Automated Waste Segregator

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***Abstract*—**Rapid increase in volume and types of solid and hazardous waste as a result of continuous economic growth, urbanization and industrialization, is becoming a burgeoning problem for national and local governments to ensure effective and sustainable management of waste. It is estimated that in 2006 the total amount of municipal solid waste generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003 (Global Waste Management Market Report 2007). The segregation, handling, transport and disposal of waste are to be properly managed so as to minimise the risks to the health and safety of patients, the public, and the environment. The economic value of waste is best realized when it is segregated. Currently there is no such system of segregation of dry, wet and metallic wastes at a household level. This paper proposes an Automated Waste Segregator (AWS) which is a cheap, easy to use solution for a segregation system at households, so that it can be sent directly for processing. It is designed to sort the refuse into metallic waste, wet waste and dry waste. The AWS employs parallel resonant impedance sensing mechanism to identify metallic items, and capacitive sensors to distinguish between wet and dry waste. Experimental results show that the segregation of waste into metallic, wet and dry waste has been successfully implemented using the AWS.

Keywords—Automation, waste segregation, metal detection, capacitive sensing, inductive sensing.

I. INTRODUCTION

In recent times, garbage disposal has become a huge cause for concern in the world. A voluminous amount of waste that is generated is disposed by means which have an adverse effect on the environment[1:11].

The common method of disposal of the waste is by unplanned and uncontrolled open dumping at the landfill sites. This method is injurious to human health, plant and animal life.

This harmful method of waste disposal can generate liquid leachate which contaminate surface and ground waters; can harbour disease vectors which spread harmful diseases; can degrade aesthetic value of the natural environment and it is an unavailing use of land resources[2:4].

In India, rag pickers play an important role in the recycling of urban solid waste. Rag pickers and conservancy staff have higher morbidity due to infections of skin, respiratory, gastrointestinal tract and multisystem allergic disorders, in addition to a high prevalence of bites of rodents, dogs and other vermin. Dependency on the rag-pickers can be diminished if segregation takes place at the source of municipal waste generation.

The economic value of the waste generated is not realised unless it is recycled completely. Several advancements in technology[3] has also allowed the refuse to be processed into useful entities such as Waste to Energy, where the waste can be used to generate synthetic gas (syngas) made up of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam; Waste to Fuel, where the waste can be utilized to generate bio fuels.

When the waste is segregated into basic streams such as wet, dry and metallic, the waste has a higher potential of recovery, and consequently, recycled and reused. The wet waste fraction is often converted either into compost or methane-gas or both. Compost can replace demand for chemical fertilisers, and biogas can be used as a source of energy. The metallic waste could be reused or recycled.

Even though there are large scale industrial waste segregators present, it is always much better to segregate the waste at the source itself. The benefits of doing so are that a higher quality of the material is retained for recycling which means that more value could be recovered from the waste[3]. The occupational hazard for waste workers is reduced. Also, the segregated waste could be directly sent to the recycling and processing plant instead of sending it to the segregation plant then to the recycling plant.

Currently there is no system of segregation of dry, wet and metallic wastes at a household level. J.S. Bajaj[4:12] has recommended that a least cost, most appropriate technological option for safe management should be developed. The purpose of this project is the realization of a compact, low cost and user friendly segregation system for urban households to streamline the waste management process.

A. Technical Background

The mixed waste is sorted based on the following methods at the industrial level[5]. Larger items are removed by manual sorting. Then the refuse is sorted based on its size by using large rotating drums which is perforated with holes of a certain size. Materials smaller than the diameter of the holes will be able to drop through, but larger particles will remain in the drum.

For metallic objects electromagnets or eddy current based separators can be used. Near infrared scanners are used to differentiate between various types of plastics based on the ability of the material to reflect light. X-rays can also be used to segregate materials based on their density.

The methodology adopted in this paper to resolve the issue of waste segregation is by making the entire process automated and to the reduce cost such that it could be adapted in a household level.

B. Proposed Solution

Waste is pushed through a flap into the proposed system. An IR proximity sensor detects this and starts the entire system. Waste then falls on the metal detection system. This system is used to detect metallic waste. After this the object falls into the capacitive sensing module. This module distinguishes between wet and dry waste. After the identification of waste, a circular base which holds containers for dry, wet and metallic waste is rotated. The collapsible flap is lowered once the container corresponding to the type of garbage is positioned under it. The waste falls into the container and the flap is raised. The waste in the containers now can be collected separately and sent for further processing.

