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Intelligent Waste Segregator: Waste Segregation, Analysis and Path Optimisation

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Abstract

The amount of waste dumped every year is a staggering2.12 billion tonnes and this value is only going to increase in the coming years. Most of this waste is either reusable or recyclable. However, due to the lack of a proper waste management system, the waste just goes to the landfills without proper segregation. This paper aims at tackling the most important problem of waste management - segregation. With the launch of the Swachh Bharat Ab- hiyan, Government of India has indicated that cleanliness, sanitation and public hygiene are among its top priorities. To help accomplish these objectives, the paper focuses on segregation of waste into dry, wet, plastic and metal. Dry, wet and metallic waste are segregated based on their dielec- tric values. Dry waste can be further segregated into plastic waste and other dry wastes such as paper, wood, glass, cloth and such items through image processing. This paper also discusses the path optimisation for waste collection and an IoT based android application that allows its users to manage their waste more efficiently based on analytical services provided. Thus, with functionalities such as waste identification, waste segregation and an optimized waste collection system, the Intelligent Waste Segregator truly becomes a smart bin which helps us in achieving our mission towards becoming a cleaner and greener world.

Index Terms: *Waste Segregation, Image Processing, Path Optimisation, Intelligent, Mobile Application, Recycle, Capacitive Sensing, Automation, Dry, Wet, Metal, Plastic*.

I. INTRODUCTION

World Environment Day 2018 targeted plastic pollution, with global host India leading the way by pledging to give up single-use plastics by 2022 [1]. This can be achieved when waste is properly segregated.

Realising the gravity of the situation, the Government as well as the people have started taking actions to tackle this problem. In many residential complexes, the residents are supposed to maintain two separate bins - one for dry waste and one for wet waste. Instead, having just one system that segregates the waste into multiple types would be very ad- vantageous. The Intelligent Waste Segregator segregates the waste into 4 different types - dry, wet, plastic and metal. The waste can be collected separately based on volume -for example since every household generates a considerable amount of wet waste everyday, it needs to be disposed off on a day to day basis. Dry, plastic and metallic waste can be collected on a weekly basis.

Currently, segregation of waste like plastic and paper which can be recycled or reused is done by hand picking. This exposes the workers to a plethora of diseases as land- fills' host a large number of hazardous materials, chemicals and disease causing microbes.

The amount of fuel that the garbage disposal trucks use while collecting the waste from the various pickup points can be saved by creating an optimisedpath for the collection of waste. The garbage disposal trucks can go to the loca- tion to collect the waste only when the bin is full or above a certain threshold. This process can be implemented in smart cities where data can be acquired easily. A lot of money will be saved on fuel expenditure as well as other resources like buying excessive number of garbage disposal trucks, thus eventually saving on the cost of the truck as well the labour cost. The driver of the truck will get an alert when the bin gets full and the shortest path of collection will be notified to him via the android application.

The app contains a daily and weekly analysis graph which will tell us the amount of waste thrown on a daily and weekly basis respectively. The app will also give suggestions on what waste can be reused or recycled. The app will also give reminders about when the bin is full or when the trash needs to be taken out.

All of this will help us get a step closer to our goal of the 3Rs- Reduce, Reuse and Recycle.

II. OBJECTIVES

The main objectives of the Intelligent Waste Segregator are as follows:

Automation:

The lid opens automatically when the user approaches the Intelligent Waste Segregator. Also, the process of segrega- tion of waste is completely automated without any human intervention.

Waste Segregation:

The Intelligent Waste Segregator segregates waste into dry, wet, metallic and plastic.

Path Optimisation:

The collection of the waste can be done in an optimised man- ner thus eventually saving on fuel and resource costs.

Analysis:

The type of waste thrown into the bin can be analysed via the android application based on the data sent and the user can see daily and weekly analysis of the disposed waste and also get corrective suggestions for the same.

