IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

IOT - SASWS - A Revolutionary Framework for Waste Management

[1]Miss. Neha Patil, [2]Prof. Mr. S. M. Karmuse, [3]Prof. Ms. Anjali R. Patil
[1]PG Student, [2,3]Assistant Professor
[1,2,3]Department of Electronics Engineering
[1]DKTE Society's Textile & Engineering Institute, Ichalkaranji, India

Abstract: In recent year's segregation of waste is the major challenge faced by all metropolitan cities worldwide, this is due to the rapid increase in population, high rate of industrialization and urbanization. There is lack of awareness and knowledge about segregation of waste at the domestic level. The major problems faced due to improper waste segregation include serious health risks to human kind, environmental issues, unhygienic disposal causing serious impacts on health issues and severe environmental degradation. These drawbacks can be overcome by proper waste segregation. The main objective of this paper is effective and efficient methods of waste segregation based on internet of things with their nature of composition i.e. metal, wet, plastic and dry. The waste is segregated accordingly in their respective segments of the dustbin.

In this paper, we are using Intel Galileo which makes the working of the system to be smooth and convenient making the design to be less complicated. Each of these wastes are detected by the respective sensors and discarded into the dustbins assigned to them wherein these wastes can be taken for recycling or reusing directly. The most important feature of this work is that, it is not only cost efficient but also compact with a simpler design thereby making the IOT based automated solid waste segregation system. As per the analysis of accuracy of automated solid waste segregation is 80% and the time taken by the system to identify the waste is 2 sec. This system can provides the reduction of manpower by 90%, reduces the pollution and health issues. It can also increases the 70% of the economic condition due to recycling of plastic.

Index Terms - **Internet of Things, Automatic Solid Waste Segregation, Automation, Solid Waste (SW), Intel Galileo, DC Motor with Motor Driver, Conveyor Belt Mechanism, Sensor Based Sorting, Inductive Proximity Sensor, Moisture Sensor, Ultrasonic Sensor, IR Sensor, Wi-Fi, Smart Dustbin, etc.**

I. INTRODUCTION

In today's world, human activities generate huge quantity of waste materials. For this paper we are considering only solid waste, and the word "Waste" typically referred to the material that is useless and unwanted. As dumping and land filling are easy and cost-effective waste disposing options, so waste has been piling up in many dumping grounds all over the world. Most of this waste is in mixed form and hence cannot be disposed of in an environment-friendly manner. Other most frequently used waste handling techniques is the burning of waste. But in both of these existing methodologies causes various forms of pollution including emission of hazardous gasses due to burning and land filling, leaching of chemicals in soils, water through land filling.

In India Municipal Solid Waste (MSW) gathering, transportation and disposal are unrealistic and unpredictable. Unmanaged disposal at the corners of villages waste and urban communities has resulted in flooding of landfill sites, which are not only difficult to recover due to the unjustified mode of dumping, but also have massive environmental impacts in terms of water pollution and contribute to it. There are mainly two types of waste such as- a) Domestic Waste b) Industrial Waste. There are 4 categories for separation of waste. This separation is done by various municipalities traditionally in the following way-

a) Separation of Metal Waste b) Separation of Wet Waste
c) Separation of Plastic Waste d) Separation of Dry Waste

At the point when the waste is isolated into fundamental streams, for example, dry, metallic and wet, the waste has a higher capability of recuperation and subsequently reused. The wet waste division is frequently changed over either into fertilizer or methane-gas or both. Manure can trade interest for compound composts, and biogas can be utilized as a wellspring of vitality. The metallic waste could be reused or recycled. The rest of the paper is organized as follows. Section II provides brief summary of the relevant literatures followed by methodology of Implementation in Section III. Experimental Design is discussed in Section IV. Theoretical analysis discussed in Section V. Results are provided in Section VI and finally conclusion in Section VII.