C. Organization of the Paper

The paper is organized as follows: Section II encompasses the design methodology of the AWS, which has a detailed description of the implementation of each block. Section III contains the results of the experiments performed to show the performance of the various blocks of the AWS. Section IV has the concluding remarks of the project.

II. IMPLEMENTATION

Figure 1 shows a diagram of the AWS. An upper enclosure ensures waste does not fall out of the sensing area. Inside the enclosure is an infra-red (IR) proximity sensor module. When the waste is dumped in by pushing the flap, the IR proximity sensor module gets activated and brings the micro controller MSP430G2553 out of low power mode. The object slides over the incline to fall on the inductance coil which is used to sense any metal object. If the object is metallic a change in parallel resonant impedance of the metal detection system is observed. The object continues and drops into the capacitive sensing module. Here, a decision is made if the waste is wet or dry based on its relative permittivity. Two DC geared motors are used to perform the final segregation based on the identification. One motor moves a circular base to get the corresponding container under the collapsible base. This collapsible base is controlled by the second motor. The process flow analysis is given in Figure 3. The individual modules are explained here as follows.

A. Entry System and Initialization

The waste is dumped into the AWS by pushing it through a flap. This flap comes in the proximity of the IR proximity sensor which marks the entry of the waste. The sensor sends an interrupt to the microcontroller which comes out of the low power mode. It then initializes the sensor modules. The initialization of all modules ensures that any dynamic changes in the environment do not affect the sensing. The sensor modules establish a base count by averaging many samples, while the waste slides over the first incline. An average of 100 counts is taken to establish a base count for the LDC1000. The object takes 240 milliseconds to slide down the incline while 100 samples take 200 milliseconds[6:12]. Once, an average for the metal detection system is established the LDC100 is switched to threshold mode and the capacitive sensing module initializes its base value by averaging 15 samples. Thus, averages of all base count values are set.

B. Metal Detection System

The object moves over the incline and falls on the inductive coil. The inductive coil is a part of a parallel inductance and capacitance (LC) circuit. As shown in Figure 2 the circuit is connected to the LDC1000 inductance to digital convertor. This measures the parallel resonance impedance of a parallel LC circuit and returns data as a proximity value. This data changes whenever another metallic object is introduced in the vicinity of the coil.

When an alternating current is passed through a coil it generates a magnetic field. When a metallic object is introduced in the vicinity of the coil, eddy currents are induced on its surface. The eddy currents are a function of the distance, size, surface area and composition of the target. This generates a magnetic field which opposes the original magnetic field which is generated by the coil. The inductive coupling between the coil and the object creates a mutual inductance effect on the coil which decreases the parallel resonant impedance of the circuit which in turn is reflected by an increase in the proximity count value. Magnetic fields do not affect the metal detection system. It can detect any conducting material irrespective of its magnetic properties[6:8].

An average of base count is set up by using LDC1000 in data ready mode which generates an interrupt every time the proximity value is ready to be read[6:21]. After a base count is established the LDC1000 is switched to threshold mode which generates an interrupt once the proximity data crosses a set threshold[6:20]. Hence, the object is inferred as metallic. The waste continues down the second incline towards the apex. If the type of garbage is not metallic then the capacitive sensing module continues to sense the object, else the sensing module is stopped and the actuators are activated.

C. Capacitive sensing module

A base count value is established once the LDC1000 has been switched to the threshold mode. Pin Oscillator method determines a count value for each pair of capacitive plates[7:330]. Three pairs of copper plates are placed along the walls of the structure which are inclined to each other at an angle of 45°. This arrangement is made to ensure that waste of all sizes can be sensed. The area of each pair of plates increases as it moves away from the apex of the structure. The sensitivity of the plate decreases with its increase in area, hence smaller plates would accurately sense objects of smaller size. Even though the sensitivity of the larger plate is decreased, it is designed to detect larger objects which will yield a change sufficient to be identified.

