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E-Waste Sorted System Using ML and Automation

Bhargavi Chaudhari[1], Sayali Patil[2], Gayatri Gond[3] ,Prof. Rohit Nemade[4]

[1,2,3] UG Student

[4] Assistant Professor

Department of Electrical Engineering GFs Godavari college of engineering Jalgaon, Maharashtra, India,425001

Email corresponding author: bhargavichaudhari2004@gmail.com

Abstract – *Inefficient waste segregation at the source remains a significant challenge for effective waste management and recycling efforts. This project presents the design and implementation of an automated, IoT-enabled smart garbage separation system capable of classifying waste into distinct categories: Dry, Wet, and Metal.*

To achieve differentiation, the system employs a suite of sensors interfaced with the Pico W. An inductive proximity sensor is utilized for detecting metallic objects, while a capacitive moisture sensor or DHT11 (for ambient humidity near the waste) identifies wet waste. Items not flagged as wet or metallic are initially classified as dry. Actuation mechanisms, such as servo-controlled flaps, are employed to physically direct the identified waste into designated bins based on the sensor readings.

A core feature of this system is its IoT capability; the Pico W transmits the raw sensor data readings wirelessly via Wi-Fi to a cloud platform (e.g., Thing Speak, Firebase) for real-time monitoring, data logging, and analysis. Furthermore, a basic Machine Learning (ML) model, developed in Python and potentially deployed either on the cloud or optimized to run locally on the Pico W (using libraries like TensorFlow Lite for Microcontrollers), analyzes patterns in the sensor data. This ML model aims to enhance classification accuracy and potentially predict the specific type of material within a category (e.g., differentiating between paper and plastic within the 'Dry' waste stream) based on subtle sensor signatures. This approach not only automates the segregation process but also provides valuable data insights for optimizing waste collection and promoting recycling initiative

Keyword – IOT, pico w, E waste, machine Learning, Sensor, WI- FI

INTRODUCTION

E-Waste, Machine Learning, and Automation in Waste Management

Electronic waste, commonly known as e-waste, is one of the fastest-growing waste streams in the world. With rapid technological advancement, large quantities of electronic devices such as computers, smartphones, televisions, and household appliances are becoming obsolete in a short period. Improper disposal of this e-waste leads to serious environmental, health, and economic issues, as many components contain toxic materials like lead, mercury, cadmium, and lithium.

Traditional e-waste sorting methods rely heavily on manual labor, which is slow, unsafe, and inefficient. Workers are exposed to harmful chemicals, and the sorting accuracy is generally low. To overcome these challenges, the integration of Machine Learning (ML) and automation technologies is emerging as a reliable and intelligent solution for modern waste management.

Machine Learning allows computers to learn from large datasets of electronic waste images and automatically classify items into categories such as plastic, metal, glass, PCB, battery, etc. When combined with automation components like conveyor belts, sensors, and actuators, the system can perform real-time sorting without human intervention.

LITERATURE REVIEW

1.Classification of Organic and Solid Waste Using Deep Convolutional Neural Networks (Dec 2021)

This research work by Ashim Dey and Famida proposes a method to automatically classify waste into four different categories using Deep Convolutional Neural Networks (DCNN). The system focuses on improving waste segregation accuracy through deep learning techniques. The proposed approach helps in efficient waste management by reducing manual effort and increasing classification speed.

2.Trash Classification: Classifying Garbage Using Deep Learning (July 2020)

In this paper, Ishika Mittal and Anjali Tiwari presented a garbage classification system based on deep learning. The system provides an effective solution for waste management and speeds up the segregation process…

3.An Automatic Garbage Classification System Based on Deep Learning (Aug 2017)

Jie Yang and Zeyi Zang proposed an automatic garbage classification system using deep learning methods. The research demonstrates how deep learning algorithms can be applied to identify and classify garbage materials automatically. The system aims to support smart city waste management and improve environmental cleanliness.

Project Objective

To develop an automated e-waste segregation system

Design a smart system that can automatically identify and sort different types of electronic waste such as plastic components, metal parts, circuit boards, batteries, and wires.

