AIOT Based Smart Waste Management System

Aditya Rane
Electronics and Telecommunications
Symbiosis Institute of Technology
Pune, India
aditya.rane.btech2020@sitpune.edu.in

Aditya Kuleyar
Electronics and Telecommunications
Symbiosis Institute of Technology
Pune, India
aditya.Kuleyar.btech2020@sitpune.edu.in

Arzoo Lakhani
Electronics and Telecommunications
Symbiosis Institute of Technology
Pune, India
arzoo.lakhani.btech2020@sitpune.edu.in

Dhruv Dolas
Electronics and Telecommunications
Symbiosis Institute of Technology
Pune, India
dhruv.dolas.btech2020@sitpune.edu.in

***Abstract*—AI and IOT Based Smart waste Management System for malls and corporations to analyse and collect data efficiently. The smartbin collects data via sensors such as load cell, ESP 32 CAM and ultrasonic sensors. The ESP 32 CAM send a video feed on a web server which captures frames and the images are classified using machine learning algorithm called Random Forest classifier. HOG pipeline and HOG classifier has been used to extract features from images. The opening and closing mechanism of the bin is automated too. Once the camera detect an object stationary in front of the bin for more than 2 seconds the bin is opened with the stepper motor rotating its shaft.An laser cut autoCAD design has be made to conceal and protect the components. The stepper motor, ultrasonic sensor are connected to the arduino while the load cell is connected to the ESP 32 cam.**

***Index Terms*—AI, IOT, random forest, hog pipeline, smartbin, arduino, load cell,ESP 32 cam, autoCAD.**

I. Introduction

The invention under consideration provides a novel solution for waste management by utilizing sensors and software in waste bins to optimize the waste collection process. The smart bin system efficiently monitors and classifies the waste generated by different companies or malls, providing valuable insights into waste generation patterns.This data can be utilized to develop strategies for reducing waste and improving waste management practices, thereby contributing towards fulfilling Corporate Social Responsibilities (CSR's) of companies.The smart bin system automates the entire waste management process by tracking the fill level of waste bins in real-time and sending notifications to maintenance crews only when necessary. This ensures efficient waste collection and disposal, reducing the cost and time associated with unnecessary waste collection.Additionally, the smart bin system automatically dispatches waste collection trucks only when the bins are full, leading to reduced labor costs and fuel consumption, and contributing towards the reduction of greenhouse gas emissions.Overall, the invention provides a cost-effective and efficient solution to waste management, benefiting the environment while also providing valuable data and insights into waste generation patterns.

The bin is part of a complete waste management and analysis ecosystem in malls. It not only solves the conventional problems of bin overflowing and hygiene, but also solve problems that food and beverage corporates face. Such as: waste management, waste analysis and waste sorting. The bin opens automatically when a person is standing in front of it. This system is fault-proof and does not open when any person is just passing by. Once the bin opens, the camera module detects the logo on the waste. The load cell senses the total weight in the bin. The detected company logo along with the newly added weight is entered into a database(csv file) that the companies can then use for analysis. The new weight is calculated by subtracting the old weight from the current new total weight. The bin then closes automatically thus avoiding any contact whatsoever in this entire process. Once the dustbin closes, the level sensor detects the fill level of the bin. If the bin is full, an alert notification is sent to the maintenance crew server. The alert notification also contains the GPS location of the bin so that it can easily be tracked by the maintenance crew. When the bin is full a message will be displayed on the LCD screen present saying "Bin is full, please go to the nearest bin (location of the nearest bin) to discard the waste". This ecosystem reduces human effort in all domains to the minimum and also fulfills the corporate social responsibilities.

II. System Description

A. Computing Hardware

- ESP 32 Cam Module-Captures video feed and uploads it on a webserver.Photos are captured from this video feed and then classified using the random forest classifier. The load cell is connect to the ESP 32 Cam Module.
- Arduino UNO- Take input from stepper motor, level sensor and stores csv file
- LCD touchscreen- Displays when the bin is full, nearest location of the empty bin

B. Electrical Components

- Stepper Motor-Opens the bin automatically via an ultrasonic sensor.Button is used to open manually.
- ULN2003 Motor Driver- Provides a direct drive interface between your microcontroller and stepper motor
- HX711 Amplifier- The HX711 load cell amplifier is used to get measurable data out from a load cell and strain gauge.
- GPS module- Sends the GPS location (latitude and longitude) of the bin that is full, to the maintenance crew along with an alert notification.