II. LITERATURE REVIEW

Kavya M, et al. proposed method the Sensor-Based Smart Dustbin (SBSD) successfully utilizes dampness sensors to isolate [1]. Santhosh Kumar B R, et al. introduced the waste separation and regulation based on IoT [2]. Sharanya.A, et al. stated an automated waste separator that can separate wet, metal plastic and paper [3]. The interfacing of Inductive Proximity Sensor, Soil Moisture Sensor, LASER LDR Module, and all the sensors has been done using Arduino UNO. Some of this model's drawbacks include that the trash size should match the opening size i.e. 100 mm x 85 mm and the trash width should be at least 30 mm. The scheme can priority-based segregation and separation only one type of waste at a time. Due to lower intensity of LASER light, segregation of the non-transparent material is not possible. Dr N. Sathish Kumar, et al. presented an embedded based intelligent alert system is invented for the proper monitoring and maintenance of the garbage [4].

A review on technologies for segregation and management of solid waste by K Sujatha, et al. [5]. Jian Wang, et al. proposed a preliminary study to apply microwave non-destructive testing technique on MSW classification [6]. An experiment conducted in this study using the microwave (300MHz) non-destructive testing technique confirmed that vertical incidence of plane wave between air and different composition of MSW generates different reflection coefficients. The experiment also shows that metal has the highest reflection coefficient while wood and leaf have the least reflection in various compositions of MSW. Amrutha Chandramohan, et al. stated there is no such scheme for separation of wastes into categories such as metallic, dry and wet wastes at the household level [7]. An Automatic Waste Segregator (AWS) utilizes inductive sensors to recognize metallic things, capacitive sensors to recognize wet and dry waste contingent on the edge esteems set. In any case, it can't isolate earthenware into dry waste since it has a higher relative dielectric steady when contrasted with other dry squanders that are isolated. The limit of this approach is that priority based separation for metal, wet and dry waste and separation one type of waste at a time. This allows the use of a framework to separate a mixed type of waste.

An intelligent separation process based on optical sensor and mechanical sorting system was developed by Jiu Huang, et al. [8]. By utilizing this framework the molecule sizes and positions, hues and states of each waste molecule can be resolved and utilized as arranging measure. The mechanical arranging gadget comprises of a packed air spout which is constrained by PC, the objective particles which were perceived by sensor were extinguished of the principle squander stream. Highlight acknowledgment by utilizing an optical sensor yield great outcomes. This exploration gives another way to deal with multi-include acknowledgment of sensor-based arranging technology. Bernardo S. Costa, et al. proposed a computer visual sense formulation to separate garbage into recycling classes could be an economical way to process waste [9]. This task aims to take waste material images and separate them into four classes: glass, paper, metal and, plastic. They used a waste material image database that comprises of around 400 images for all class and different models. Experimentation have said that the models are accurate to around 93 present.

From the summary of literature review, it is observed many techniques have been employed for waste management. Still with certain drawbacks including cost, quality of jobs, lifespan, and man power requirements.

Similarly, observation of methods mention above of have shown there is difficulty in separation of useful materials from waste such as metals, plastic, wet and dry waste.

The collection data of solid waste organization is required for current future up gradations. This requires cost-effective IOT based innovative solution in a solid waste segregation process, using advanced controllers like Intel Galileo. Appropriate performance parameters can be evaluated for the performance evaluation of the proposed solid waste management unit. Accordingly, our dissertation problem statement and observations as further.

III. METHODOLOGY

The efforts to achieve the objectives are to be carried out in systematic experimentation phases with respect to the Fig.1.

