and surveying, expressway toll collection, multipoint routing, shortest path of transport and logistics, and intelligent transportation system. In this algorithm, it can get adjacent vertices in the shortest path. It can avoid infinite looping of routes and it can solve the problem of more than one vertices at the same time [13] [14].

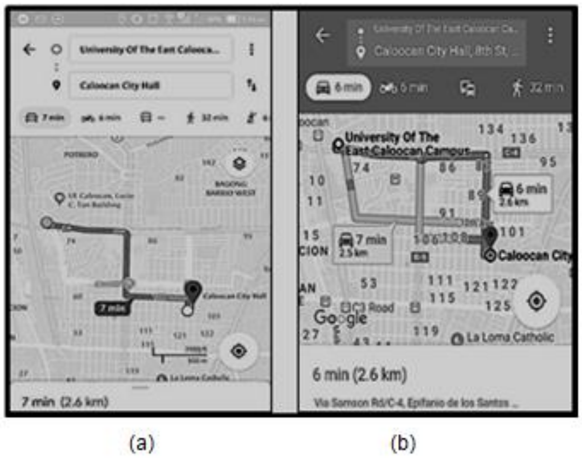

Fig. 3. Navigation Direction of (a.) Normal Google Map and (b.) Mobile Application of the System

Fig. 3 shows the result of google map in giving direction and the result of the mobile application of the system that uses Dijkstra Algorithm. The results had both 2.6km of distance from the destination of the garbage collector track and the destination but the results also shows the difference in terms of the time in reaching the destination. Using the google map, the destination can be reached in seven (7) minutes while the result of the mobile application of the system is six (6) minutes lesser. Using the said algorithm, the destination can be reach faster than using the google map application [14]. To further prove the result, the researchers tested the mobile application in twenty (20) different distances and compared the time in reaching the destination to the result of the google map.

TABLE 2

RESULTS OF THE SIGNIFICANT DIFFERENCE BETWEEN THE TIME RESPONSE OF GOOGLE MAP AND THE PROPOSED SYSTEM

	Levene's Test for Equality of Variances	t-test for Equality of Means				Decision	Recommendation
	F	t	df	Sig. (2-tailed)	Difference		
GMapGrab	2.814	2.216	36	.033	2.684	Reject Ho	Significant Difference

Table 2 shows the result of the significant difference between the time response of the google map and the proposed system. It can be seen that the p-value is 0.033 with a mean difference of 2.684. The decision is to reject the null hypothesis and therefore, the difference between two means is statistically significantly different at the 0.05 level of significance. It can be said that the time response given by the google map is significantly different to the time response given by the proposed system [15] [16]. The figure below represented the difference of the time response of the google map and the proposed system. It explains that the proposed system can give faster response time than the google map using the Dijkstra Algorithm.

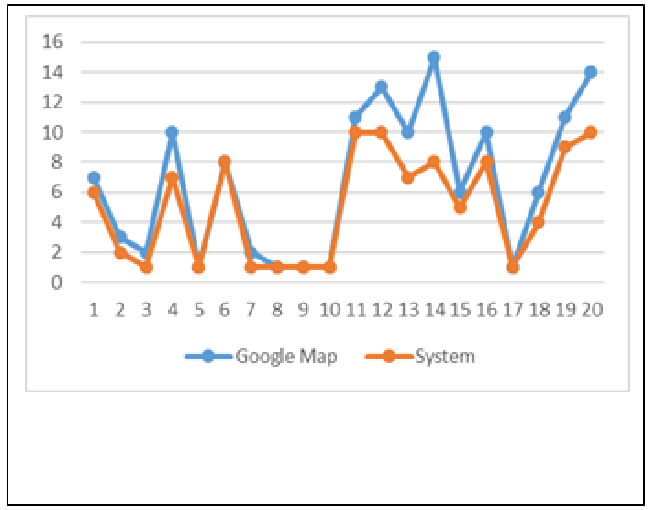

Fig. 4. *Graphical Representation of Time Response of Google Map and the System*

Fig. 4 shows the graphical representation of time response of the google map and the proposed system. The researchers tested the mobile application in twenty (20) destinations with different distances using the Dijkstra Algorithm in giving time (in minutes) in reaching the destination and compared it to the result of the google map. It can be seen in the graph that the mobile application gives lesser time to reach its destination compared to the time response given by the google map.

4 CONCLUSIONS

The proposed system is part of the waste management system which is made for homeowner in order for them to dispose and recycle their wastes systematically. The garbage collector responded on time whenever the container waste is reaching a critical level. The system prevents the overflowing of wastes and the collection wastes is done easily by applying the concept of Dijkstra Algorithm. The use of hardware and software components and their integration are better innovation that can be applied in waste management system. It is concluded that the proposed system is more systematic and teach the homeowners to be a disciplined citizen and responsible in their waste.

5 RECOMMENDATIONS

The system can only segregate the paper plastic bottle and non-recyclable wastes. It is recommended to add features by including cans in segregation since it is also included as one of the recyclable waste. It is also recommended to add more features in the system like data mining and other features that would improve the waste management. It is recommended to present the system to local government so that it can be implemented nationwide.

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