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A Solar Powered Self Segregating Dustbin/Comveyor Belt for Waste Management

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ABSTRACT:
The integration of a smart dustbin powered by a Raspberry Pi and a camera module for waste detection is a clever solution. Being able to identify and separate different types of waste like dry, wet, and metallic automatically is a significant step towards efficient waste management .Moreover, the inclusion of in-dustbin segregation mechanisms to sort the waste into appropriate categories is a practical feature. The incorporation of a shredder to process the waste for potential use as organic fertilizer demonstrates a sustainable approach to handling garbage. Utilizing solar energy to power these dustbins makes them versatile and viable for deployment in remote areas, addressing waste management challenges in various locations. Overall, this project seems comprehensive, addressing multiple facets of waste management while incorporating smart technology and sustainable practices.

***Keywords* –** Sorting, Waste, Automatic, Image Processing, Raspberry Pi, Shredder, Wet, Metallinc, Solar Powered etc.

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I. INTRODUCTION

Solid waste segregation is a major challenge facing urban areas and metropolitan cities around the world. In India, where environmental regulations are weak, the situation is particularly dire. Smart dustbins are a system that can help to address this problem, or at least reduce its impact.

India's Prime Minister, Narendra Modi, has introduced the concept of 100 smart cities in India. The "Swachh Bharat Abhiyan" (Clean India Mission) was launched to ensure a clean environment. Many viruses and bacterial infections develop in polluted environments. It is essential to protect the environment using technology at this time.

Restaurants should be modernized using smart technology to reduce pollution. The amount of waste generated is largely determined by two factors: population and consumption patterns.

This paper discusses one of the most efficient ways to keep our environment clean and green. Dustbins are a common and essential fixture in every community. However, it is often observed that garbage can accumulate in dustbins due to irregular garbage removal. This can lead to a number of problems, including the spread of disease, the breeding of pests, and the unsightly appearance of the community.

In today's world, where technology is constantly evolving, there is a need to find new and innovative ways to address this problem. One potential solution is to use smart dustbins. Smart dustbins are equipped with sensors that can detect when they are full. When a smart dustbin is full, it sends a signal to a central system, which then dispatches a garbage collection crew to empty the bin. This ensures that garbage is removed regularly, preventing it from accumulating and causing problems.

Smart dustbins are a promising new technology that has the potential to help us keep our communities clean and green. By using smart dustbins, we can reduce the spread of disease, eliminate pests, and improve the overall appearance of our communities. The proposed paper deals with the concept of smart automatic waste sorting dustbins/conveyor using image processing system.

II. LITERATURE REVIEW

Before the start of the project it is very necessary to study the proposed project area in deep to know the problems faced and probable solutions on the same. The number of research papers were studied to arrive at the problem definition and the way around to tackle it. The some of the notable ones are given in the literature review below.

Aleena V.J. et al. [1] proposed a system that automatically segregates waste into three categories: metal, plastic, and wet (organic) waste. Wet waste is organic waste such as vegetable peels and leftover food. Waste separation is essential because the amount of waste generated today is a major problem. The proposed system can also monitor the solid waste collection process and manage the overall collection process.

The inlet section of the system is equipped with an open and close mechanism to regulate the flow of waste onto the conveyor belt. An inductive proximity sensor is used to detect metallic waste. A blower mechanism is used to segregate dry and wet waste. The timing and movement of the conveyor belt are controlled by an Arduino Uno microcontroller. This prevents any particular section of the system from operating continuously or unnecessarily.

Ashwini D. et al. [2] conducted experiments to test the effectiveness of an automatic waste segregator. The results showed that the waste was successfully segregated into four categories: glass, metallic, wet, and dry. Wet waste refers to organic waste, such as vegetable peels and garden waste. Dry waste includes paper waste, plastic bottles, etc. Metallic waste includes safety pins, foil paper, etc. Glass waste includes window glass, glass bottles, etc. The project was tested on different categories of waste. The results showed that the segregator was able to successfully separate wet, dry, and metallic waste. The glass waste was not as well-segregated, but the authors believe that this can be improved with further testing.

Nagaraj D.C. et al. [3] proposed a cheap and easy-to-use automated waste segregator (AWS) that can be used at households to sort waste into metallic, wet, and dry waste. The AWS uses a parallel resonant impedance sensing mechanism to identify metallic items, and capacitive sensors to distinguish between wet and dry waste. Experimental results show that the AWS can successfully segregate waste into these three categories.