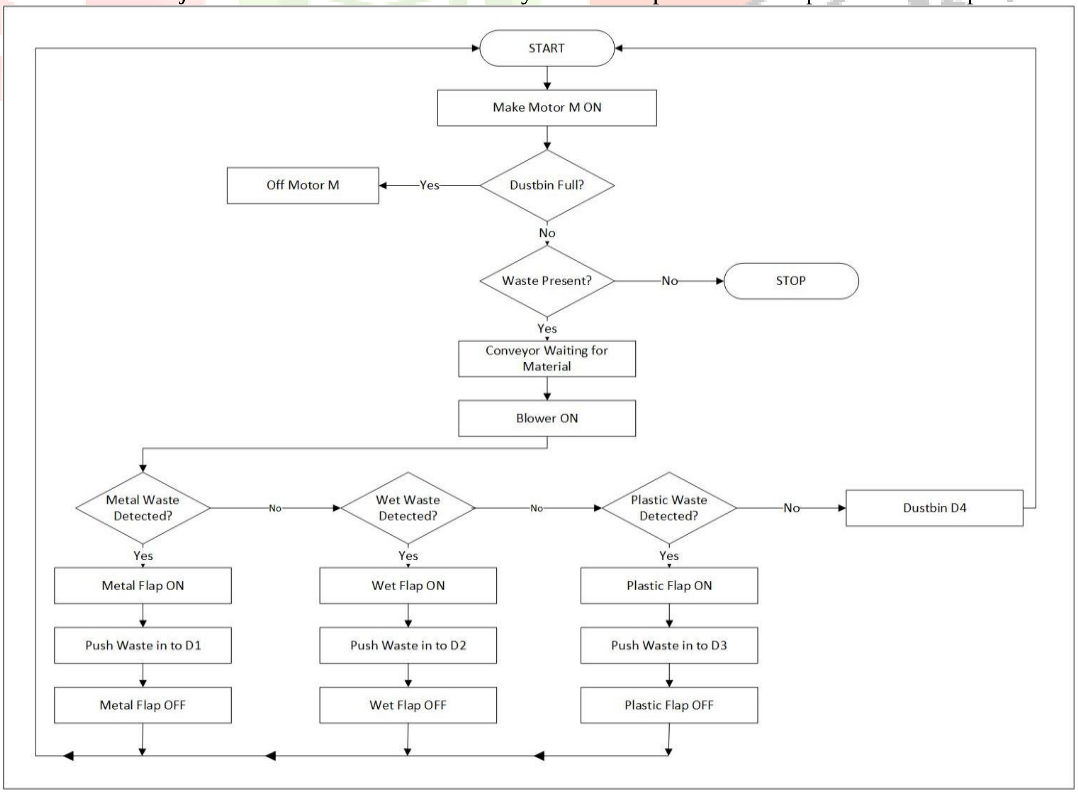


Fig. 1 Flowchart of the System

The conveyor belt motor turns on and starts moving when waste enters the belt. The sensors, micro-controller, all the motors are turned on. Initially the condition of dustbins D1 to D4 is checked. If anyone of the four is full, the conveyor belt is stopped. And if all dustbins are empty, then the status of wastes are checked, whether the waste is present or not in the system. If the waste is not present the process will stop automatically and if waste is present then the conveyor waiting for material and blower will ON.

The waste moving towards sensors. The inductive proximity sensor detects the metal or non-metal waste. When the waste is metal waste, Metal Flap is turned ON. It moves the waste into the metal waste bin (D1). Then Metal Flap is turned OFF. And the system starts again for checking condition of dustbin. When the waste is not a metallic waste, M is kept ON where it comes in contact with the moisture sensor which detects the waste is wet waste or dry waste by measuring the moisture content of the waste. When the waste has humidity it is sensed as wet waste then Wet Flap is turned ON. It moves the waste into the wet waste bin (D2). Then Wet Flap is turned OFF. And the system starts again for checking condition of dustbin. When the waste is plastic waste, Plastic Flap is turned ON. It moves the waste into the plastic waste bin (D3). Then Plastic Flap is turned OFF. And the system starts again for checking condition of dustbin. When waste is not metal, not wet or not plastic then M is kept ON. It moves the waste into the dry waste bin (D4) placed at the end of the conveyor belt.

Finally the wastes are pushed into the respective bins and the segregation process is completed. All the data stored, displayed, visualize and many other things through Blynk App. It can control hardware remotely.

IV. Experimental Design

This system has two parts -

i) Mechanical Part

ii) Electronics Part

When the input waste is on the conveyor belt, the conveyor belt starts to move and all the sensors are switched on and the sensing and segregation start. When we are given Intel Galileo as data, the metal sensor, the moisture sensor and the plastic sensors that are used to get the segregate in place. The final output is the segregated wastes into various dustbins.

