A Project Report

on

ResponsiBin
-An IoT-based smart dustbin

carried out as part of the course CS 1634 Submitted by

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Abstract

Waste Management is crucial not only in maintaining the cleanliness of our surrounding but also keeping in mind the good health of the people. This requires logical and meticulous planning because a lot is at stake and the effectiveness of this process will benefit everyone as well. Often people don't give much thought to dustbin criteria while dumping trash resulting in a uncategorised and flawed waste storage. Currently waste separation is done after collection but due to the mixture with organic waste this process becomes more difficult and less efficient. Waste separation at initial stage is one possible solution to this problem, this is where this study comes into the picture. Existing use of IOT in this field is limited only to waste monitoring and level indication.

This study is aimed towards development of an IOT based smart dustbin which will be able to distinguish between two main criteria of waste - Recyclable and Organic. It also provides cloud based monitoring of ResponsiBin's locations. The current waste level can be tracked and the responsible authorities will be notified to come and clear out the bin. Identification of different waste criteria is made possible by the use of Pre-trained image classification model deployed using Keras and TensorFlow 2.0 and later converted to TensorFlow Lite for use in Raspberry Pi.

Such classification of waste at primary level can increase the percent of waste being recycled and dumping of organic waste free of harmful materials can be done successfully. The project's desired result is to make a dustbin which can detect interaction, capture images and process them in real time thus giving rise to opening of correct dustbin lid. It would also be able to upload data on cloud indicating its level and location.

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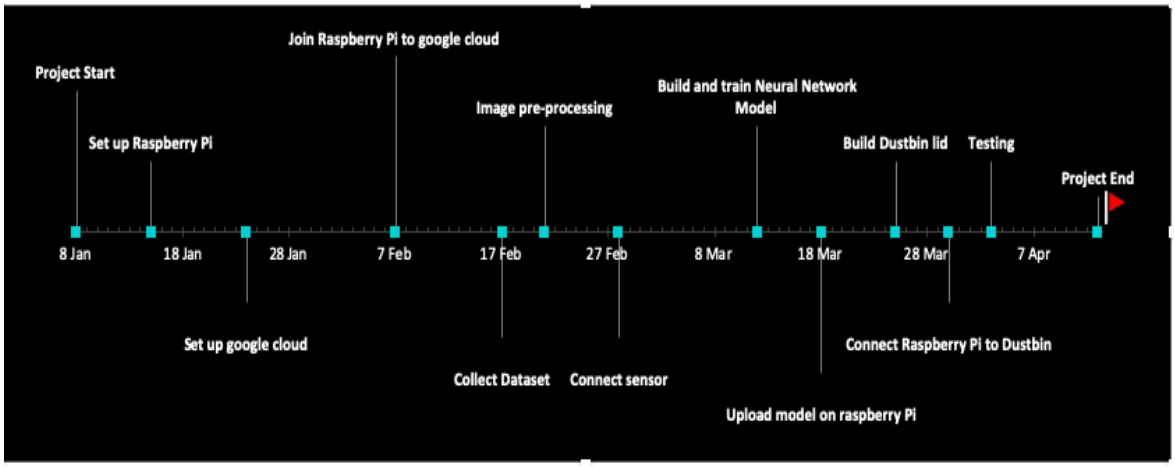
Introduction

- ## Scope of Work

  - Project Objective:

    - Implementation of Deep Learning for waste category classification.
    - Use of Ultra-Sonic sensor for person and level detection.
    - Data transmission to Google Cloud, mainly waste level and GPS data.

  - Schedule/Milestones:



  - Deliverables:

    - A trained model capable of waste categorization.
    - A dustbin which can implement project objective.
    - A project report indicating accuracy and explaining working of ResponsiBin.
    - An API with GPS and dustbin level information.