Amrutha Chandramohan et al. [4] conducted an experiment to test the effectiveness of a waste segregation system. They used a large volume of dry waste objects and a minimum quantity of one object each for wet waste objects to consider the worst-case scenario. The system works by first detecting the waste through an IR proximity sensor. The waste then falls onto a metal detection system, which identifies any metallic waste. After this, the object falls into a capacitive sensing module, which distinguishes between wet and dry waste.

Once the waste has been identified, a circular base with containers for dry, wet, and metallic waste rotates to the appropriate position. The collapsible flap is lowered, and the waste falls into the container. The flap is then raised, and the waste can be collected separately and sent for further processing.

The experiment showed that the system was able to successfully segregate waste into the three categories. The authors believe that this system could be used to improve waste management in urban areas.

T. Saminathan et al. [9] proposed a prototype of a municipal waste segregator that can segregate waste immediately, leading to more recyclable paper. The smart bin is divided into three components, each with a specific function. The first component consists of an IR sensor and a metal detector. This component is used to detect metallic waste. The second compartment consists of another IR sensor and a moisture sensor. This component is used to detect dry and wet waste. The third component is divided into three bins for collecting the segregated waste. The entire system is controlled by an Arduino MEGA board. Each component is interfaced to the Arduino board.

Wu, I-Ting & Hsiao, Shih-Wen. [23] published an article which focuses on the implementation of a waste bin sorting system on a university campus, aiming to promote effective recycling and waste reduction. To begin with, the article employs user behavior observation to precisely define the existing problems. Subsequently, an Objective Tree analysis is utilized to establish design criteria and specifications. The Morphological Chart method is then employed to meticulously model and elaborate on the key components of the proposed product. This design scheme is further subjected to the Analytic Hierarchical Process (AHP) and Pugh concept selection to optimize the overall design. The findings of the research demonstrate that this design approach not only emphasizes innovation in terms of both appearance and functionality but also takes into account user requirements and design quality to enhance the product's feasibility. As a result of this systematic design process, the campus waste bin introduces novel concepts and user experiences, departing from conventional practices. Particularly, it achieves significant advancements in waste classification information. This not only enhances the efficiency of waste sorting on campus but also contributes to a neater surrounding environment, aligning with the established design objectives. The design framework proposed in this article has implications beyond campus waste bins and can be extended to other design domains. Its adaptability and relevance make it well-suited for broader applications in diverse design fields.

Arayakandy, Adwait. [24] suggested SVM for thrash classification. According to him Support Vector Machines (SVMs) represent a novel method in supervised classification, particularly relevant to land cover mapping within the cartographic domain. Emerging from the realm of statistical learning, SVMs inherently function as binary classifiers. In our specific classification scenario, the task revolves around analyzing images of individual objects and assigning them to distinct recycling material categories. The input fed into our processing pipeline comprises images wherein a solitary object is positioned against a pristine white backdrop.

C. Udhayakumar, M. Nithin Nandha, V. Pradeesh et.al [25] carried out a project which introduces an innovative approach to intelligent waste management that significantly cuts down on the costs associated with maintaining a clean urban environment. This approach involves deploying sensor models to detect, measure, and transmit trash volume data through the IoT. The collected data, including trash can identifiers and geographic locations, is then processed using regression, classification, and graph theory techniques. This processing enables us to dynamically and efficiently manage waste collection by predicting waste levels, categorizing trash bin locations, and monitoring waste generation trends.

H. Abdu and M. H. M. Noor[26],proposed Domestic Trash Classification with Transfer Learning Using VGG16. Environmental pollution stands as a significant concern impacting inhabitants across various habitats. Within residential areas, an abundance of waste materials, encompassing both solid and hazardous substances, pervades, triggering profound environmental pollution and potentially giving rise to life-threatening illnesses if not managed appropriately. A pivotal factor in addressing this challenge lies in the effective categorization of waste, as misclassification greatly hampers recycling efforts. Often, human classification of waste relies on personal comprehension of the object rather than its potential for recycling, leading to frequent inaccuracies in manual sorting. Moreover, direct exposure to toxic waste poses physical risks to those involved. Numerous machine learning and Deep Learning (DL) methodologies have been suggested, employing standardized datasets for trash classification. However, the prevalent use of transparent or white backgrounds in these benchmark datasets hampers model adaptability, particularly in real-world scenarios. In this study, we present a Deep Learning model based on the VGG16 Architecture designed to precisely categorize diverse types of waste items. Leveraging the TrashNet dataset and supplemented with images captured from real-world environments, our model achieved an accuracy exceeding 96%.