C. Sensing Devices

- Ultrasonic Sensor- Senses if the dustbin is full or not. Sends an alert to the maintenance crew if the dustbin is full.
- Load Cell- Captures the weight added to bin and sends to it the maintanenece crew via ESP32

D. Circuit Design

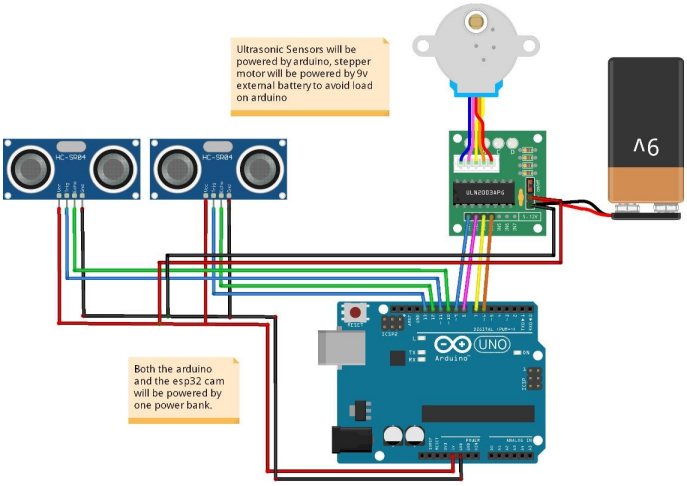

Fig. 1. Arduino Circuit - Stepper motor and Ultrasonic sensor

The above figure contains two circuits one with Arduino and second circuit is of the ESP 32 Cam Module. The Arduino is responsible for the fault proof opening and closing of the bin. For this, we have connected an ultrasonic sensor that detects if an object is in front of the bin for more than 2 seconds. If yes, then the stepper motor's shaft rotates at an angle of 90 degrees to open the bin. This is achieved using the ULN2003 motor driver and unipolar stepper motor connected to it. The bin then automatically closes using the same mechanism.

The ESP32 cam is initially responsible for video capture streaming it to a web server. After that the images are captured from the web server and trained using an ML model. Later, the camera is used for capturing images of logos and classifying them into respective classes. The ESP32 cam module does not have an on-chip programmer of power module. Hence, it is paired with an FTDI module for this. The FTDI module also allows serial communication hence letting us display the

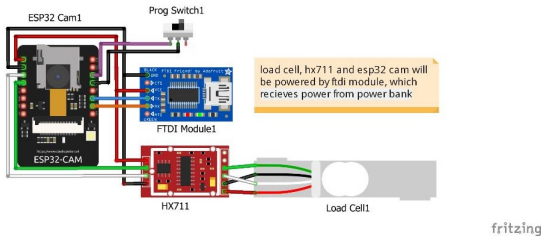

Fig. 2. Esp32 Circuit - OV260 Camera module and Load cell

predictions on serial monitor of Arduino IDE. The OV260 camera module is attached to the esp32.

E. Dataset

A custom dataset was created using the ESP32 Cam Module. The Module sends a video feed on a web server. Frames are captured from this video using the MjpegCollector class in python.

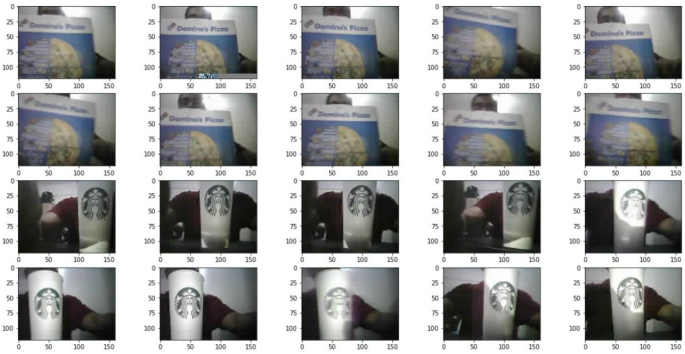

Fig. 3. Custom Dataset

F. Computer Vision

The Module sends a video feed on a web server. Frames are captured from this video using the MjpegCollector class in python. These frames are then manually classified into different classes using everywhereml library in python. The images in the dataset are resized and converted into grayscale. Unlike CNN traditional Machine Learning Algorithms like random forest classifier cannot extract features from an image automatically, hence we have used the HOG (Histogram of Oriented Gradients) pipeline.

This pipeline extracts features from the dataset in the form of feature vectors, these feature vectors are then given as input to the random forest classifier. The random forest classifier is trained on the basis of these feature vectors. The HOG pipeline and HOG classifiers python codes are then converted into C++ codes to be interfaced with the ESP 32 Cam Module using the function to_arduino_file of everywhereml

G. AutoCAD Design

The laser cut design has a total of 3 holes on its face. As seen in the above picture, 2 holes are for the ultrasonic