- **Product Scenarios**
    - **Test case 1:** *User carries Organic waste and level is below 95%*
        - ResponsiBin detects it as Organic waste and opens the lid of Organic box.
        - After each usage, it uses Ultrasonic sensor to detect the current level.
    - **Test case 2:** *User carries Organic waste and level is above 95%*
        - ResponsiBin detects it as Organic waste but the level is full, hence resulting in full indication with no movement of lid.
        - Cloud notifies the responsible authorities about the level, indicating that the bin must be emptied and restored.
    - **Test case 3:** *User carries Recyclable waste and level is below 95%*
        - ResponsiBin detects it as Inorganic waste and opens the lid of Inorganic box.
        - After each usage, it uses Ultrasonic sensor to detect the current level.
    - **Test case 4:** *User carries Inorganic waste and level is above 95%*
        - ResponsiBin detects it as Inorganic waste but the level is full, hence resulting in full indication with no movement of lid.
        - Cloud notifies the responsible authorities about the level, indicating that the bin must be emptied and restored.

Requirement Analysis

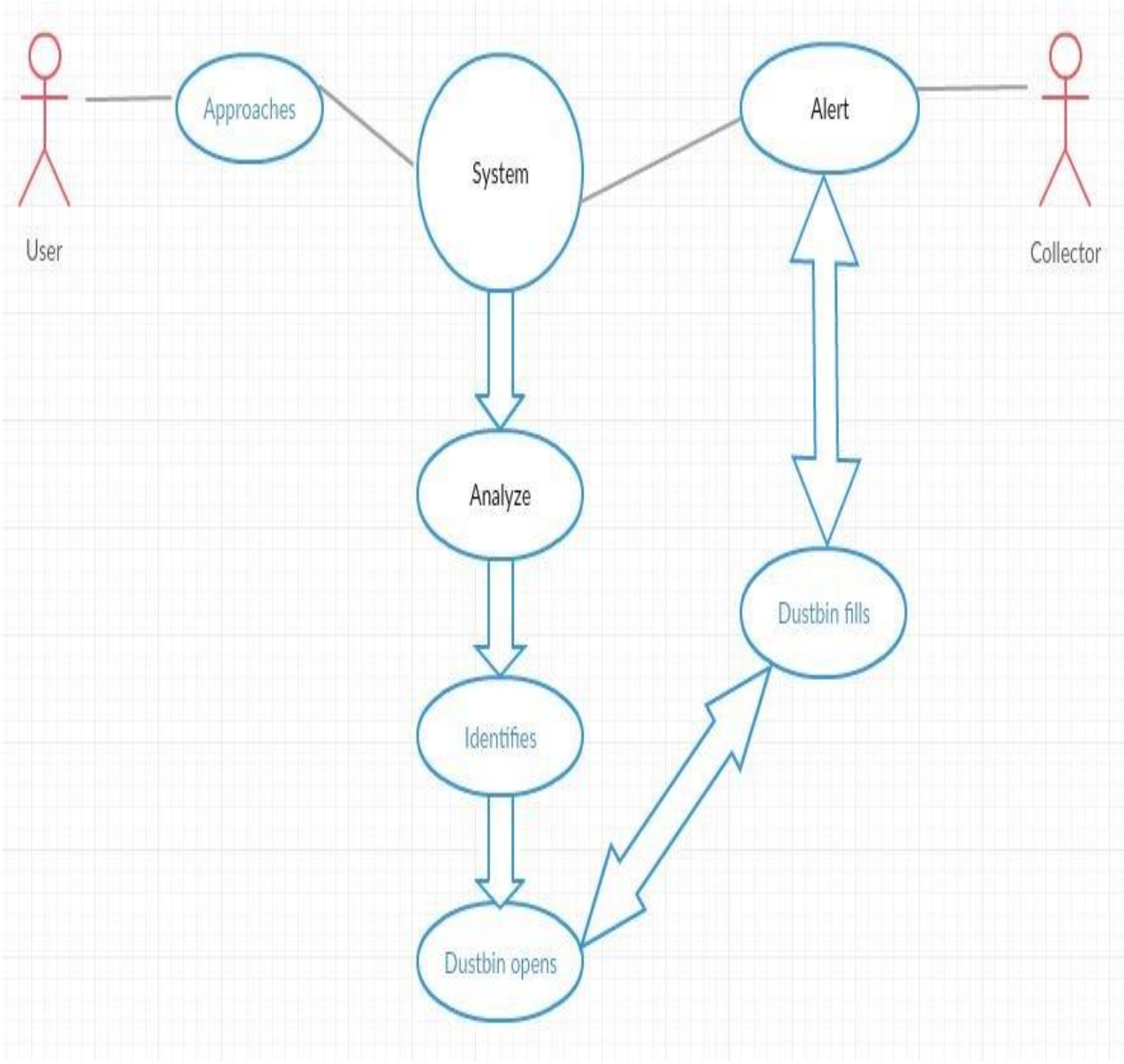
- **Functional Requirements**

Functional Requirement	Description
Interaction	It should be able to detect a person when he/she is closer than 30cm.
Image capture	Camera module should be able to capture images
Deep Learning	Images are required to process through pre-trained neural network.
Criteria Detection	Deep learning model result is required to switch servo motor on/off of correct compartment.
Wi-Fi Connection	Raspberry Pi should be able to connect to internet.
GPS	Raspberry pi should be able to identify location coordinates.
Level detection	It should be able to use ultrasonic sensor to detect current level of trash in dustbin
Cloud Data Upload	Raspberry Pi should be able to establish connection with cloud and can upload GPS and waste level data

- **Non-Functional Requirements**

Requirement	Description
Reliability	It should be able to detect waste with a satisfactory accuracy.
Security	Unauthorised change in location should be alerted to authorities.
Response Time	Response time or the time taken to open the lid should be reasonable.
Maintainability	Batteries replacement and sensor depreciation should not be often.
System Management	Raspberry Pi software and model update must be timely.
Network Architecture	Cloud network connection and protocols must be reliable.