4.1Mechanical Part: Mechanical Conveyor Belt Assembly:

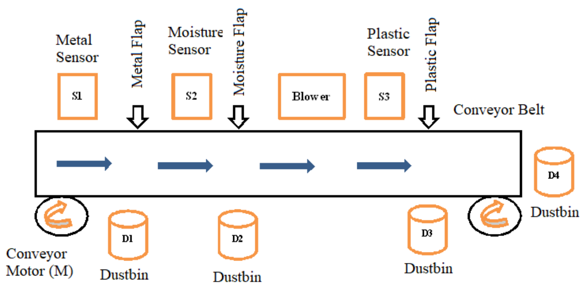


Fig. 2 Mechanical Conveyor Belt Assembly

The mechanical conveyor belt assembly as shown in Fig. 2 It consists of Motor driving the Conveyor Belt Motor (M), Blower, 3 types of sensors- Metal Sensor (S1), Moisture Sensor (S2), Plastic Sensor (S3), 3 types of Flaps- Metal Flap, Moisture Flap and Plastic Flap for Metal Sensor, Moisture Sensor, Plastic Sensor, 4 Dustbins for each material which is detected by sensors and 4 Dustbin Sensors – Dustbin Sensor (D1), Dustbin Sensor (D2), Dustbin Sensor (D3), Dustbin Sensor (D4) to check the status of dustbin i.e. half or full or empty.

4.2Electronics Part: Block Diagram of IoT Based Smart Automated Solid Waste Segregator (IoT-SASWS)

The block diagram shown in Fig. 3 represents the IoT based smart automated solid waste segregator where four types of materials are segregated namely Metal, Wet, Plastic and dry. This IoT-SASWS mainly consists of the Wi-Fi Modem, Blower, Motor driving the conveyor belt (M), Motor driving the segregator to put metal waste (M1), wet waste (M2), plastic waste (M3) and dry waste into the respective dustbin D1, D2, D3 and D4. The Intel Galileo Board is used as controller. A waste is placed on the conveyor running on a 12v, 1A motor that is connected via the motor driver and is programmed by the Intel Galileo to run in clockwise direction.

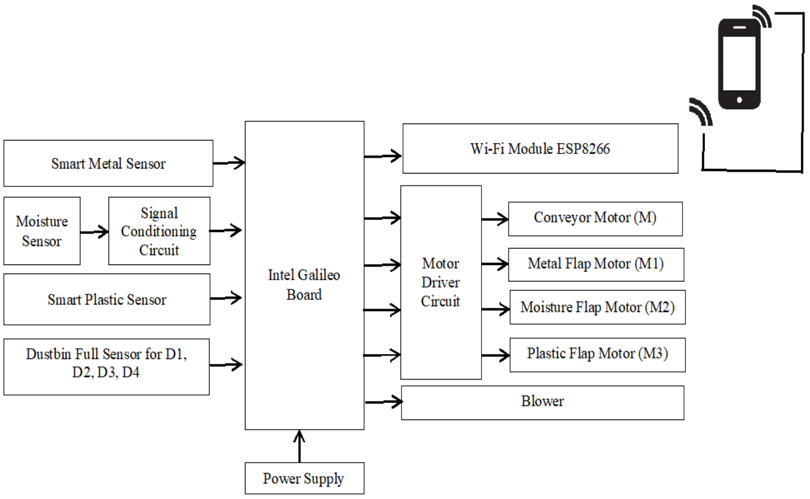


Fig. 3 Block Diagram of System

V. THEORETICAL ANALYSIS

Automated Solid Waste segregator is critical and very important process in solid waste management. The following Intel Galileo Board and sensors that are going to be used are listed as- Inductive Proximity Sensor, Moisture Sensor, Infrared Sensor, Ultrasonic Sensor, Wi-Fi Module ESP8266 (ESP – 01).

