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A Low-Cost Automated Sorting Recycle Bin powered by Arduino Microcontroller

Harnani Hassan
Faculty of Electrical Engineering
Universiti Teknologi MARA, UiTM
Shah Alam, Malaysia
harnani@salam.uitm.edu.my

Fadzliana Saad
Faculty of Electrical Engineering
Universiti Teknologi MARA, UiTM
Shah Alam, Malaysia
fadzlianas@salam.uitm.edu.my

Muhammad Suhaimi Mohd Raklan
Faculty of Electrical Engineering
Universiti Teknologi MARA, UiTM
Shah Alam, Malaysia
suhaimiraklan@gmail.com

***Abstract*— The increase on amount of waste daily in Malaysia due to lack of waste management and enforcement by the government, has created unpleasant views of overflowed waste at the landfill. This paper presents the development of a low-cost recycle bin that automatically sorts different type of recycle waste using an Arduino microcontroller. The objectives of this work are to construct a recycle bin prototype with a sensing mechanism that is able to sort recycle waste (such as metal, paper and plastic) and automatically assign the waste to specific bin partition according to their types. This paper also presents the sensitivity analysis of the recycle bin prototype to sort the waste correctly. The construction of the recycle bin prototype is divided into two parts: i) sensing and ii) mechanical. The sensing part detects type of waste material such as metal, paper and plastic. The metal-based waste is detected using an inductive proximity sensor; while, for paper and plastic-based waste, a light emitting diode (LED) and a light dependent resistor (LDR) are utilized. The mechanical part assembled a servo motor together with the microcontroller to sort the waste type accordingly. The outcomes of this work show that the recycle bin prototype is able to sort the waste successfully especially the plastic waste and it is highly potential to be utilized in the future. However, the prototype sensitivity on paper and metal-based waste need to be further improved for an effective segregation of waste.**

Keywords—recycle bin, recycle waste, inductive proximity sensor, LDR sensor, servo motor

I. INTRODUCTION

According to Jabatan Pengurusan Sisa Pepejal Negara, the amount of waste produced every day in Malaysia is 25,000 tons and it is expected to increase by 2% per year. It means that in a year, 13.5 million tons waste are produced. Thus, the cost to dispose waste in a year is about RM2.2 million [1]. Considering the population growth of Malaysia at 1.3% which is from 31,633.5 in 2016 to 32,049.7 in 2017 [2], the waste and cost for waste disposal, will increase tremendously in the future. Therefore, to reduce the waste being produced, recycling technology should be fully utilized.

Recycling is referred to a process that converts waste material into new materials and objects[3], which can be reduced and reused. In Malaysia, the level of awareness on recycling is still low. Basically, we already have our own recycling system with three separate bins of different colours to collect different material. For example, the yellow bin is for cans, blue bin is for papers and red bin is for plastics. Apparently, people have to think and decide into which bin the waste should be thrown. For people with less awareness on waste recycling, they may just throw the waste without considering the bin's colour or type of waste. This situation is very related to waste sorting behaviour, a study done by Ó. A. Ólafsson [4] where he stated that with given rules and procedures, people are still not assured to follow the instructions in sorting the waste accordingly. Therefore, there is still a need to help users in highly utilizing recycle waste bin by constructing an automated sorting bin.

Suwon Shin et al. [5] had designed a smart automatic recycling trash basket to solve on the inconvenience of recycling metal and paper. The metal and motion sensor are used to detect the presence of metallic waste. The project is only focusing on recycling metal and paper. It consists of a capacity check feature that is using infrared sensor to detect the level of trash in the basket and light up the LED that act as an indicator to show whether the basket is full or not. Meanwhile, Yann Glouche et al. [6] had designed a smart waste management with self-describing objects. This project is based on Radio Frequency Identification (RFID) tags detection which detects the RFID tag at the recycle waste. Basically, this project was intended for future use because it is predicted that all products' barcode will be replaced by RFID tag in future. Parkash and Prabu [7] had designed an IoT based waste management for smart city to solve the problem that is related to trash overflow that causes an unhygienic condition to the surroundings. This project senses the waste level inside the dustbin to avoid overflowing waste. Next, the smart recycle and reward Bin designed by Melissa Lim et al. [8], which is a recycle bin that is focusing on recycling the used beverage containers and applied the Reverse Vending Machine (RVM) concept. By using this concept, the user will get points for recycling material and the points are stored into a smart card. In order to differentiate between the type of recycle materials, the image processing sensor is used. This type of identification system is used to avoid the machine from being fooled and giving extra points to the customer.