- **Use Case Scenarios**



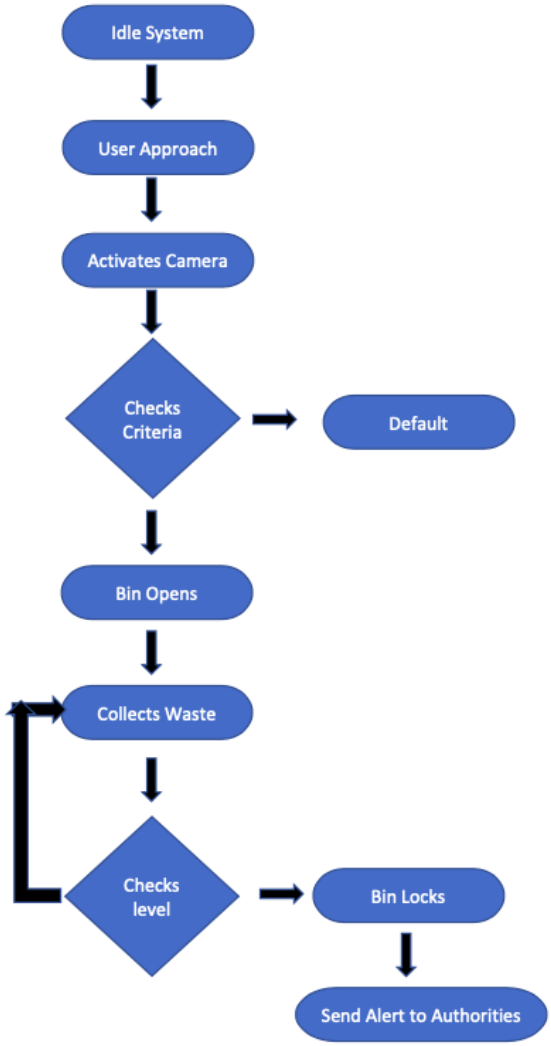
System Design

- ## Design Goals

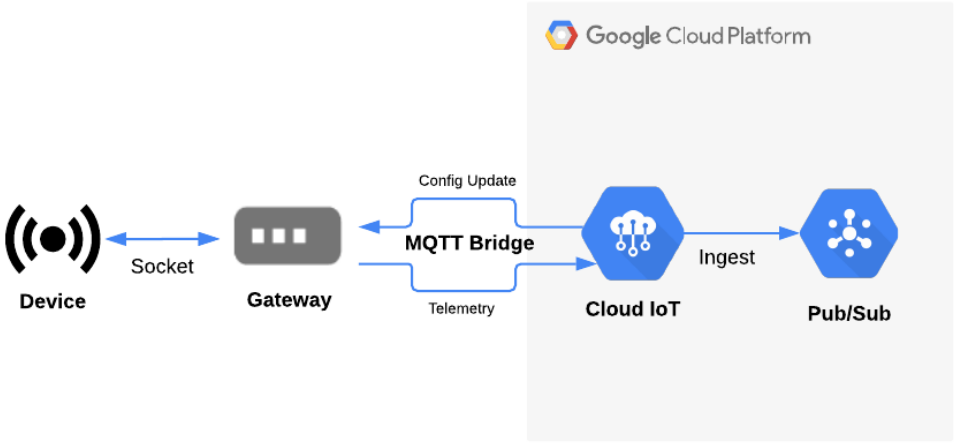
    - System must be able to communicate within itself smoothly.
    - Different sensors and hardware must share information between each other seamlessly.
    - System should be able to categorize waste and open correct lid.
    - System can send GPS and level data to the cloud.

- ## System Architecture

    - Device Architecture



- Cloud Architecture



- **Detailed Design Methodologies**

  - Ultrasonic sensors are used for interaction and level detection.
  - GPS sensor collects location data.
  - Camera module which is activated after response of interaction from Ultrasonic sensor is used to capture images.
  - Images captured from camera module are processed by pre-trained model resulting in waste criteria.
  - Result from pre trained model is used to signal Servo motors which then opens the correct lid.
  - Raspberry Pi embedded Wi-Fi module is used to upload data on Google cloud where project Pub/Sub is already set-up.