5.1 Intel Galileo Board:

The 2nd generation Intel® Galileo Board gives a single board controller to understudies and expert engineers. Galileo is a microcontroller board that relies on a chip (SoC) Intel® Quark SoC X1000 Application Processor, 32-bit Intel Pentium-class system. It is Intel® architecture board designed to be pin-compatible hardware and software with Arduino shields designed for the Uno R3. It has 14 digital input or output pins, which 6 provide PWM output (and the GND and adjacent AREF pins), the power header, 6 analog input pin, several input/output ports, ICSP header, and the UART port pins (0 and 1) are all on the Arduino Uno R3. This is also called as the Arduino 1.0 pinout.

This Intel Galileo board is software compatible with the Arduino Software Development Environment (IDE) applications. Galileo is designed to supports the 3.3V or 5V shields. In addition to Arduino software and hardware compatibility, the Galileo board has several PC industry standard Inupt/Output ports - A full sized mini-PCI Express slot, Micro-SD slot, USB Host port, 100Mb Ethernet port, RS-232 serial port, USB Client port and 8MByte NOR flash come standard on the board.

5.2 Inductive Proximity Sensor:

An inductive proximity sensor can identify metal objects, without any physical contact with the object. They do not identify non-metal objects such as paper, plastic, and wood. According to the operating theory, Inductive Proximity Sensors are basically categorized into the following three types: the high-frequency oscillation type using electromagnetic induction, the magnetic type using a magnet, and the capacitance type using the change in capacitance. The Sensing Range is depends on the type of metal being detected.

There are four components of an inductive proximity sensor; the coil, oscillator, detection circuit and output circuit. Eddy current based Inductive proximity sensor. Inductance is the phenomenon in which a fluctuating current which has a magnetic component by definition induces an electromotive force (emf) in a target object. In order to amplify the inductance effect of a device, a wire isolated into a tight coil of sensor through which current passes.

One type of inductive sensor drives a coil with an oscillator. A metallic object moving toward the coil will adjust the inductance of the coil, delivering an adjustment in recurrence or an adjustment in the current in the coil. These progressions can be recognized, enhanced, contrasted with a limit and use to switch an outer circuit. The coil may have a ferromagnetic center to make the attractive field progressively exceptional and to expand the affectability of the gadget. A coil with no ferromagnetic center ("air center") can likewise be utilized, particularly if the oscillator coil must cover a huge territory.

5.3 Moisture Sensor:

The Moisture sensor is used to measure the moisture content (water content) of the waste. When the soil has water shortage, the output of the module high otherwise the output low. This sensor alters the consumer to water their plants and also measures the soil's moisture content. It was frequently used in farming, land irrigation and botanical gardening.

5.4 Infrared Sensor:

IR sensor has a wide range of applications at both domestic and industrial level. IR module is a sensor module containing an IR transmitter as well as a receiver. The Infrared Sensor as shown in Fig. 4.13. This module performs a voltage of 5 volts and the range of obstacle detection is 5 cm which can be extended by 15 cm. An IR sensor can detect an object's heat, as well as any surrounding motion. An IR module is working fairly straightforward. When powered, IR transmitter starts transmitting continuous IR waves when there is an obstacle in the path of the waves; they get reverted back from the obstacle and are received by the receiver.

5.5 Ultrasonic Sensor (HC-SR04):

HC-SR04 Ultrasonic sensor. Ultrasonic sensors measure the higher frequencies sound waves not normally recognized by human being i.e. ultrasonic sensor is an device that uses ultrasonic sound waves to determine the distance to an object. This sensor typically does not require physical contact with their target. Ultrasonic Sensor plays a vital role in the proposed system. HC-SR04 Ultrasonic Sensor uses to sense the depth of the bin to get the waste level or garbage level.

It composed of two transducers namely Transmitter and Receiver. An ultrasonic sensor utilizes a transducer to send and get ultrasonic signal that relay back data about an object's proximity. High frequency sound signals return from boundaries to generate distance echo patterns.

Ultrasonic sensors operate by sending out a sound wave of sound at frequencies above human hearing range. The sensor transducer works as a microphone for receiving and sending out the ultrasonic signal. This ultrasonic sensor utilizes a single transducer to send a pulse and to get the echo. The sensor decides the distance to an objective by estimating delays between the sending and getting of the ultrasonic pulse.