To apply Machine Learning techniques for waste classification

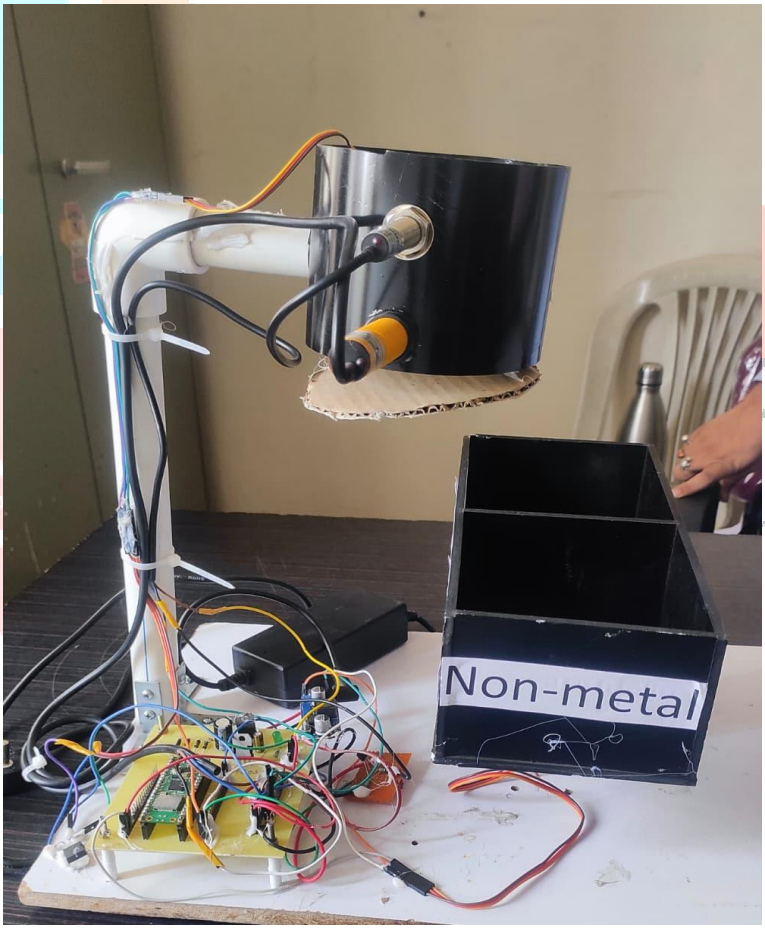
Use Machine Learning algorithms and image processing techniques to recognize and classify e-waste materials accurately based on their shape, color, size, or component type.