  - Responsible authorities are notified when Dustbin level is full using google cloud API.

Work Done

- **Development Environment**
    - Hardware
        - Raspberry Pi 3
        - Ultrasonic Sensor
        - GPS Module
        - Camera Module
        - Servo motor
    - Software
        - TensorFlow 2.0 for training
        - TensorFlow Lite for deployment
        - Keras
- **Results and Discussion**
    - Person detection and waste categorization.
    - Opening of correct lid.
    - Level and GPS information being uploaded to cloud.
    - Authority notification when bin is full.
- **Experimental Dataset**
    - The dataset namely Trashnet dataset was collected by mobile devices, which contains 2527 images with six classes such as glass, paper, cardboard, plastic, metal, and trash. The object of images was placed on a white background and using sunlight and/or room lighting.

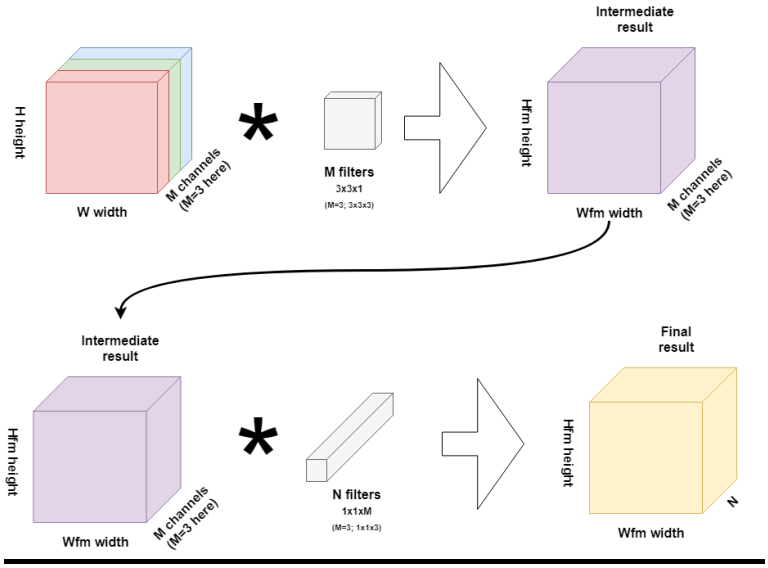
No	Classes	Number of images
1	Glass	501
2	Paper	594
3	Cardboard	403
4	Plastic	482
5	Metal	410
6	Trash	137