5.5.1 Timing Diagram:

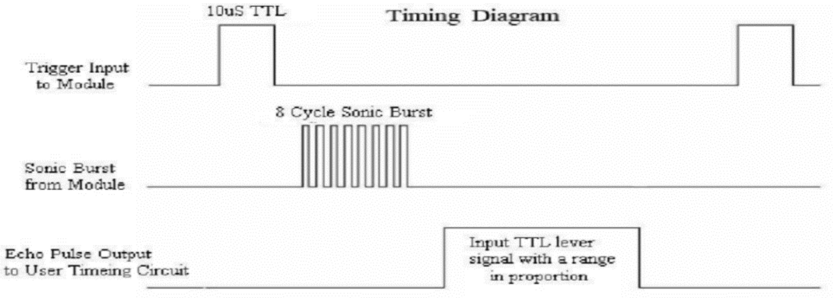


Fig. 4 Timimg Diagram

5.5.2 Working principle of Ultrasonic Sensor:

- The working standard of this module is straightforward. It has 4 connecting Pins - VCC, Trigger Pulse Input, Echo Pulse Output and GND. It sends out an ultrasonic pulse out at 40kHz that passes through the air and where an obstacle or object is present, it will revert back to the sensor. The distance can be calculated by measuring the travel time and computing the speed of sound.
- We need to provide a short 10us high level signal to the trigger input to start the ranging, and then the module will send out an 8 cycles burst of ultrasound at 40kHz. This helps to detect the presence or absence of pulse signal back (raise its echo) as shown in above Fig. 4.
- The Echo is a distance entity which is in proportion to the pulse width and the length. The range can be calculated through the time intermission between sending trigger signal and getting echo signal.
- Formula:

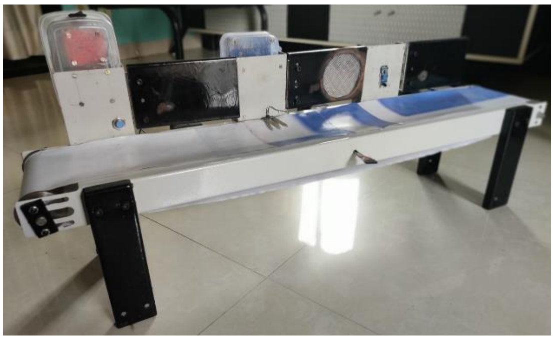
$$\text{Range} = \frac{High\ Level\ Time}{Velocity\ Of\ Sound\ /2}\text{, (Velocity Of Sound: 340m/sec)} \qquad (1)$$

5.6 Wi-Fi Module ESP 8266 (ESP-01):

ESP8266 is a chip (SoC) module with Wi-Fi enabled system developed by Espressif. It's mainly used to build embedded applications for IoT (Internet of Things). The ESP 01 ESP8266 Serial Wi-Fi Wireless Transceiver Module is a self-contained SOC with integrated TCP/IP protocol stack that can give access to your Wi-Fi network to any microcontroller. The ESP8266 can either host an application or discharge some Wi-Fi networking function from another application processor.

Each ESP8266 module comes with pre-programmed firmware set of AT commands, get Wi-Fi functionality as a Wi-Fi Shield (and that's just out of the box)! The module ESP8266 is an extremely cost-effective board with a large, and ever-growing, community.

The Complete setup of IoT Based Smart Automated Solid Waste Segregator (IoT-SASWS) is as shown in below Fig. 5



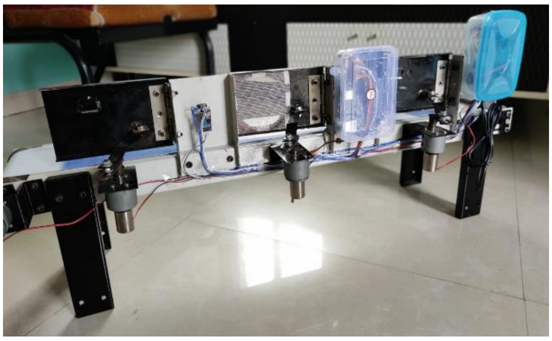


Fig. 5

Experimental Setup of IoT Based Smart Automated Solid Waste Segregator (IoT-SASWS)