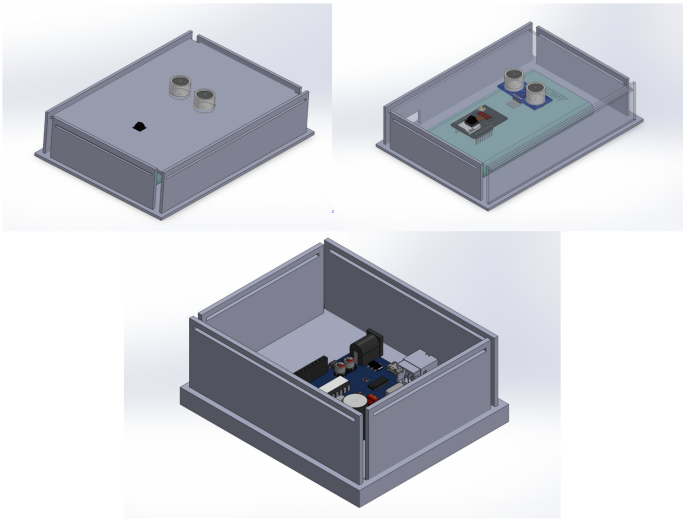

Fig. 4. AutoCAD Design for protecting electronics

sensor and 1 small hole is for the esp32cam module. It also has a rectangular slit on the sides to allow the power bank wire to pass from front to back of bin, so that it can power both the micro-controllers. This design was created to protect both the micro-controllers(Arduino and ESP32 cam), multiple sensors, and the power bank. This design was fed in the laser cutting machine and the parts were assembled. This design can also act as a module by itself that can be attached to any bin independently to convert it into a smart bin.

H. Results & Experimentation

Having our very own dataset of images, we need a way to transform each image into something a Machine Learning model can classify. With Neural Networks, you usually feed the raw image as input and the network learns by itself how to extract meaningful features from it. With traditional Machine Learning it's different, we have to extract the features by ourselves. For this, we have used the everywhereml package, it has all the tools that are required. First of all, our feature extractor will work with grayscale images, so we convert the dataset from RGB to Gray. Now it's time to actually convert the images to feature vectors. There exist many feature extractor for images, in this project the Histogram of Oriented Gradients(HoG) pipeline is used. It is lightweight and pretty fast, so it's a good fit for embedded environments like the Esp32-cam. To speed the processing up, we will rescale our source image to a lower resolution (40 x 30).

The output of the code is a dataset made of feature vectors, instead of images. These feature vectors are now suitable for Machine Learning models. To get a visual idea of how informative the extracted features are, we can plot a pairplot of them. A pairplot compares each feature against the others in a grid format. Well defined clusters as seen in the UMAP as well with 2 different classes – Starbucks, Dominoes. Last step is to convert the HogPipeline and RandomForestClassifier to C++ code that can run on your Esp32-cam

	hog0	hog1	hog2	hog3	hog4	hog5	hog6
count	941.000000	941.000000	941.000000	941.000000	941.000000	941.000000	941.000000
mean	0.252473	0.170117	0.128185	0.227171	0.129601	0.047671	0.044830
std	0.315454	0.168568	0.129483	0.258759	0.196648	0.073353	0.081300
min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25%	0.035604	0.048629	0.045200	0.024356	0.000000	0.000000	0.000000
50%	0.099504	0.119377	0.089593	0.155397	0.042005	0.007275	0.000000
75%	0.387834	0.216771	0.172035	0.313401	0.168076	0.072461	0.066358
max	1.000000	1.000000	1.000000	1.000000	1.000000	0.491762	0.664836

Fig. 5. HOG Classification Outcome

Fig. 6. Feature Extraction Plot from Random Forest Classifier

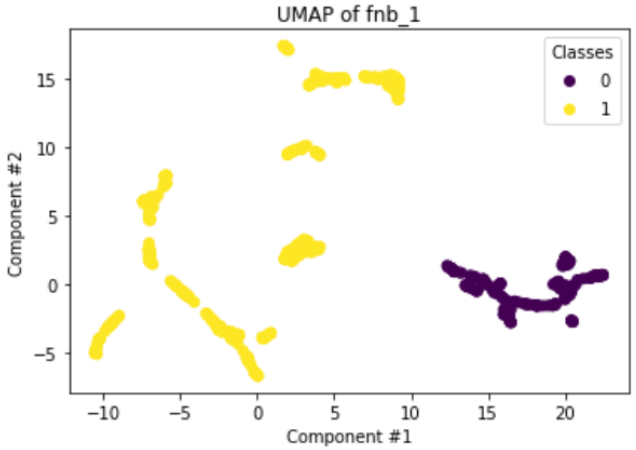

Fig. 7. UMAP of two classes (Starbucks and Dominoes)

Conclusion

Thus the multiple problems such as waste management, waste analysis, labour decrease, hygiene, automation , overfilling bins, inefficient waste collection, lack of transparency in waste collection, corporate social responsibilities (CSR's) and systematic approach towards waste disposal are solved.

The figure below depicts a prototype of the bin. We can see that the laser-cut cases are attached on the front and back of the bin. The front case consists of the Esp32 cam circuit and the ultrasonic sensor for automatic opening. The front case also holds the remote power source in this case which is the power bank. The back case consists of the Arduino circuit and stepper motor connections. The load cell is mounted and configure in a proper way inside the bin and a steel plate is attached to it on the top that acts as a base for the bin. The level sensor is attached on the lid of the bin to ensure it measures the filling of bin efficiently. A button is attached on side of the bin to open it manually as well.

Fig. 8. Prototype of AIOT based smart bin

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