    - About 400 organic waste images are also collected

- **Deep Learning Model**

  - Custom VGG 16 model was used to train dataset for identification of seven categories:
    - Cardboard
    - Metal
    - Glass
    - Plastic
    - Paper
    - Organic
    - Trash

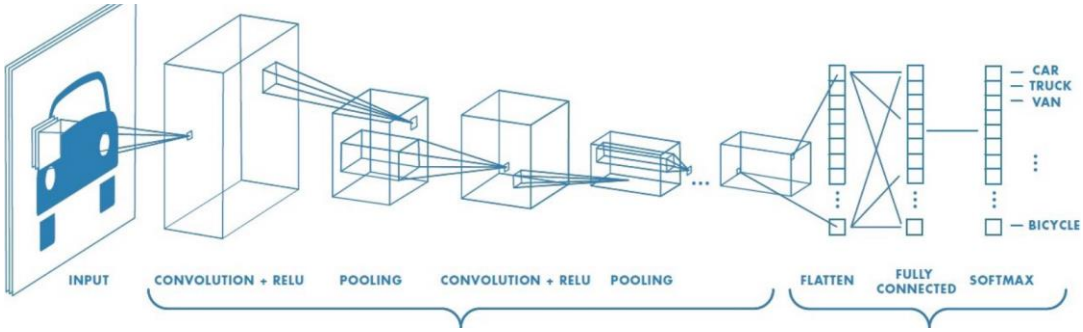
  - Separable Convolution was used for better efficiency:



  - Model Basic Structure:

    - No. of Conv2d Layers=2 filter 16
    - No. of SepearableConv2d:
      - 2 filter 32
      - 2 filter 64
      - 2 filter 128
      - 2 filter 256
    - No. of Dense layers:1 unit 512, 1 unit 128, 1 unit 64, 1 unit 1
    - Echos=10
    - Activation=relu
    - Output activation=softmax
    - Optimizer=adam

- CNN structure:



- **<u>Individual Contribution</u>**

  - <u>Abhishek Choudhary</u>

    - Building of Neural Network
    - Training of Deep learning model
    - Cloud Platform Setup