Based on the previous works done by other researchers [5-8], this project proposes for an automated sorting recycle bin powered by Arduino microcontroller. The aim for this project is to automatically sort the recycle waste into three different compartments. The waste is sorted based on the type of material being detected. Thus, the user does not need to decide which bin is correct for the recycle waste. As the target area of testing for this project is mainly the campus area, the recycle bin will only focus for three different common materials being thrown by the students that are; papers, aluminum cans and plastic bottles. Furthermore, the sorting of material are depending on the type of material detected by the sensors, where inductive proximity sensor is for metal detection of cans and LDR sensor for measuring light intensity that is penetrated through papers and plastics.

II. RESEARCH METHOD

Fig. 1 shows the block diagram of the recycle bin. The whole project is divided into two parts, which are the sensing part and the mechanical part. The sensing part is mainly for identifying on type of recycle waste and mechanical part is particularly for the sorting and movement of the recycle waste compartment.

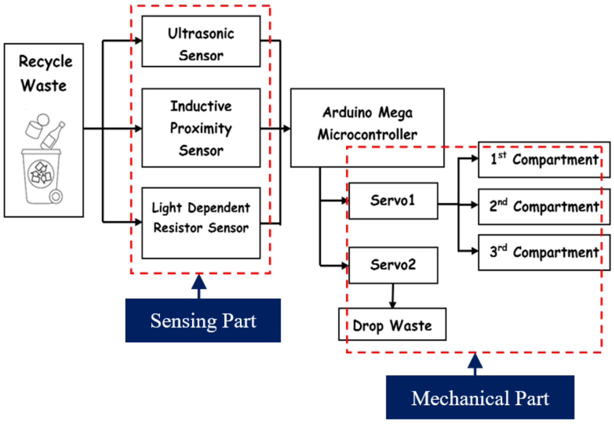

Fig. 1. Block diagram of recycle bin

A. Development of Sensing Part

In the sensing part, the sensing circuit is constructed using ultrasonic sensor, inductive proximity sensor and LDR sensor as shown in the Fig. 1. Each sensor has a different function in order to distinguish the different type of recycle waste. Based on Table I, the ultrasonic sensor is used to detect the distance of waste, the inductive proximity sensor is used to detect the presence of metal and the LDR sensor is used to differentiate between paper and plastic bottle.

TABLE I. LIST OF SENSORS

Type of Sensor	Type of Detection	Measurement Unit
Ultrasonic Sensor	Distance	Centimeter (cm)
Inductive Proximity Sensor	Magnetic field	Tesla (T)
LDR Sensor	Light Intensity	Lux (lx)

The ultrasonic sensor is the first sensor to be utilized by the system on sensing the presence of any recycle waste inside the sensing part. After the ultrasonic sensor detects the presence of an object, it will trigger another sensor to operate and starts the material detection process. The detection distance of an ultrasonic sensor is set from zero until 24cm. Then, the inductive proximity sensor starts to detect the presence of an aluminum material.

If the inductive proximity sensor does not detect any presence of aluminum, which means the detection value of inductive proximity is below 200T, the LDR will start to operate and determine the level of light intensity captured to differentiate between paper or plastic. Besides that, there is also one LED attached in opposite to the LDR to ensure the initial light captured by the LDR is stable. Thus, if the light intensity captured by LDR are below 500lx, it means there is a paper thrown into the recycle bin, while for a plastic bottle, the light intensity captured must be above 500lx. The measurements for waste classification are based on Table II.