The 3 Rs:

The main aim and goal of the Intelligent Waste Segregator is to reduce, reuse and recycle the waste through various technologies and data analytics.

III. SYSTEM DESIGN

The figure below shows the architecture of the Intelligent Waste Segregator:

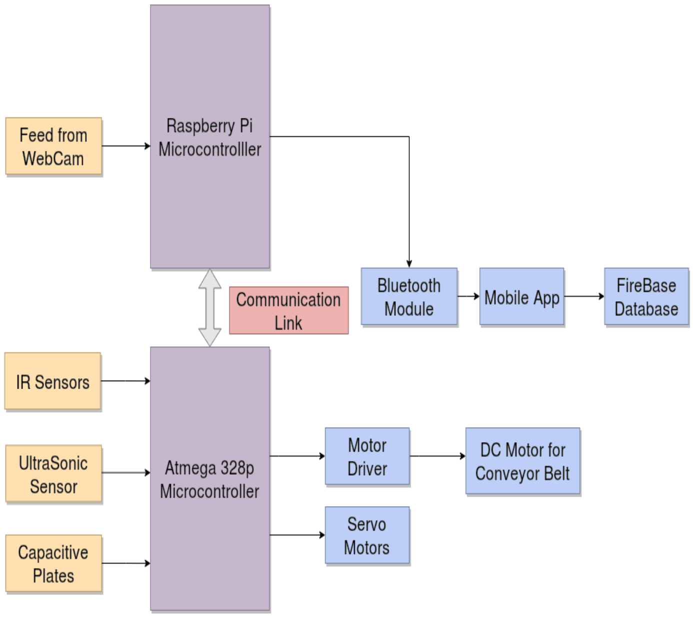

Figure 1: Block Diagram of Intelligent Waste Segregator

IV. HARDWARE REQUIREMENTS

Raspberry Pi 3: Raspberry Pi is a palm sized computer, which is very cost effective and can be used as a computing unit. There are 40 General Purpose Input/Output (GPIO) pins with 1GB of available RAM. Along with Bluetooth, it also has ports for Display Serial Interface, Ethernet and the Camera Serial Interface. It is used for image processing forplastic waste identification and for communication with the android application.

Atmega 328p: Atmega328p is an 8-bit microcontroller with enhanced RISC architecture. It is a 28 pin IC with one serial programmable USART

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and one 8-channel 10-bit suc- cessive approximation ADC.

Thus, in Intelligent Waste Segregator, the sensors and mo- tors are controlled by Atmega while the computation inten- sive tasks are performed by Raspberry Pi.

IR Sensors: IR Sensors are electronic devices that mea- sure the heat radiated by any object or detect motion of any object. Infrared sensors are used to measure radiation which lie in the infrared range of the spectrum, which is not visible to the naked human eye. IR sensors are used in the Intel- ligent Waste Segregator to notify us when any one of the chambers of the bin gets full.

Capacitive Plates: Copper clads are rectangular copper plates which are generally used to manufacture circuit boards. However, here they are used to calculate the capaci- tance value of any material placed between the plates.

Servo Motor: Servo motors are high precision rotary ac- tuator devices which are used to rotate or move objects. For controlling the movement of the servo motors shaft, one con- trolling signal is used and it restricts the total rotation from 0 to 180 degrees. Servo motors are used to open or close the lid of the dustbin and to control the movement of the shutters in the conveyor belt.

Ultrasonic Sensor: Ultrasonic sensor is a device used to detect obstacles. In Intelligent Waste Segregator, it is used to determine the proximity of the user from it and to accord- ingly open the bin when the user approaches the bin.

WebCam: USB WebCam captures high resolution image of waste placed in the segregator and feeds it to Raspberry Pi. Raspberry Pi then uses an image classification neural network to classify the waste into plastic or other dry waste.