  - <u>Aishwarya Murali Padikkal</u>

    - Data Collection
    - Image Pre-processing
    - Sensors, Raspberry Pi setup

Literature Review

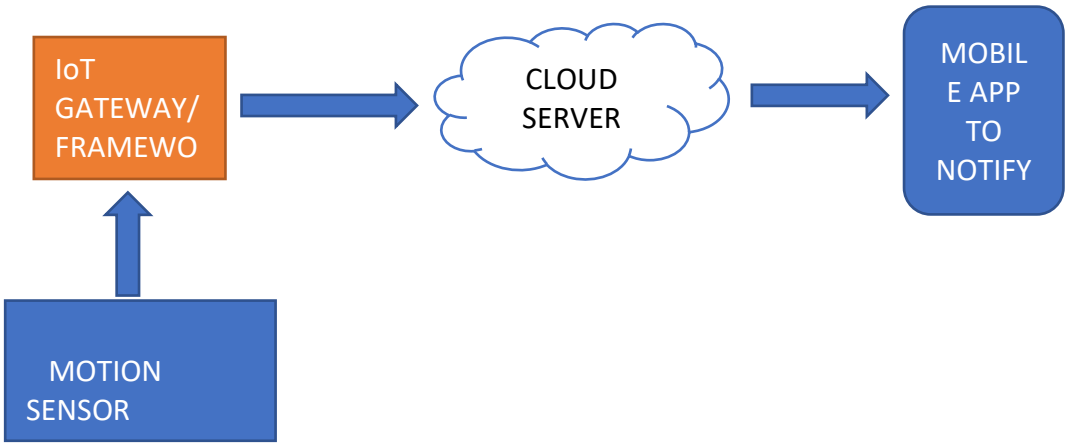
Conceptual Framework

The concept of smart garbage bins and systems have been in discussion for quite some time. However the technologies at disposal to develop this smart system are continuously evolving and progressing. Some of the key variables seen in this project are IoT, Sensors, Smart garbage bins and Waste Management. A better understanding of these can be got from the following figures.

IMPORTANT KEYWORDS: IoT, Sensors, Smart Garbage Bins, Waste Management

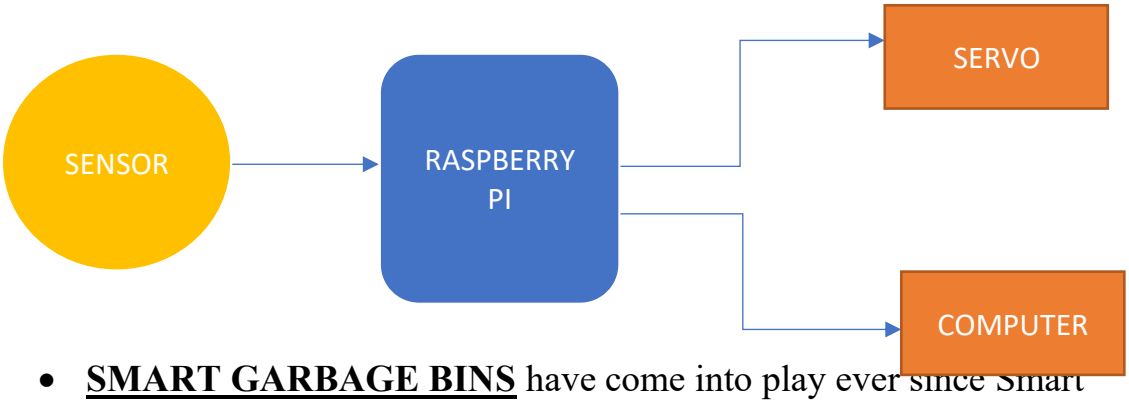
- **IoT** plays an important role to ensure seamless transmission of data between the hardware and software.