To reduce manual effort and human error

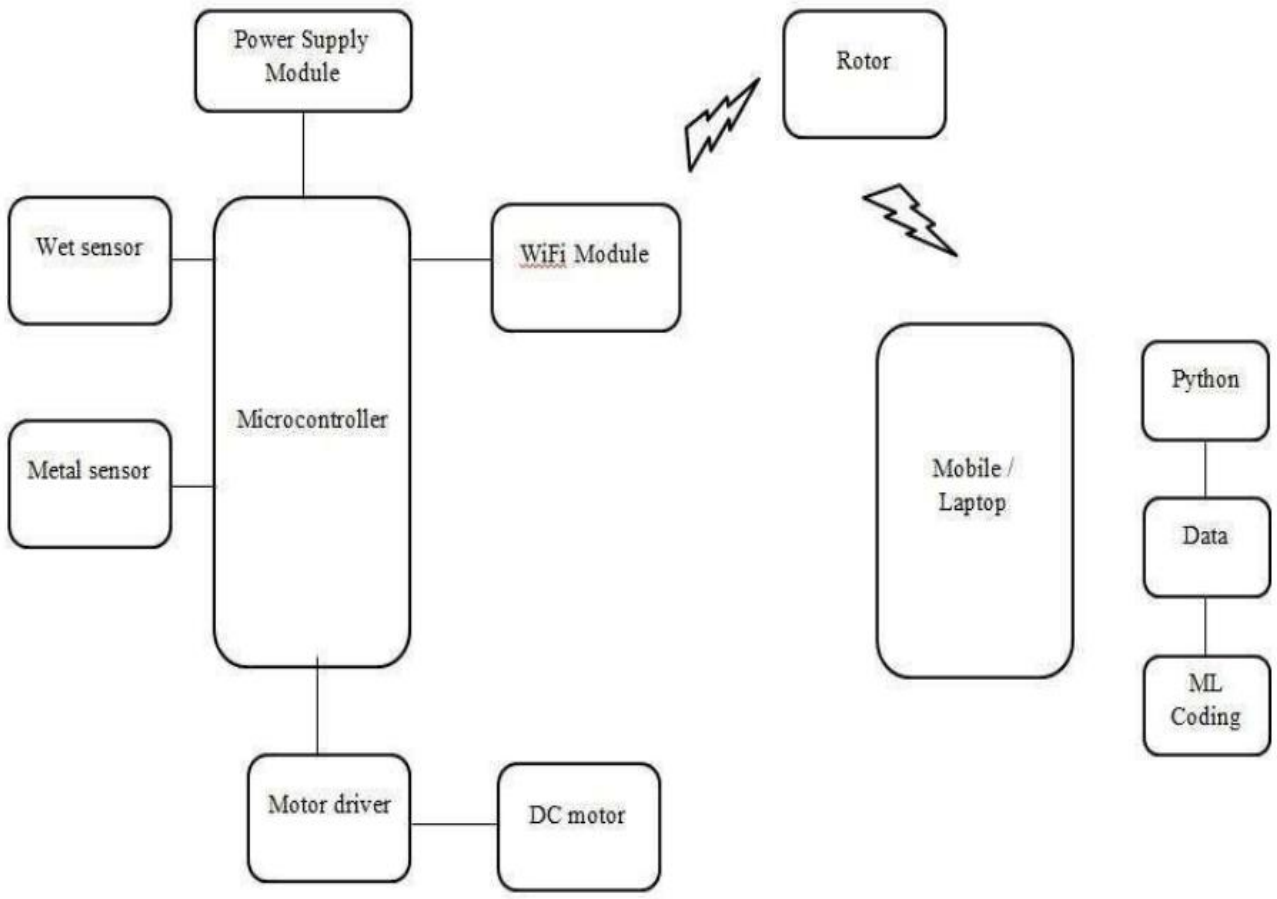
Minimize human involvement in the sorting process to improve safety, efficiency, and accuracy in handling hazardous electronic waste materials.

To improve recycling efficiency

Ensure proper segregation of reusable and recyclable electronic components so that valuable materials can be recovered effectively.



Block Diagram



METHOLOGY

ALGORITHM:

CNN - CNN stands for Convolutional Neural Network, a type of deep learning algorithm designed specifically for processing grid-like data, such as images and videos. CNNs are powerful tools for image recognition, image generation.

Step 1: Input Layer

The process begins with the input layer, where the network receives the raw data. In the context of image analysis, this could be a pixel values of an image.

Step 2: Convolutional Layer

In this step, the input data undergoes a series of convolutions with learnable filters (also known as kernels).
Each filter scans a small portion of the input data at a time.

Step 3: Pooling Layer

Pooling (subsampling or down-sampling) reduces the dimensionality of each feature map but retains essential information. A common technique is max-pooling, where the maximum value in a small rectangular neighborhood is selected, and the rest are discarded. Pooling helps in making the detection of features invariant to scale and orientation changes.

Step 4: Flattening

After several convolutional and pooling layers, the high-level reasoning in the neural network is done through fully connected layers. To connect these layers, the dimensions of the data are flattened into a vector. This flattening step prepares the data for input into the neural network's hidden layers.