The principle of working for the pin oscillator method in the microcontroller is shown as in Figure 4. The microcontroller uses two timers. One timer is used to control a fixed time window, while the second timer uses the output of the schmitt trigger as clock. The input of the Schmitt trigger is connected to a resistor and a plate of the capacitor. The other plate of the capacitor is connected to ground. The second terminal of the resistor is connected to a multiplexer output which supplies the rail voltages alternately based on the output of the Schmitt trigger. As a result, the capacitor charges and discharges and the Schmitt trigger toggles which generates a train of pulses at the output. These pulses are applied to the second timer as a clock input. This process continues till the first timer counting window is complete. The count value in the second timer is the capacitive count value. When an object is introduced between the plates, the capacitance increases and thus the capacitor takes a longer time to charge and discharge. Hence the count value stored in the second timer is lower than the base count value. The difference between the two count values is used to identify whether the waste is dry or wet.

The property used for segregation of waste is the relative dielectric constant. Once a dielectric is introduced between the plates of the capacitor the capacitance increases. Wet waste has a higher relative dielectric constant than that of dry waste because of the moisture, oil and fat[8], content present in kitchen waste. If the change in the capacitive count is greater than threshold then the type of garbage is inferred as wet waste else it is dry waste. Since the capacitance value of the plates is different, the change observed for the same object by the different plates is different. Hence different threshold levels are assigned for each pair of capacitors. Thus, the type of waste is identified as either wet or dry and the actuators are activated.

D. Segregation Module

To achieve the segregation, two DC geared motors are used. They are cheaper as compared to the stepper motor and provide a solution suitable for this application. The containers are placed on a circular base which is mounted on the axle of a DC geared motor. The circular base rotates as the axle of the DC geared motor rotates. If the container corresponding to the type of garbage is not under the flap then the motor is rotated clockwise or anticlockwise according to the Table 1. An IR sensor module is positioned under the circular base such that it generates an interrupt when the required container positions itself under the flap. This interrupt is used to stop the motor by the microcontroller. To avoid overshooting of the container due to the momentum of the base, the DC motor is rotated at lower speeds by using pulse width modulation (PWM) which is generated from the microcontroller's timer.

Once the required container is positioned under the flap, a second DC geared motor lowers the collapsible flap by rotating the motor clockwise by 45° it then waits for 2 seconds to ensure that the waste falls down and finally raises the flap back to the initial position by rotating the motor anti clockwise by 45°. PWM is used to rotate the motor. Thus the segregation is complete and the detected garbage type is stored to determine the direction of rotation for the next iteration. After this the microcontroller is put to low power mode until the entry of the next waste material into the system.

III. RESULTS

The reading for change in the capacitive count value for different non-metallic objects is shown in Table 3. The experiment has been conducted for large volume of the dry waste objects, and a minimum quantity of one object each for wet waste objects. This is done to consider the worst case scenario. The change of capacitive count value is greater for wet waste. The threshold is set at 30 for the smallest plates as the change in count value for dry waste fall well beneath this value. The change observed in the capacitive count value for onion peel is low as it has low relative dielectric constant. However, a piece of onion gives a significant change. The system is designed to detect both. The change for potato peel and carrot peel is very high. The dielectric constant of these objects is amongst the lowest in kitchen waste[9]. Ceramic is detected as wet waste because of a higher relative dielectric constant. It is also the highest among dry waste[8:22]. However, ceramic waste is very rarely generated at home. Other objects like glass and wood have intermediate relative dielectric constant and thus are detected as dry waste. Figure 5 shows the plot of change in the capacitive count value for various objects. Plate1 represents the smallest pair of plates which is positioned at the apex of the structure. Plate2 represents the intermediate pair of plates. Paper, dry cloth and plastic bags are objects that belong to dry waste. Onion peel and dried lemon are wet waste.

The reading for Change in proximity count for Aluminium balls of different diameters is shown in Table 4.A plot of change in proximity count for various diameters of aluminium balls made with foil paper is shown in Figure 6. As the size increases the change in proximity count increases, thus bigger metallic objects can be detected easily.

The size of various objects and their corresponding proximity count value is available in Table 2. This shows that the sensing is independent of the composition of a conducting material. A plot of the proximity count for various objects is shown in Figure 7. The threshold is set at 150 to make sure that there are no false triggers occurring due to noise.