VI. RESULTS AND DISCUSSION

The experiments conducted using above methodology are tested with performance parameter such as True Acceptance Rate, True Rejection Rate, False Acceptance Rate and False Rejection Rate are as follows.

$$True\ Acceptance\ Rate\ (TAR) = \frac{No.\ of\ True\ Acceptance\ (NTA)}{No.\ of\ Identification\ Attempts\ (NIA)} \qquad (2)$$

$$True\ Rejection\ Rate\ (TRR) = \frac{No.\ of\ True\ Rejection\ (NTR)}{No.\ of\ Identification\ Attempts\ (NIA)} \qquad (3)$$

$$False\ Acceptance\ Rate\ (FAR) = \frac{No.\ of\ False\ Acceptance\ (NFA)}{No.\ of\ Identification\ Attempts\ (NIA)} \qquad (4)$$

$$False\ Rejection\ Rate\ (FRR) = \frac{No.\ of\ False\ Rejection\ (NFR)}{No.\ of\ Identification\ Attempts\ (NIA)} \qquad (5)$$

The readings are recorded and various objects are detected on conveyor belt like metal, wet, and plastic as shown in Table 1. The experiment carried out in a small quantity of the waste materials and containing at least one object of each type of waste materials like metal, wet and plastic. The results of Metal Waste Segregation, Wet Waste Segregation and Plastic Waste Segregation are as shown in Table 2 and Table 4 and 6.

The result will be analyzed as further-

i. Results in terms of status of dustbin full or empty for all types of waste such as metal, wet, plastic and dry.
ii. Identifying the full dustbin and associating with the kind of wastes and displaying.
iii. Sending the status of dustbin to the attender through mobile.

This system is tested with diverse materials using true acceptance rate, true rejection rate, false acceptance rate and false rejection rate as shown in Table 3, Table 5 and Table 7. The dry waste is as shown in Table 8. The Status of Dustbin is shown in Table 9. (Height of the dustbin is 30-40 cm)

6.1 Results of Descriptive Statics of Study Variables

Table 1. Detection Status

Test No.	Material	Status Of Detection
1	Metal Waste	Yes/No
2	Wet Waste	Yes/No
3	Plastic Waste	Yes/No

Table 2. Metal Waste Segregation

Sr. No.	Type of Metal Waste	Status Of Detection
1	Lock	Yes
2	Nut-Bolts	Yes
3	Tinned Can	Yes
4	Paper Clips	No
5	Small Container	No

Table 3. Acceptance & Rejection of Metal Waste

Sr. No.	Type of Metal Waste	True Accept	True Reject	False Accept	False Reject
1	Lock	100%	--	--	--
2	Nut-Bolts	100%	--	--	--
3	Tinned Can	100%	--	--	--
4	Paper Clips	40%	--	--	60%
5	Small Container	40%	--	--	60%

Table 4. Wet Waste Segregation

Sr. No.	Type of Metal Waste	Status Of Detection
1	Vegetable Peel	Yes
2	Fruit Piece	Yes
3	Tea Bag	Yes
4	Egg Shell	Yes
5	Flower Waste	Yes

Table 5. Acceptance & Rejection of Wet Waste

Sr. No.	Type of Wet Waste	True Accept	True Reject	False Accept	False Reject
1	Vegetable Peel	100%	--	--	--
2	Fruit Piece	100%	--	--	--
3	Tea Bag	100%	--	--	--
4	Egg Shell	100%	--	--	--
5	Flower Waste	100%	--	--	--

Table 6. Plastic Waste Segregation

Sr. No.	Type of Metal Waste	Status Of Detection
1	Milk Covers	Yes
2	Small Broken Toys	Yes
3	Wafer's Wrap	Yes
4	Plastic Bag	Yes
5	Shampoo Bottle	Yes