V. SOFTWARE REQUIREMENTS

Image Processing: Image processing/classification is done using the OpenCV and Tensorflow library of Python. The image of the material in the bin is obtained from the WebCam and it is used by Raspberry Pi for identification of plastic from dry waste. The classification is done with the help of a neural-network. Transfer learning was used to cre- ate a model from a pre-trained Inception Model. Inception Model is a convolutional neural network which is trained on the ImageNet database to classify objects into 1000 different classes. This model uses 25 million parameters for classifi- cation of a single image and therefore this results in a very high accuracy of classification[2].

Path Optimisation : For path Optimisation, A* (A Star) search algorithm is used. This algorithm is an improved ver- sion of Dijkstra's algorithm in terms of finding the shortest path. The shortest path between different locations on the map will help save a lot of fuel and other resources.

Android Application:

- For Users:
  - Mobile Application with an active Internet connection
- For Administrators:
  - Python with suitable libraries installed
  - Google FireBase Database
  - Analytical Tools like - RStudio, Python with suitable libraries installed.

VI. METHODOLOGY

Figure 2 shows the flowchart of the Intelligent Waste Segregator.

Intelligent Waste Segregator has different working modules as explained below:

Automatic door:

When the user approaches the bin, the lid of the bin automat- ically opens. Intelligent Waste Segregator uses ultrasonic sensors instead of IR sensors for this since ultrasonic sen- sors are more accurate than IR sensors. Ultrasonic sensors make sure the bin opens

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only when the user approaches the bin and not every time the user passes the bin.

Waste segregation:

Waste is segregated into wet, dry, metal and plastic in the following steps:

Dry, Wet and Metal segregation: For segregation of wet, dry and metallic waste we compare their capacitive values. The value of the capacitance depends on the di- electric present between the plates. Garbage is collected in an arrangement consisting of two copper clad plates fixed at 45◦ to the horizontal. The permittivity of wet waste is considerably higher than that of dry waste. Hence the capacitance of wet waste is more than that of dry waste[3][4]. The capacitance of metallic waste is infinite.

We have taken the following range of capacitive values for determining the type of waste as mentioned in the table below:

Plastic segregation: Dry waste can be further classified into plastic waste and other kinds of waste like paper, glass. This is achieved with the help of image processing and image classification. The concept of Transfer Learn- ing has been applied here where a pre-trained neural- network namely Inception-v3 model which is widely usedfor high accuracy image classification. Inception model is a 48 layer neural-network and it consists of two parts: fea- ture extraction (done in the earlier layers) and classifica-tion (done in the later layers). In order to classify plastic waste from other waste, Inception Model was retrained based on the new set of images which consisted of differ- ent images of plastic waste[5]. The weights of the earlier layers which consisted of feature extraction were frozen and the weights of the later layers which classified the images were changed/trained as per the new dataset[2].