Satvilkar, Mandar[27] proposed image based thrash classification using machine learning. This research paper delves into the realm of Trash classification, presenting a distinctive and socially significant endeavor where the utilization of Image processing and Analytics can contribute to enhanced waste and garbage management. A notably effective strategy for processing waste based on its recyclability involves accurately determining its classification. Analytics holds the potential to streamline this complex undertaking by employing image classification techniques to accurately assign waste items to their respective categories. The primary objective of this endeavor is to capture images featuring individual items, subsequently isolating and categorizing them into five distinct classes: cardboard, glass, metal, paper, and plastic. To accomplish this, a dataset containing approximately 400-500 images for each of the aforementioned classes will be employed. This dataset has been made publicly accessible and is hosted on the creators' GitHub repository. For the model architecture, a Convolutional Neural Network (CNN) will be selected due to its remarkable and efficient performance within the domain of machine learning, particularly in the context of image classification. Additionally, an implementation of Extreme Gradient Boosting will be explored and evaluated to determine whether it can outperform the CNN. Throughout the research, various methods will be examined and compared in order to identify the optimal approach or combination of techniques that can offer the most advantageous and efficient outcomes for image classification.

From the literature review carried out it can be concluded that the project has wide scope. Though the research work carried by so many research scholars in the particular field, there exists an literature gap. The following inferences can be made.

1. The current literature review focuses sensor based approach for waste segregation which is impractical in real world scenarios
2. The majority of current research work can be implemented at the waste segregation plants and there is no approach to segregate the waste at the source or collection point itself.

This motivates us to develop the concept of solar powered self segregating dustbins / conveyors which uses image processing and deep learning to determine the type of waste and segregate automatically..

III. METHODLOGY

The entire code of conduct of the project follows the following methodology. Everything is carried out in phases so that the final project will be complete without any errors. The following methodology is implemented step by step in the project.

1) Material survey and selection:
2) The chassis or the frame fabrication
3) The garbage Dump Inlet
4) The metallic segregation mechanism:
5) The waste detection and classification system using image processing and ANN
6) The Collection Bin fabrication:
7) The power system: Solar PV cells (80 watts) & Battery
8) The shredder system implementation
9) Assembly and testing

The methodology for the conduct of the project is given below:

- First data sets of the different waste materials are created. Then using Python and
- Open CV, the features are detected from the datasets
- Collect large datasets for each separate category to be classified and segregated and
- prepare the data to train our ANN model
- Feature Extraction is done using OpenCv and ROI to get the object information to
- train our ANN model
- Train the ANN model using Python using transfer learning approach and fine tune the
- parameters to prevent over fit
- Deploy the trained model capable of segregation of domestic waste onto raspberry Pi
- which will then control motors and segregation bins to automatically sort the waste into wet, metallic and other categories

IV. WORKING PRINCIPLE

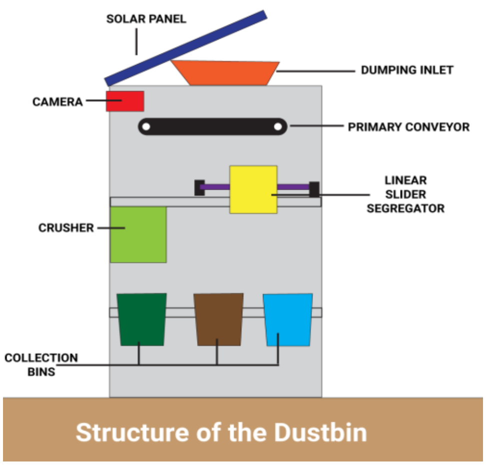

Fig 1.Working Principle

The figure above shows the illustrative diagram of the project. As shown in the illustrative diagram the proposed system consists of a dumping area where the garbage will be dumped. Once dumped the conveyor gets activated which will initially segregate the metallic and non-metallic waste using the metal sensor. The remaining waste passes through the segregating chamber which consists of camera module interfaced with the raspberry pi. The camera module detects the type of waste using image processing and deep learning and then segregates it respectively using the smart segregator. The shredder is also Implemented which will shred the waste into smaller pieces which can be used as an fertilizer for gardening

V. HARDWARE AND SOFTWARE ASSEMBLY

The following hardware is used for the implementation of the Self segregating dustbins.