IV. CONCLUSIONS

Automated Waste Segregator has been successfully implemented for the segregation of waste into metallic, dry and wet waste at a domestic level. However, it cannot segregate ceramic into dry waste because of its higher relative dielectric constant when compared to other dry wastes. Noise can be eliminated in the sensing module to increase accuracy and overall efficiency. The system can segregate only one type of waste at a time with an assigned priority for metal, wet and dry waste. Thus, improvements can be made to segregate mixed type of waste by the use of buffer spaces. Since, the time for sensing metal objects is low the entire sensing module can be placed along a single platform where the object is stable to ensure better result.

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APPENDIX

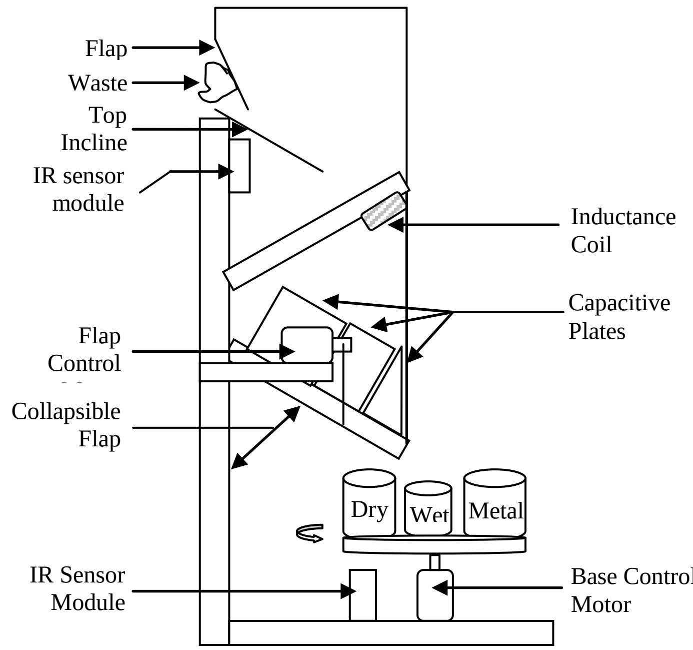

Figure 1: Automated Waste Segregator

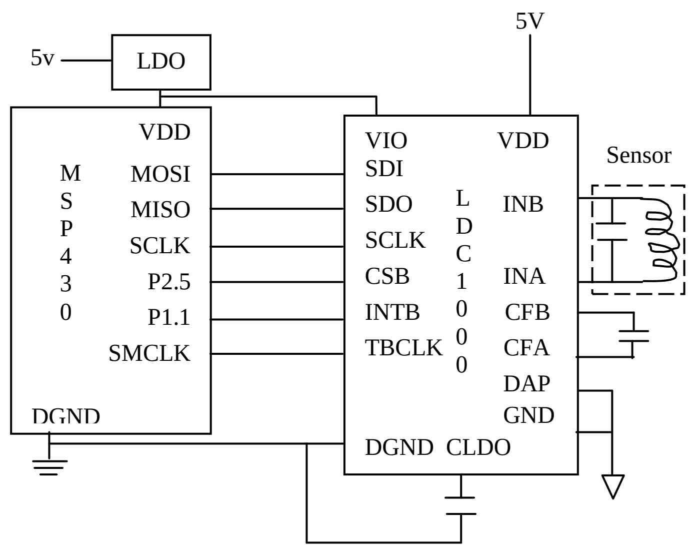