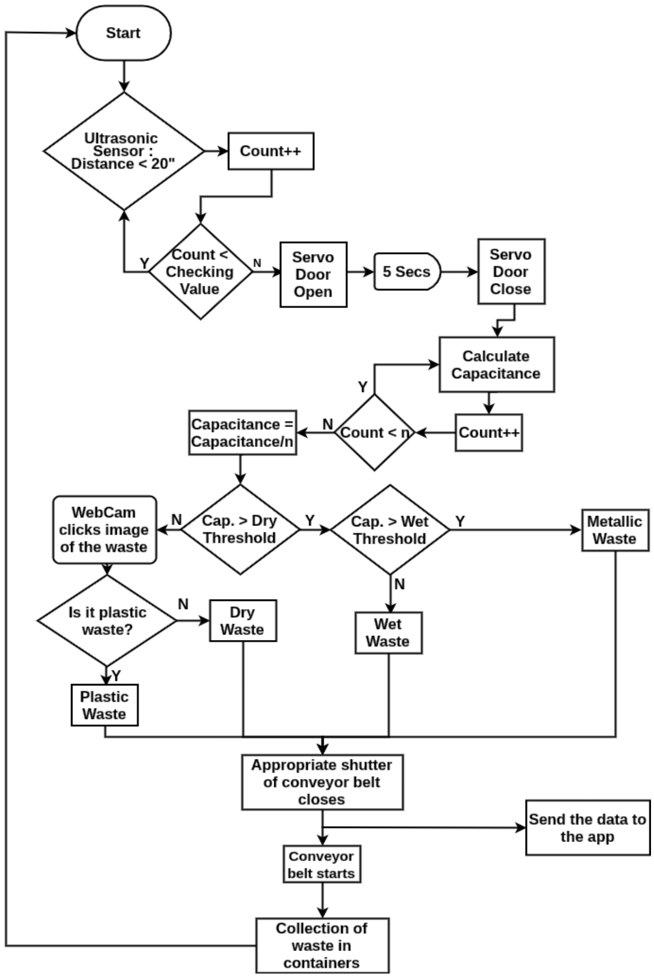

Figure 2: Flowchart of Intelligent Waste Segregator

Type of waste	Range (Capacitance in pF)
Dry	0-20
Wet	20-500000
Metallic	Infinite

Table 1: Capacitive Range of different waste materials

Once the waste is identified, the appropriate shutter closes on the conveyor belt and then the conveyor belt starts moving with the help of a 12V DC motor, and the waste on reaching the shutter, slides down into the bin placed below the shutter.

Path Optimisation:

Each bin will have an IR sensor attached to it. IR sensors will determine if the waste in the bin is full

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or not. If it is, then that bin will be declared full and the user will be intimidated about it via the android app. In a smart city, when the bin gets full, the garbage disposal truck driver will be intimidated about it via the android app. Then using the data acquired from the bins at different locations, we can find the shortest path using A* search algorithm. The A* search algorithm is a heuristic search algorithm and helps us find the shortest path between two points. With the devel- opment of machine learning and artificial intelligence, the A* algorithm has been improved many times, and is widely used in robot path planning, intelligent transportation, graph theory, automatic control, and various such applications[6]. The driver goes and collects the waste from the different lo- cationswhere the bins are full based on the shortest path which will be given to him via the android app which is linked to google maps.

Alerts and Updates through Android Application:

Once the waste is identified, the data is sent to the android application. The app has many features like suggestions on what waste can be recycled or reused and this helps the user to manage his/her waste more efficiently. Once the user is logged into their respective accounts, the data is sent and re- ceived from the cloud storage. Information like the amount of waste in each bin is also sent. This data is useful for de- termining the path to be used for garbage collection[7]. The android application also has a feature that allows the user to view their daily and weekly waste disposal statistics. For this, a query is fired from the app to the FireBase Database. After resolving the received query, the response is sent to the requesting application.

The app contains the user name of different people using the application along with their unique identification number (UID)[8]. The app also shows the information received from different users. For a given user, information is stored on a daily basis. This information include details like date, email (user id), user's latitude and longitude, the amount of waste in dry, wet, metal and plastic bins[9].

Figure 3: Daily and weekly analysis on Android Application

The above images represent the daily and weekly analy- sis.

VII. RESULTS

The front and top view of the prototype can be seen in the images below:

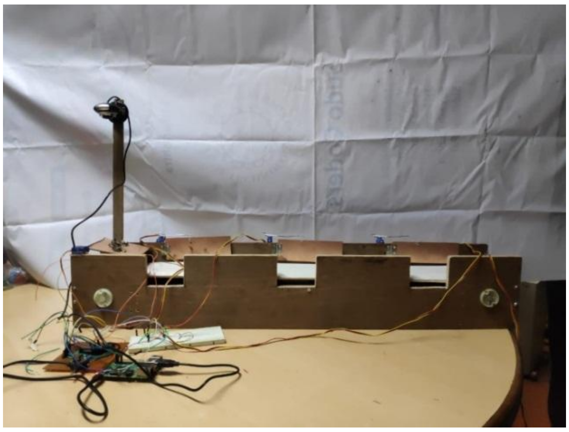

Figure 4: Front view of the prototype

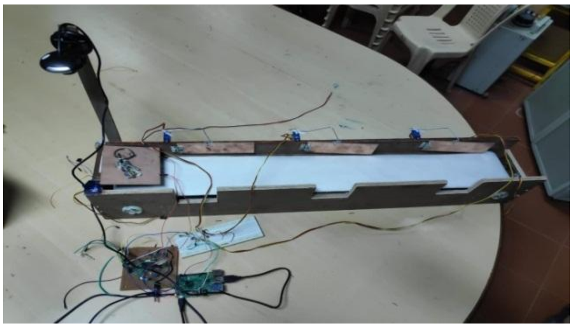

Figure 5: Top view of the prototype

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The following table contains a few sample observations for the segregation of waste through their capacitive values:

Waste	Capacitance	Waste Type
Flat Bread (Chapati)	100uF	Wet
Paper	6pF	Dry
Banana Peel	180uF	Wet
Plastic Wrapper	3.5pF	Dry
Keys	Infinite	Metallic

Table 2: Waste Values and Classification

```
Capacitance Value = 5.912 pF
d
Capacitance Value = 6.399 pF
d
Capacitance Value = 6.942 pF
d
Capacitance Value = 6.981 pF
d
```

Figure 6: Capacitive Value of Dry Waste (paper)

In Figure 6,thecapactive value of paper is shown which is displayed on the Serial Monitor. The typical value obtained when paper is placed within the plates is 6 pF.

```
Capacitance Value = 175.864 pF
w
Capacitance Value = 172.709 pF
w
Capacitance Value = 182.487 pF
w
Capacitance Value = 184.212 pF
w
```

Figure 7: Capacitive Value of Wet Waste (banana peel)

In Figure 7, the capactive value of banana peel is shown which is displayed on the Serial Monitor. The typical value obtained when the peel is placed between the plates is 180 pF.

```
Capacitance Value = inf nF
m
Capacitance Value = inf nF
m
Capacitance Value = inf nF
m
Capacitance Value = inf nF
m
```

Figure 8: Capacitive Value of Metallic Waste

In the Figure 8, the capactive value of metallic strip is shown which is displayed on Serial Monitor. The typical value obtained when a metal strip is placed within the plates is infinite.

The following images are the results of the image classi- fication using neural networks for the segregation of plastic and other dry waste:

Figure 9: Paper image classification

Figure 10: Plastic image classification

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VIII. CONCLUSION

Using capacitive sensing we identify dry,wet and metal wastes. Capacitive plates return the capacitance value of the material placed between them. The capacitance of dry waste is lower than wet waste and ranges from 0 pF to 20 pF. The capacitance of wet waste ranges from 20 pF to 500 uF. Lastly, if capacitance of material is higher than the thresh- old of wet waste it is classified as metallic waste. Plastic is classified as dry waste because the capacitance of plastic is similar to that of dry waste. But it can then be segregated by using image processing. Once any one of the bin holding the waste gets full, the user is intimidated via the app which also gives the user a daily and weekly analysis of the type of waste thrown along with suggestions on what to do with the waste. In smart cities, when the bin gets full, the driver of the garbage disposal van is intimidated and the shortest path for the collection of the waste is drawn on the app thus optimising the path.

IX. FUTURE SCOPE

Identifying the exact waste and not just waste type will help determine which waste can be reused or recycled. For ex- ample, identifying paper waste and intimidating the collec- tor via the app about the amount of paper waste can help the collector know and deliver the paper waste for recycling, rather than dumping it straight in the landfills. Also, by pre- dicting what kind of waste will be thrown majorly in a par- ticular locality by applying machine learning algorithms to the data, we will collect information about the amount and type of waste thrown in a particular area. With this data col- lected from a particular locality, special arrangements can be done. For example, horticulture can be promoted near an area where the amount of wet waste generated is higher.

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