Step 5: Fully Connected (Dense) Layers

In these layers, the neural network learns to associate specific features from the previous layers to the output classes. Each neuron in a fully connected layer is connected to every neuron in the previous layer. This stage is where the network learns to classify the features extracted by the previous layers into the appropriate class labels

Step 6: Output Layer

The final fully connected layer produces the output of the network. In the case of classification tasks, it usually employs a SoftMax activation function, which converts the raw scores from the previous layer into class probabilities. The class with the highest probability is the predicted output of the network.

Step 7: Loss Calculation and Backpropagation

During training, the network's output is compared to the actual labels, and a loss (error) is calculated. The goal of training is to minimize this loss. This is typically done using a loss function like categorical cross-entropy for classification problems. After the loss is calculated, backpropagation is used to adjust the network's weights and biases, minimizing the error.

Step 8: Training

The entire process (steps 2-7) is repeated multiple times (epochs) on the training dataset. Each pass helps the network to learn weights and improve its ability to make accurate predictions.

Step 9: Testing and Prediction

Once the network is trained, it can be tested on new, unseen data to evaluate, its performance. The network's ability to accurately classify or predict unseen data is a measure of its generalization ability

1. **Problem Identification**

Electronic waste (E-waste) contains different materials such as plastic, metal, glass, batteries, and circuit boards. Manual segregation is slow, unsafe, and less accurate.

The proposed system uses automation and Machine Learning (ML) to identify and sort different types of E-waste automatically.

2. System Overview

The system consists of:

Conveyor belt for moving waste

Camera or sensors for capturing images/data

Machine Learning model for classification

Microcontroller/processor for control

Automated actuators or robotic arms for sorting

Separate bins for different categories

CONCLUSION

The “E-Waste Sorted System using Machine Learning and Automation” project represents an innovative step toward addressing one of the growing global challenges—electronic waste management. With the rapid advancement of technology, the amount of discarded electronic devices has increased significantly, leading to severe environmental and health issues. Through this project, we have demonstrated how modern technologies such as Machine Learning (ML), Image Processing, and Automation can work together to create a sustainable, efficient, and intelligent e-waste management solution.

Our system is designed to automatically identify, classify, and sort different types of e-waste materials such as metals, plastics, glass, and circuit components. The use of machine learning algorithms enables the system to recognize various e-waste items with high accuracy, reducing human involvement and minimizing the chances of errors during sorting. The integration of sensors, conveyor mechanisms, and actuators ensures that the process is fully automated, fast, and reliable. By combining both hardware and software components, we have created a smart prototype that mimics a real-world industrial e-waste sorting unit.

The system not only helps in reducing the burden on manual labor but also contributes to environmental conservation. By ensuring that each type of waste is sorted correctly, the recycling process becomes more effective, leading to the recovery of valuable materials and minimizing landfill waste.

Furthermore, the project highlights the importance of interdisciplinary learning—combining computer science, electronics, and environmental engineering. The application of machine learning in waste management opens the door for future advancements such as real-time monitoring, data analytics, and predictive maintenance of sorting systems. With further research and development, the accuracy and efficiency of the system can be improved even more, making it suitable for large-scale industrial applications.

In conclusion, the E-Waste Sorted System using ML and Automation provides a practical and intelligent approach to one of the most critical issues of modern society. It demonstrates how technology can be leveraged to build a cleaner, greener, and more sustainable future. Our project serves as a foundation for future innovations in smart waste management systems and reinforces the belief that technological advancement, when directed responsibly, can significantly benefit both humanity and the environment.

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Future Scope

Research Opportunities:
Ongoing research in this field can lead to new and innovative waste management solutions.

Global Adoption:
IoT-based waste management may become a global standard, addressing waste-related challenges worldwide.

Smart Cities:
IoT-based waste management can be integrated into smart city initiatives, making urban areas cleaner and more sustainable.

Environmental Impact:
Effective waste segregation and recycling can significantly reduce the environmental impact of waste disposal, contributing to sustainability goals.

Improved Recycling:
Deep learning algorithms can help identity and sort recyclable materials, increasing recycling rates and reducing landfill waste.

Technological Advancements:
As IoT and deep learning technologies advance, the scope for waste segregation will expand, enabling more accurate and automated processes.

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