TABLE II. MEASUREMENT FOR WASTE CLASSIFICATION

Type of Sensor	Type of Material	Detection Range
Ultrasonic Sensor	All	Below 24cm
Inductive Proximity Sensor	Metal	Below 200T
LDR Sensor	Plastic	Above 500lx
	Paper	Below 500lx

When all the sensors have categorized the waste according to the type of material, an information is sent to the microcontroller and the mechanical part will start to sort the material.

All processes that are involved on confirming the type of material, classifying on type of recycle waste and deciding on the movement of motor for waste sorting, are done by the control system part which is the Arduino Mega microcontroller. This microcontroller is used as the brain of the system to control and instruct the whole system. Lastly, all sensors are interfaced with the microcontroller to enable an effective sensing operation based on the programming that is uploaded onto the microcontroller.

B. Development of Mechanical Part

The mechanism on rotating the waste separation part and dropping the waste into the correct partition of the bin are the mechanical part for the recycle bin as shown in Fig. 1. This part consists of two servo motors and three sorting openings with compartment for the plastic bottles, cans and papers. The servo motors used for this project and their locations are listed as in Table III.

TABLE III. LIST OF SERVO MOTORS

Servo Motor	Location
Servo1	Lower part / Rotating part
Servo2	Upper part / Dropping part

The servo2 is attached to the sensing part that is the upper part of the bin in order to drop the waste into the storage. It is inclined by approximately 70° after the type of material is detected by the sensor. The servo1 is used to move the sorting parts, which is created using lightweight material such as plywood. This is to ensure that the servo1 is able to hold the load and operate accurately as the motor rotating. It is attached to the three sorting openings. The first sorting opening is set for aluminum cans while the second sorting opening is for papers and the third sorting opening is for plastic bottles. The rotation of servo1 is based on the angle set in the Table IV.

TABLE IV. ANGLE OF ROTATION FOR SORTING WASTE AT SERVO1

Type of Materials	Angle of Rotation (°)
Plastic Bottle	5
Paper	50
Aluminum Can	95

Basically, the angle of rotation for servo1 is set based on how the mechanical part moved and synchronized with servo2 to check whether the rotation of servo2 is able to rotate into the sorting opening or not. Thus, trial and error method is used in order to set the angle for servo1 and this is to ensure that the recycle material is dropped successfully. Since this work is focused for three different materials, three different angles are used to classify the recycle waste before dropping it. When the LDR sensor captures high light intensity (above 500lx), the servo1 is moving to 5°, which means that the plastic bottle is detected. But if the LDR sensor captures low intensity of light (below 500lx), the servo1 will rotate to 50° indicating for paper waste. Meanwhile, if metal is detected by the inductive proximity sensor, the servo1 is rotating to 95°.

In addition, the body of the recycle bin prototype is made by various type of materials. The front cover of the recycle bin are made from acrylic plastic which is transparent. This material is chosen in order to show the sorting system works and to verify whether the recycle waste is dropped into the correct compartment or not. Thus, the efficiency and validation of the project can be justified based on the correctness of waste dropped into the storage.