BASIC IOT ARCHITECTURE

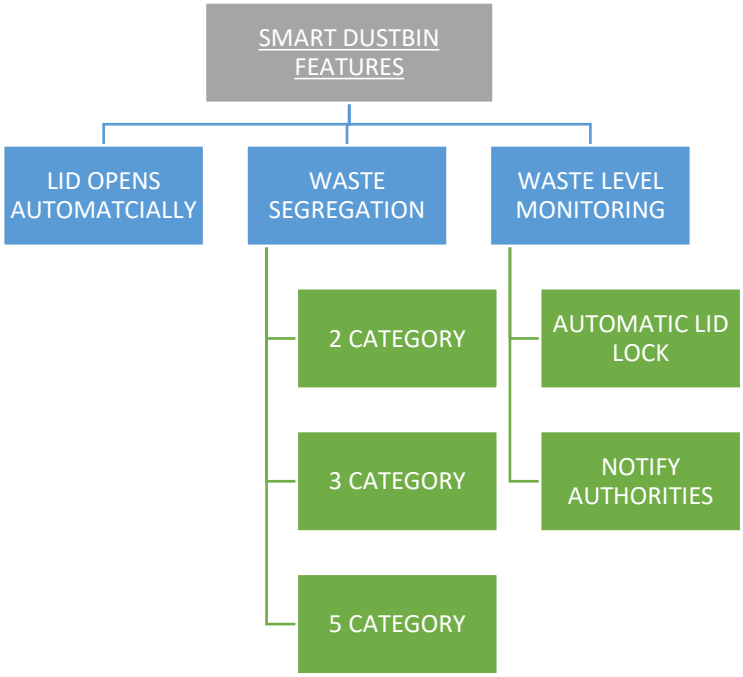


- **SENSORS** such as the HC-SR 04 Ultrasonic Sensor is essential to detect human interaction with the dustbin and also for level indication.

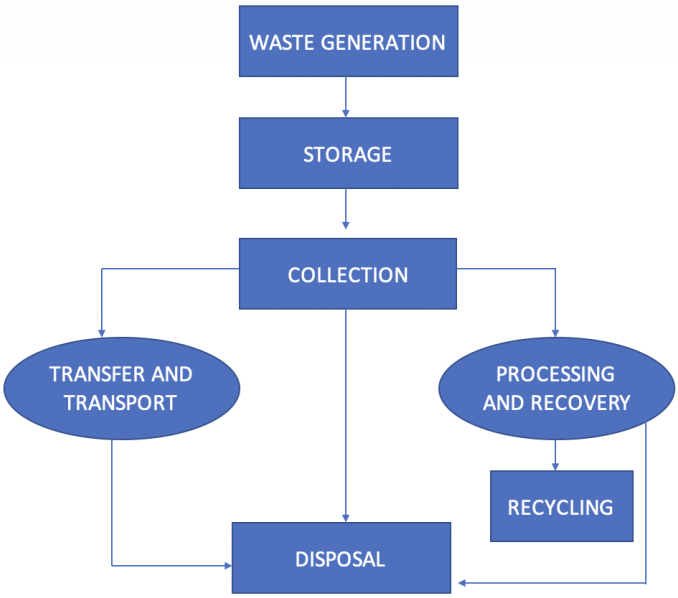
SENSOR INTERFACE



- **SMART GARBAGE BINS** have come into play ever since Smart Cities became the new buzz word. They have various features such as automatic lid opening, automatic waste classification, waste level detection, monitoring and so on.



- **<u>WASTE MANAGEMENT</u>** involves the following steps in its complete procedure.



Theoretical Framework

The worldwide implementation of Internet of Things is made possible with a cloud-centric vision. This work exploits some future possibilities, key technologies and applications that are likely to drive IoT research further in the direction of "smart" usage. But a strong foundation to our work is provided by the basics and applications of *Deep Learning*.

Deep learning is an upcoming subset of Machine learning which is still in its research and mainly aims to bring ML even more closer to one of its focuses: i.e. Artificial intelligence. Deep learning techniques are used in applications where adaptive learning is done. Deep learning can do cognitive learning as well which comprises of learning the features, characteristics and attributes with the help of good algorithms that can learn by itself. The family of deep learning has been increasing its hold through neural networks, various unsupervised and supervised learning algorithms for recognizing features such as Convolutional Neural Network or CNN which is used in our project. It has the capacity to process complex data given as input and results in giving the predicted output through effective recognition, in this case the segregation of waste.

Deep learning allows processing of multiple layers between the initial and final layer, known as hidden layers. Deep learning makes use of the back propagation algorithm to discover complex structures in huge data sets.

In this project, the neural network model is trained with the help of a data set of images containing both biodegradable and non-biodegradable waste. After this, the pre-trained model becomes capable of processing the images obtained using a camera module, in order to make the appropriate classification. This ability of the pre-trained neural network is further used to signal the correct Servo motor to open the specific lid of the smart dustbin. So that sums up the theory behind the automatic waste segregating dustbin, which is also the USP of our project compared to the others in the market currently.