Table 7. Acceptance & Rejection of Plastic Waste

Sr. No.	Type of Wet Waste	True Accept	True Reject	False Accept	False Reject
1	Milk Covers	100%	--	--	--
2	Small Broken Toys	100%	--	--	--
3	Wafer's Wrap	100%	--	--	--
4	Plastic Bag	100%	--	--	--
5	Shampoo Bottle	100%	--	--	--

Table 8. Dry Waste Segregation

Sr. No.	Types of Dry Waste Separation
1	Paper
2	Box Sheet
3	Groundnut Shell
4	Cotton Ball
5	Thermocol Sheet

Table 9. Status of Dustbin (Dustbin Height=30-40cm)

Sr. No.	Total Distance Measured from Ultrasonic Sensor in cm	Dustbin Full in % Value	Dustbin Status
1	Waste < 6cm	0%	Empty
2	Waste > 6cm	90%	Full

VI. Conclusion

The method reported in this paper is an effective solution for present waste segregation issue which efficiently segregates wastes materials such as metal, wet, plastic and dry. The experiment performed in a small quantity of the waste materials and the system can separate only one form of waste at a time with specific metal priority, wet, plastic and dry waste for example nuts, plastic covers in small pieces, vegetable waste, etc. were used for the testing.

It simplifies the process of the segregation at source level and thus reduces the manpower and curbs emission produced by inappropriate waste segregation at source level.

The system discussed in this paper is tested for different waste materials performance parameters such as acceptance rate and rejection rate were used in the system. The detection of metals as shown in Table 3 shows 90% true acceptance and 10% false rejection of metal type materials. The detection of wet waste and plastic waste are as shown in Table 7 and Table 10 with 100% true acceptance and 0% true rejection.

References

[1] Kavya M, Sahana P, Shruthi G, Sunitha M C, Jyothi A P. 2017. Sensor-Based Smart Dustbin fir Waste Segregation and Status Alert. IJARIIE- ISSN(O)-2395-4396 Journal, Volume 2, Issue 5.

[2] Santhosh Kumar B R, Varalakshmi N, Soundarya S Lokeshwari, Rohit K, Manjunath, Sahana D N. 2017. Eco-Friendly IOT Based Waste Segregation and Management. IEEE Conference, International Conference on Electrical, Electronics, Communication, Computer and Optimization Techniques (ICEECCOT).

[3] Sharanya. A, U. Harika, N. Sriya, Sreeja Kochuvila. 2017. Automatic waste Segregator. IEEE Conference.

[4] Dr N. Sathish Kumar, B. Vijaylakshmi, R. Jenifer Prarthana, A. Shankar. 2016. IOT Based Smart Garbage alert system using Arduino UNO. IEEE Conference.

[5] Siddappaji, K Sujatha, Radha R C. 2016. Technologies for Segregation and Management of Solid Waste: A review. IEEE Conference.

[6] Jian Wang, Bingfeng Deng, Hongji Ren. 2016. Municipal Solid Waste Classification Using Microwave Nondestructive Testing Technique. IEEE Conference, 13th International Conference on Ubiquitous Robots and Ambient Intelligence (URAl), at Sofitel Xian on Renmin Square, Xian, China.

[7] Amrutha Chandramohan, JoyalMendonca, Nikhil Ravi Shankar, Nikhil U Baheti, Nitin Kumar Krishnan*, Suma M S. 2014. Automated Waste Segregator. Texas Instruments India Educators' Conference, DOI 10.1109/TIIEC.2014.9, IEEE Conference.

[**8]** Jiu Huang, Thomas Pretz, ZhengfuBian. 2010. Intelligent Solid Waste Processing Using Optical Sensor Based Sorting Technology. IEEE Conference, 3rd International Congress on Image and Signal Processing (CISP2010).

[9] Bernardo S. Costa, Aiko C. S. Bernardes, Julia V. A. Pereira, Vitoria H. Zampa, Vitoria A. Pereira, Guilherme F. Matos, Eduardo A. Soares, Claiton L. Soares, Alexandre F. Silva, "Artificial Intelligence in Automated Sorting in Trash Recycling".