Figure 2: Interfacing LDC1000 with the Microcontroller

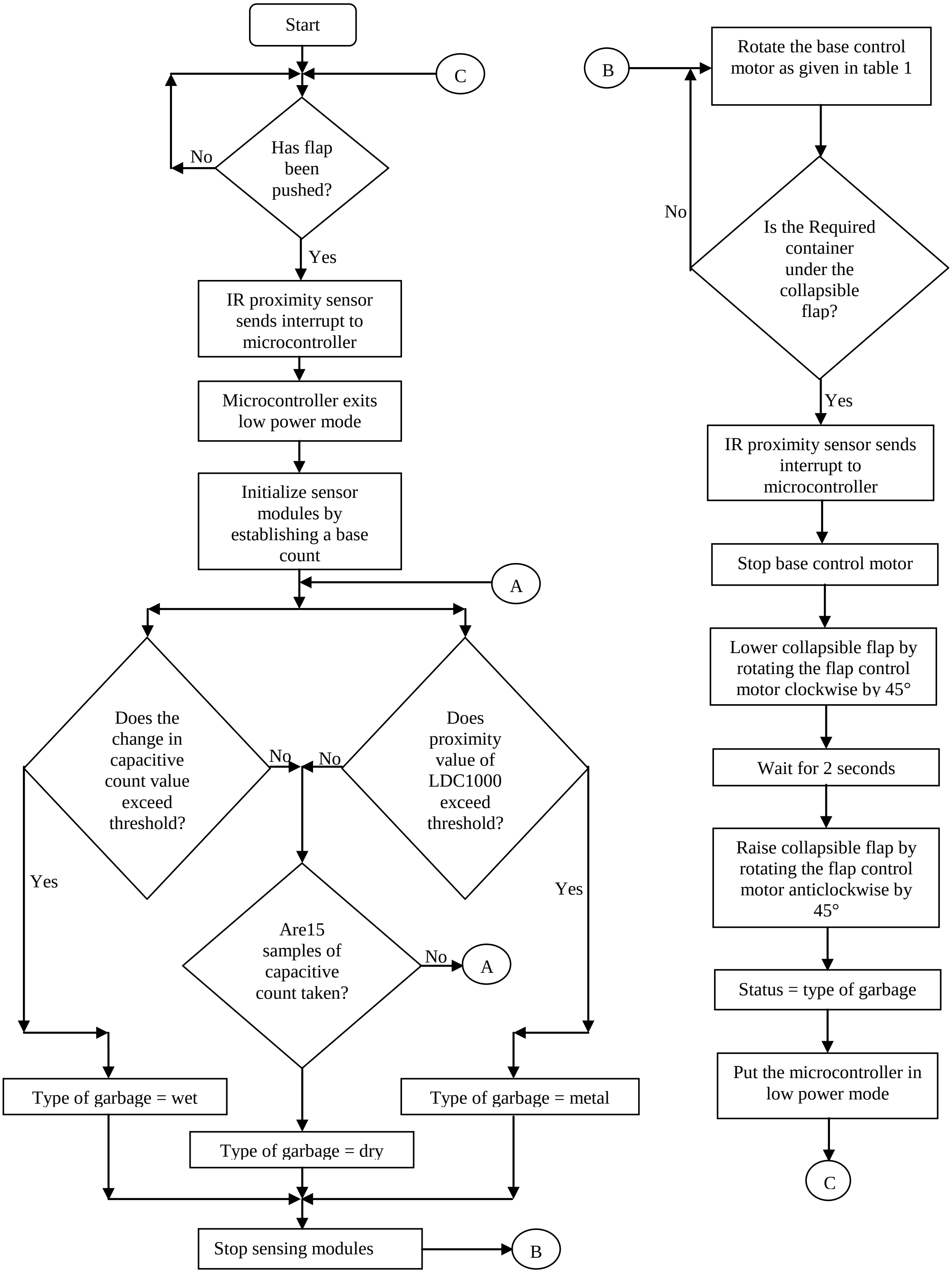

Figure 3: Process flow of the Automated Waste Segregator

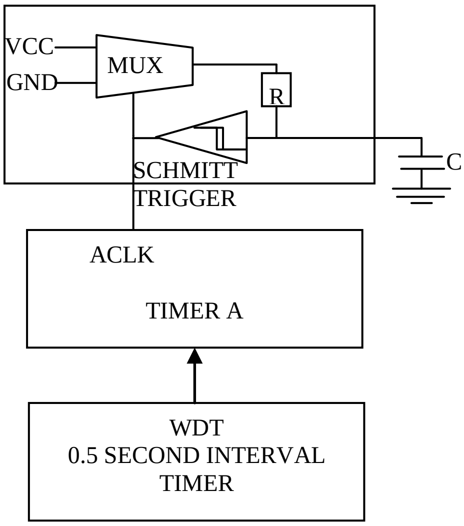

Figure 4: Working of the pin oscillator method

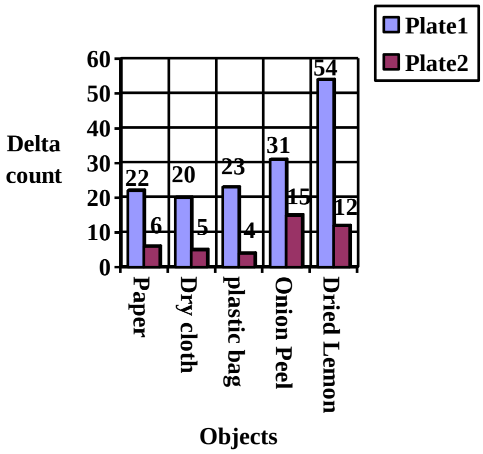

Figure 5: Plot of change in capacitive count measurement for the corresponding object

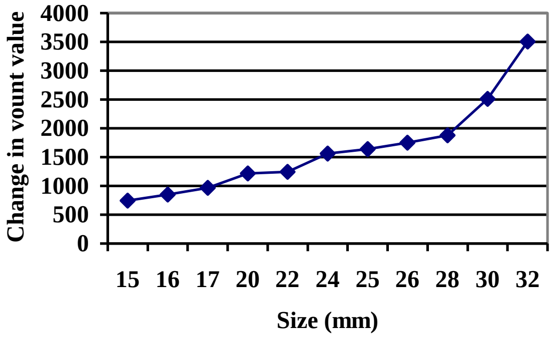

Figure 6: Proximity count value v/s metallic object size

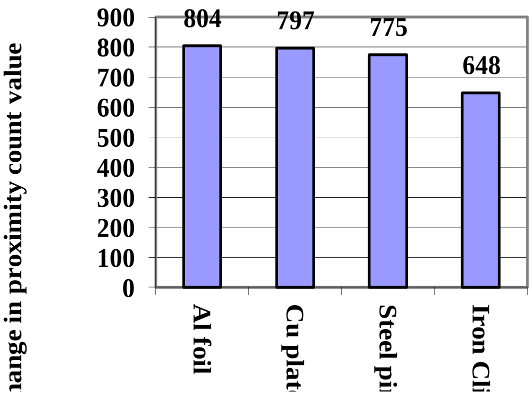

Figure 7: Change in proximity count value plotted for metal objects

Table 1: Look up table for the rotation of the base control motor

Type of Waste	Status of bin	Direction of Rotation of motor
Dry	Dry	No rotation
Dry	Wet	Clockwise
Dry	Metal	Anticlockwise
Wet	Dry	Anticlockwise
Wet	Wet	No rotation
Wet	Metal	Clockwise
Metal	Dry	Clockwise
Metal	Wet	Anticlockwise
Metal	Metal	No Rotation

Table 2: Proximity count values for different metal objects

Metallic Object	Metal	Dimensions (cm)	Change in count