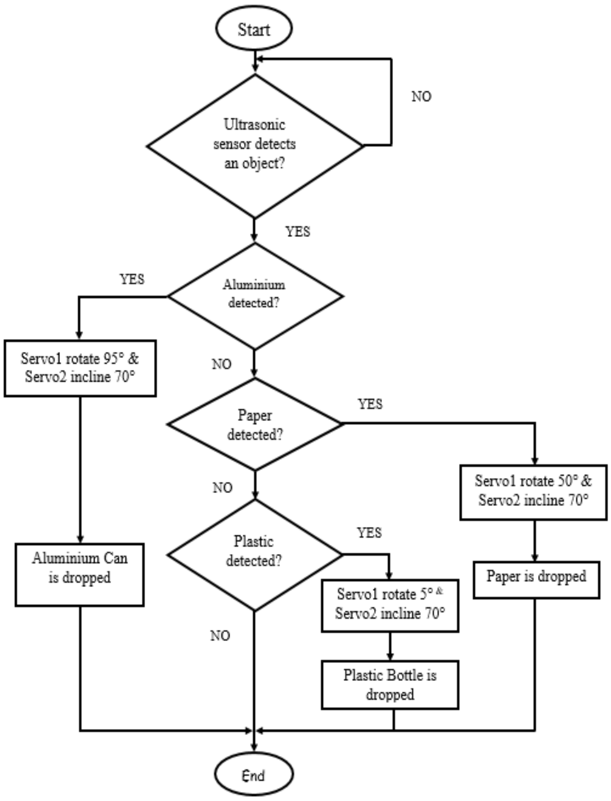

Fig. 2. Flow chart of the recycle bin

Fig. 2 shows the flow chart of the automatic recycle bin operation. Firstly, the waste that is thrown by the user will be detected by the ultrasonic sensor. The ultrasonic sensor is used to detect the presence of an object within 24cm distance. After the ultrasonic senses the presence of an object, the inductive proximity sensor will start to operate and sense whether there is an aluminum material or not. If the aluminum material is detected, the servo1 will rotate to 95° then the servo2 is inclined to 70°. But, if the inductive proximity sensor does not detect any presence of metal, the LDR sensor will start to operate. The LDR sensor is used to determine whether the presence object is a paper or plastic by measuring the light intensity. If the plastic is detected, the servo1 will rotate to 95° while the servo2 is moved to 70° and dropped the plastic into the plastic compartment. Meanwhile, when paper is detected, the servo1 will rotate to 50°, then the servo2 is moving towards 70° in order to drop the paper into its compartment. After that, both servos will return to their initial condition.

C. Development of Programming Part

In order to instruct the sensors and the mechanical part to perform a specific task, the programming part is required for the microcontroller. For this work, only basic C++ programming is used. It is used to declare the pin to connect the input and output components. On the other hand, the library of the components that have been used also need to be included. The library contains the function for the C++ standard input and output. In addition, the algorithm used is only 'if else' statement. This statement is used for decision making and based on the decision, the next block of code will be executed. For example, the servo is rotated based on the different signal that are received from two different sensors. If a proximity sensor is detecting the aluminium, the servo will decide to move to 95° based on the decision made in the program.

D. Circuit Design

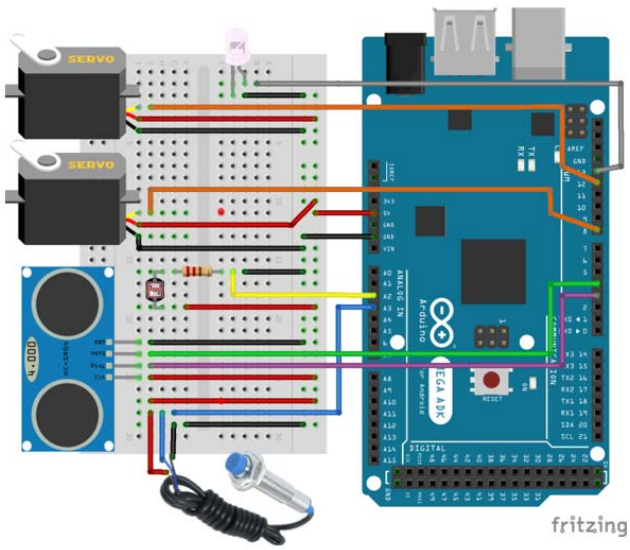

Fig. 3. Circuit Connection for the System

Fig. 3 shows the circuit connection for all input sensors and all output servos with the microcontroller. The circuit connection is sketched using Fritzing software.

III. Results and Discussion

A. The recycle bin prototype

Fig. 4 shows the prototype of the recycle bin while Fig. 5 shows the sketch diagram of the recycle bin. Based on both figures, the recycle bin is divided into two parts, which are the sensing part and the mechanical part. For the sensing part, it includes all the sensors that are needed to detect and differentiate three different types of material. For the mechanical part, a servo motor is attached with a board that has three sorting openings to store the different type of materials which are aluminum cans, papers and plastic bottles.