Empirical Review

Each idea appears to be similar but is slightly different at its core and our proposed work is no exception from the same. Some of the contemporary works are:

1. ***IoT Based Automated Waste Segregator for Efficient Recycling***

   Authors: T. Saminathan, Akash Musipatla, P. Manideep Varma,

   Research Work: The Smart bin is divided into three compartments, one for an IR sensor and metal detector, second with a moisture sensor, for dry waste and wet waste and the third has 3 bins for collecting the segregated waste. Each compartment has their own function and the whole system is controlled by an Arduino Megaboard.

2. ***Garbage Collection and Monitoring System for Smart cities using IOT***

   Authors: Neha Shinde, Sayli Bhambre, Shraddha Thakur

   Research Work: A low cost embedded device is attached to the dustbins located in different parts of the city, and a unique ID is provided for each dustbin. This helps in tracking the level of the garbage bins. When the level reaches the threshold limit, the device will transmit the this information along with the unique ID provided to the concerned authorities to notify which dustbin is full and needs to be emptied.

3. ***IoT Based Garbage Management System For Smart City Using Raspberry Pi***

Authors: Manish Chetia Patra, Navaneethan.N, Mani.P.K

Research Work: Using an alert system, the municipal corporation is informed to remove the waste from the waste bin because of two reasons. One is that the waste bin is full and the other one is that the odour from the bin is too much. By this alert, the municipal cooperation can take quick action and remove the waste from the waste bin. The waste bin we use is fixed with three types of sensors, Ultrasonic sensor, load sensor and ZigBee sensor.

4. ***Iot Based Waste Management Using Smart Dustbin***

Authors: Ms. Amrutha P.V, Ms. Chaithar B.N, Ms. Kavyashree

Research Work:An automatic open dustbin that can automatically open the lid when it detects the people who want to throw out their trash. It also can detect the level of the trash that inside the dustbin. If the dustbin is full of trash at the certain level, the lid will not open even when there are people who want to throw out their trash. dustbins are provided with a sensor which helps in tracking the level and weight of the garbage bins

Knowledge Gap

Though most of the requirements of a Smart Dustbin are being covered already, as seen in our project proposal as well as some others being currently researched, there is still scope for advancement. The dustbin can be powered using solar panels, and the segregation can take place in two layers, where disposal occurs in the first and classification in the second. An app can be used to manage and keep track of the various dustbins in the city, their waste levels and their locations with a unique ID for each. Finally, we can also aim to speed up the process of decomposition by implementing it right from the disposal stage. Implementing chemically induced reactions in the organic compartment of the dustbin is one way to achieve this. Technology can also be developed where the user can throw both biodegradable and non-biodegradable waste mixed together, and a manual system inside the dustbin can perform a more detailed level of segregation.

Conclusion and Future Plan

- ## Conclusion

An effective waste management system was proposed, designed and successfully implemented. The deep learning and IOT application will look into proper disposal and monitor the filling of the waste bins. The primary objective allows creating a green environment for the growing and developing cities. The proper management and treatment of the waste will allow us to use our waste as energy resources.

It decreases the manual effort in separating the waste for recycling process. The users can also keep track of waste bins and it helps the user by notifying it when the bins are completely filled. The smart waste management system helps to provide the environment an eco-friendly solution, given the rapidly growing population.

- ## Future Work

Many different adaptations, tests, and experiments have been left for the future due to lack of time (i.e. the experiments with real data are usually very time consuming, requiring even days to finish a single run). Future work concerns deeper analysis of particular mechanisms, new proposals to try different methods, or simply curiosity.

The following adaptations can be made in future:

- Speeding decomposition of organic waste by implementing chemically induced reactions inside the dustbin.
- A two stage separation process where user dumps the trash in upper layer and categorization happens after that.
- Use of solar panels for power.
- An app which can show dustbin locations and their levels.

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