Foil	Aluminium	1.7	804
Plates	Copper	2*3	797
Staple Pins	Stainless Steel	5*1	775
Paper clips	Iron	3*2	648

Table 3: Change in capacitive count reading for different objects

Type of Waste	Object	Dimensions (cm)	Change in Capsense count value		
			Plate1 (smallest plate)	Plate2 (intermediate plate)	Plate3 (largest plate)
Dry Waste	Paper	8	22	6	0
	Polythene bag	7.5	23	4	0
	Plastic bottle	5*14	23	5	0
	Plastic box	12*6.5*2.5	22	7	0
	Plastic lid	11*2.5	20	5	1
	Dry cloth	20*20	2	4	2
	Ceramic plate	20	35	30	1
	Wood	8*8*2	28	9	1
Wet waste	Onion	Piece of onion	180	45	2
	Onion peel	From an onion	38	15	0
	Banana peel	From a banana	1189	810	1
	Carrot peel	From a carrot	327	368	1
	Potato peel	From a potato	189	219	1
	Dry lemon	Half a lemon piece	54	12	1

Table 4: Change in proximity count for Aluminium balls of different diameters

Diameter (mm)	Change in Proximity count
15	746
16	851
17	967
20	1218
22	1244
24	1562
25	1638
26	1751
28	1876
30	2512
32	3507