Fig. 4. Overall prototype of recycle bin

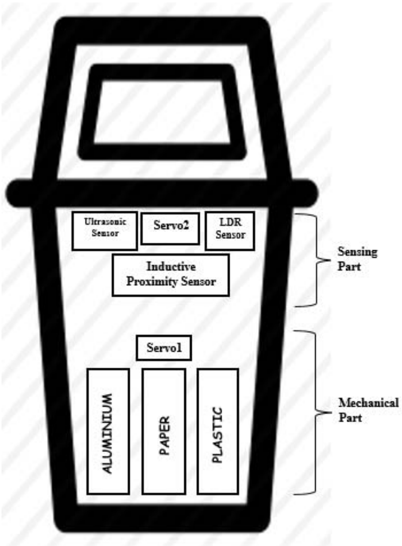

Fig. 5. Sketch diagram of recycle bin

B. Sensing Part

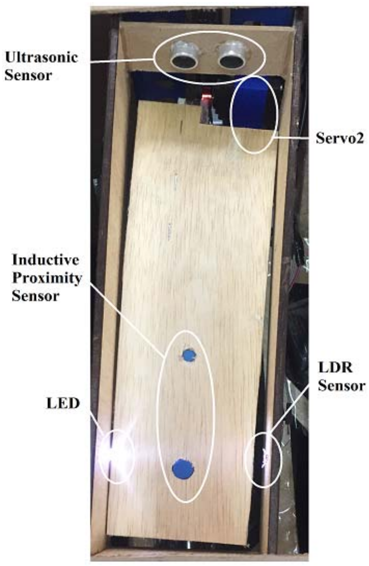

Fig. 6. Sensing part of recycle bin

In Fig. 6, there are three different sensors used in the sensing part, which are ultrasonic, inductive proximity and LDR sensor. Firstly, the ultrasonic sensor will detect the presence of any recycle waste. After the object is detected, it sends the signal to the microcontroller. The detection distance of the object for an ultrasonic sensor is less than 24cm.

The next sensor is the inductive proximity sensor, which is used to detect the presence of the metal object without any contact to the object. The inductive proximity sensor is used in order to detect the presence of an aluminum can. For example, when the user throws the aluminum can, the ultrasonic sensor will detect the presence of the object, which then followed by the inductive proximity sensor that identifies either it is a metal or non-metal. If the metal is detected, the servo1 rotates to 95° and sorts the aluminium can into the metal part.

Then, LDR is used to capture the light intensity emitted by the LED attached opposite to it. Thus, when a paper is thrown, the light emitted by the LED will be blocked by the paper and the light intensity captured by the LDR is reduced. Meanwhile for the plastic bottle, which is a transparent object, the LDR will capture higher light intensity than a paper. If the LDR had captured low light intensity, the servo1 rotates to 50° and the waste is dropped into the paper compartment. For high intensity light captured, the servo1 will rotate to 5° and drop the plastic bottle into the plastic compartment.

C. Analysis Result on Sensitivity of Sorting

Table V shows the results obtained throughout the testing being done for the recycle bin prototype. Twenty attempts on throwing waste to the recycle bin are done for the test.

TABLE V. TESTING RESULTS

Materials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Plastic Bottle	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Paper	/	/	/	/	x	/	/	/	x	/	/	/	/	/	/	/	/	x	/	/
Aluminium Can	/	x	/	/	/	/	/	x	/	/	/	x	x	/	/	/	/	/	/	x

$$Percentage\ of\ error = \left(\frac{Number\ of\ attempt - successful\ attempt}{Number\ of\ attempt}\right) x\ 100\% \tag{1}$$

The equation (1) above is used to identify the percentage of error that occurs for each material test. The percentage is calculated in order to determine the sensitivity and efficiency of the recycle bin. The attempt that is not successful will be divided with total number of attempts and times with 100 percent to obtain the percentage error.

TABLE VI. ANALYSIS OF DATA COLLECTION

Type of Material	Percentage of Error
Plastic	0%
Paper	15%
Aluminum	25%

Table VI shows the percentage of error as calculated form the results obtained.