- Raspberry Pi
- Raspberry Pi camera Module
- Metal proximity sensor
- Ultrasonic sensor
- Buzzer
- LCD Display
- Motor Driver Module
- DC geared Motors
- I2C module
- Battery

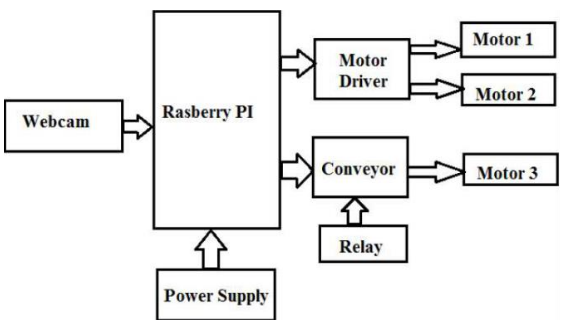

Fig.2 Block Diagram Of the Implemented System

VI. DESIGN CALCULATIONS

Power and torque transmitted to the conveyor shaft:
From the data sheet obtained from the motor specifications
We get:

Operating voltage = 12 V
Current = 1.41 A

Therefore the power transmitted to the conveyor shaft is given by :
P = V x I
= 12 x 1.41

=17 Watt-----------------------------1

We also know P = 2 π N T /60
Substituting P form 1

We get
17 = 2 π 30 T/60

T= 5.411 N-m

Similarly power transmitted to the segregating mechanism

The motor specifications of the segregating mechanism are :
Operating voltage = 12 V
Current = 1.6 A

Therefore the power transmitted to the clamping mechanism is given by :
P = V x I
= 12 x 1.6
=19 Watt-----------------------------1
Substituting P form 1
We get
19 = 2 π 200 T/60

T= 0.0907 N-m

IMPLEMENTATION
In this section the results of the approach are discussed. This mainly deals with the deep learning based model for detection of different types garbage's. Total of 400 images were collected.

Collected Data:

SAMPLE NAME	LABEL
paper.381uufgl	paper
paper.381uueqc	paper
paper.381uuecd	paper
paper.381uue0n	paper
paper.381uudl4	paper
paper.381uudb1	paper
paper.381uud4m	paper
paper.381uuck7	paper

Fig.3 Collected Dataset

The collected data is split into train and test. 82 percent of the collected images were put in train and 18 percent in test.

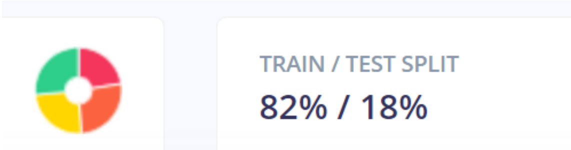

Fig.4 The Train Test Split

After the images were the extracted features from the collected dataset are shown below.

Fig.5 Feature Extraction

The graph of extracted features form the dataset is as shown below. This graph shows that the features are extracted and projected in 3d space for 4 different classes, paper, cardboard, tomato and metal waste.

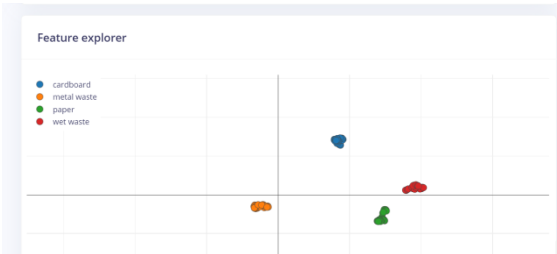

Fig.6: Graph of Extracted Features

After the Features are extracted the model is ready to trained. The output of the training and results are as shown below.
The validation set was used to calculate the accuracy the output of which is shown below. From the validation set results we can conclude the model training gave the accuracy of almost 100% with a loss of 0.04.

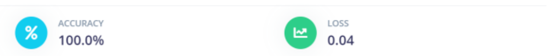

Fig.7 Accuracy Vs Loss

For better understanding of the result analysis the confusion matrix is as plotted below.

Confusion matrix (validation set)

	CARDBOARD	METAL WASTE	PAPER	WET WASTE
CARDBOARD	100%	0%	0%	0%
METAL WASTE	0%	100%	0%	0%
PAPER	0%	0%	100%	0%
WET WASTE	0%	0%	0%	100%
F1 SCORE	1.00	1.00	1.00	1.00

Fig.8 The Confusion Matrix

From the confusion matrix analyzed we can conclude that the results are 100 percent accurate at least on the validation set. This is a perfectly fitting waste classification model without over fit

The Data explorer graph for correct and incorrect detections is as shown below:

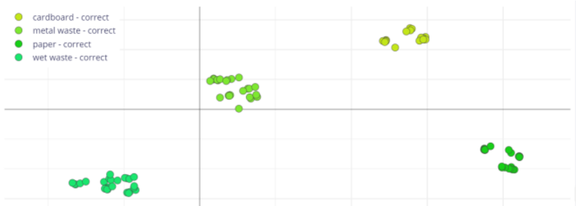

Fig.9 The Data Explorer Graph

From the data explorer graph we can conclude that all the items are classified correctly without any incorrect or false detections.
After the model was trained it was deployed on the fabricated hardware. The figure below shows the hardware fabrication details.