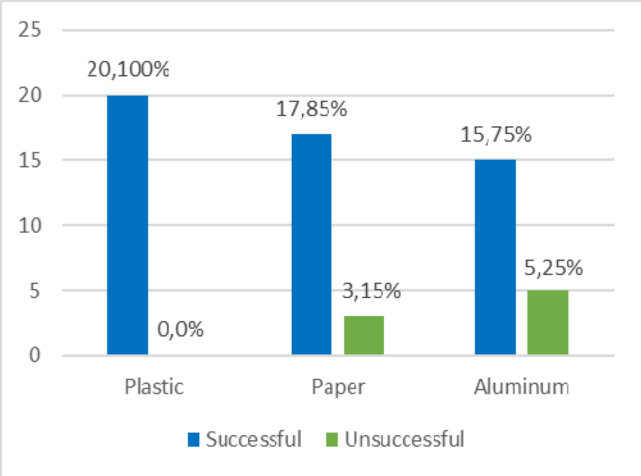

Fig. 7. Sensitivity of the recycle bin

Fig. 7 shows the analysis result on sensitivity of the sorting system. For plastic-based waste, all attempts are successful which means all 20 plastic bottles are dropped into the correct compartment. This means that there is no percentage error for the plastic material. When the ultrasonic sensor detects an object within 24cm range and the LDR captures high intensity light, it means the plastic material is detected. The success of attempt may be caused by the size of plastic bottle, which is large enough to be detected by the ultrasonic sensor and it can be easily classified as plastic-based waste.

In addition, for paper-based waste, only three out of 20 attempts are unsuccessful. It means that the percentage error for paper is 15%. This problem occurs may be due to the size and surface of the paper. Sometimes, the ultrasonic sensor cannot detect the presence of paper when the surface of paper is not flat. Referring to the basic concept of an ultrasonic sensor, the ultrasonic wave is transmitted in the air and the wave will be reflected back towards the sensor if there is any obstacle in front of it. Then, the reflected ultrasonic wave is observed by the ultrasonic receiver. In this situation, if the surface and shape of object is flat, the wave reflected is more accurate but if the surface is not flat, the reflected wave is not as accurate as the expected measurement.

Lastly, for an aluminum-based waste, five attempts are not successful. This can be due to the number and allocation of the inductive proximity sensor which is not suitable with the position of can that is thrown by the user. The space of sensing part is quite large, therefore if the user threw the can out of the sensing range of the inductive proximity sensor, the sensor cannot detect the presence of the aluminum material. Therefore, the can will be detected and classified as paper because the light intensity that is captured by the LDR is low. In order to increase the accuracy of aluminum detection, the number of inductive proximity sensor that is attached to the sensing part needs to be increased.

IV. Conclusion

In this paper, the development of a low-cost automated sorting recycle bin powered by Arduino microcontroller is presented to effectively sort waste according to its base. During the development process, the recycle bin prototype control system and sensing mechanism are integrated with an Arduino Mega microcontroller. The sensing part is built to distinguish among three types of recycle waste: i) metal (aluminum), ii) paper and iii) plastic. The aluminum-based waste utilized the inductive proximity sensor in relation to the magnetic field concept. However, the plastic and paper-based waste used LDR to verify on the light intensity. The prototype of recycle bin possessed high sensitivity on plastic-based waste in comparison to other type of waste. This means that the paper and aluminum-based waste sensitivity need to be improved for effective sorting. In this case, the number of sensors for metal and paper-based need to be increased with each of these sensors possess a specific detection angle to improve the sensing mechanism.

The proposed concept and developed prototype have the potential to be utilized in reducing cost of solid waste disposal in the future. An improved prototype of recycle bin with IoT features to update and notify end user through mobile application (Apps) on waste status ('full' or 'not full') will increase the effectiveness of the waste collection management. A 'reward point' system can also be introduced in the future as it will increase awareness of recycling. Thus, a smart card system to redeem money when the points reached certain values can be implemented in a robust recycle bin system.

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