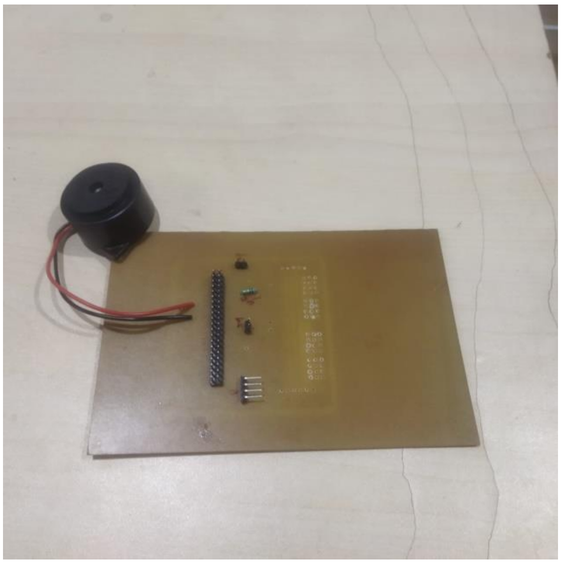

Fig.10 Farbricated PCB

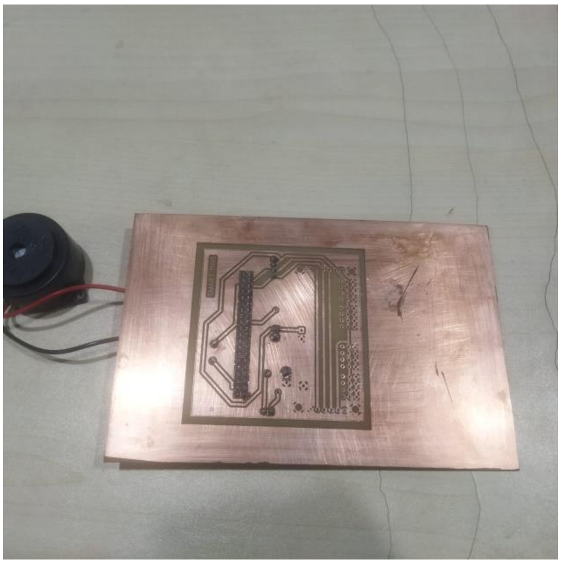

Fig.11 Fabricated PCB Rear

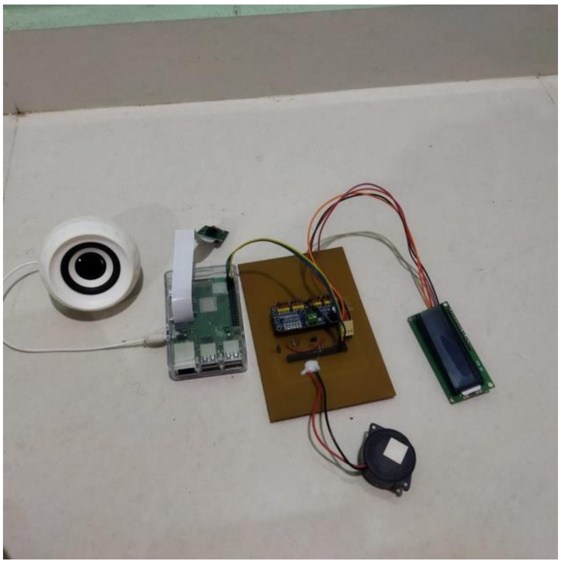

Fig.12 Completely Assembled E System

VII. Conclusion

India is a developing country with the second largest population in the world. As a result, it produces a large amount of waste every day. In urban India, 62 million tons of municipal solid waste (MSW) are produced each year. Of this, 70% is collected and 20% is treated.

The different types of waste make it difficult to dispose of. Segregation plays an important role in reducing waste by reusing it. Treating waste is also easier if it is segregated at the source.

The approach suggested in this research paper can solve the problems of domestic waste sorting by providing a automated segregation system by implementing smart thrash bins which can sort the waste using image processing techniques and collect in respective sub bins. The proposed system is expected to eliminate the process of manual sorting as the system sorts the waste automatically inside the smart bins using camera and image processing. This not only saves the time and capital required in sorting the domestic waste but the system also segregates the waste into wet and dry providing a provision for conversion on wet waste to organic fertilizers. This proposed system is good enough to carry out practically as it has advantages such as having less time delays, quick response time, fully automated system and also having low power requirements

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