EFFICIENT E-WASTE MANAGEMENT USING IOT

by

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Report submitted in partial fulfilment
of the requirements for the degree
of Bachelor of Engineering in
Electronics and Communication Engineering

Sri Ramakrishna Institute of Technology

Coimbatore – 641010

May, 2025

BONAFIDE CERTIFICATE

Certified that the project titled **EFFICIENT E-WASTE MANAGEMENT USING IOT** is the Bonafide work done by **ASHWIN M (Register Number: 71382104008), YOGIRAJ G (Register Number: 71382104049), SRIHARI S (Register Number:71382104303)** in the FINAL YEAR PROJECT (Phase - II) of this institution, as prescribed by Sri Ramakrishna Institute of Technology for the **EIGHTH** Semester / B.E. Electronics and Communication Engineering programme during the academic year 2024-2025.

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ACKNOWLEDGEMENT

Behind every achievement lies an unfathomable sea of gratitude to those who actuated it, without them it would never have into existence. To them we lay the word of gratitude imprinted within us.

We would like to express our gratitude to the SNR management Trust and the Principal **Dr. J. David Rathnaraj**, for giving us access to all the necessary technological resources.

We express our gratitude to **Dr. S. Anila**, Professor &Head, Department of Electronics and Communication Engineering for her conscientious guidance and encouragement.

We would like to extend our sincere gratitude to our Project Supervisor & Final Year Project coordinator **Mr. R. Ramakrishnan**, Assistant Professor, Department of Electronics and Communication Engineering for her cordial support and guidance.

We sincerely thank all the teaching and non-teaching staff of Electronics and Communication Engineering department for all what they have been for their enquiry about the project.

APPROVAL AND DECLARATION

This project report titled EFFICIENT E-WASTE MANAGEMENT USING IOT was prepared and submitted by ASHWIN M (Register Number: 71382104008), YOGIRAJ G (Register Number: 71382104049) and SRIHARI S (Register Number:71382104303) has been found satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirement for the Bachelor of Engineering (Electronics and Communication Engineering) in Sri Ramakrishna Institute of Technology, Coimbatore.

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May, 2025

EFFICIENT E-WASTE MANAGEMENT USING IOT

ABSTRACT

Efficient E-Waste Management Using IoT is a project that automates the identification and separation of waste into e-waste and general waste categories using image processing techniques. The system leverages IoT technology to improve waste handling efficiency and address environmental challenges posed by improper e-waste disposal.

The implementation involves image analysis in MATLAB, using convolutional neural networks (CNNs) trained with the Levenberg-Marquardt algorithm for waste classification. Based on the results, a conveyor belt system directs the waste to appropriate bins with the help of servo motors. Key hardware components include an ESP-32 microcontroller, ultrasonic sensors, and DC motors. The system also integrates the Blynk IoT platform to notify users when bins are full, ensuring prompt waste collection.

This project demonstrated reliable waste classification, effective bin usage, and automated notifications, significantly reducing manual intervention while enhancing waste management efficiency.

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LIST OF SYMBOLS AND ABBREVIATIONS

CNN	Convolutional Neural Networks
UART	Universal Asynchronous Receiver/Transmitter
IDE	Integrated Development Environment
LCD	Liquid Crystal Display
SRAM	Static Random-Access Memory
RGB	Red Green Blue
GPIO	General Purpose Input / Output
IoT	Internet of Things
E- Waste	Electronic Waste
ESP	Electronic Stability Control
OTA	Over-The-Air
WiFi	Wireless Fidelity
ADC	Analog to Digital Converter
PWM	Pulse Width Modulation
SPI	Serial Peripheral Interface
I2C	Inter-Integrated Circuit
GPS	Global Positioning System
GSM	Global System for Mobile Communication

CHAPTER 1

INTRODUCTION

1.1 Introduction

The rapid growth of technology and the growing reliance on electronic gadgets have resulted in a large increase in electronic garbage (e-waste). The inclusion of dangerous elements such as lead, mercury, and cadmium makes improper e-waste handling a severe environmental and health risk. Effective e-waste sorting and disposal have become crucial for reducing its environmental impact while also permitting the recovery of valuable materials such as gold, silver, and copper. Traditional methods of e-waste management frequently rely on manual segregation, which is time-consuming, error-prone, and inefficient. This has generated an essential need for an automated, intelligent solution to address the issue.

This project, "Efficient E-Waste Management Using IoT," addresses this issue by creating a system that uses image processing techniques and IoT-enabled hardware to automate the separation of e-waste from regular waste. The system intends to transform waste management operations by enhancing classification accuracy, eliminating manual involvement, and assuring timely waste collection and disposal.

The suggested system combines image analysis for waste identification, a conveyor belt mechanism for physical separation, and IoT monitoring and alerting. Waste images are analyzed and identified using MATLAB's convolutional neural network (CNN), with the training process optimized by the Levenberg-Marquardt algorithm. Servo motors and a conveyor belt guide classified waste to the right bins, ensuring accurate segregation. The hardware solution is built around an ESP-32 microcontroller, which controls sensors and motors and communicates with the cloud-based Blynk IoT platform to notify users when bins are full.

1.2 Implementation Challenges

Accuracy in Waste Classification: One of the key implementation issues was ensuring correct waste classification as e-waste and general waste. The image processing algorithm required extensive training with diverse datasets to account for variations in lighting, angles, and object types. Furthermore, optimizing the CNN to balance processing speed and accuracy was a huge problem.

Integration of Hardware and Software: The seamless integration of MATLAB-based image processing with hardware components including the ESP-32 microcontroller, ultrasonic sensors, servo motors, and conveyor belt required accurate measurement. Synchronizing software classification findings with hardware actions required accurate coding and real-time processing capabilities.

IoT Connectivity and Reliability: Establishing a reliable IoT framework using the Blynk platform was essential to ensure timely notifications when bins reached capacity. Network stability, data transmission delays, and cloud-server compatibility had to be addressed to ensure the system's responsiveness and reliability

Scalability and Cost Optimization: Designing a system that is scalable and cost-effective was another major hurdle. The use of affordable hardware components such as the ESP-32 microcontroller and readily available sensors helped reduce costs. However, ensuring that the system could be scaled for larger waste management facilities without compromising performance required careful planning.

Environmental and Mechanical Durability: The physical system, including the conveyor belt and bins, had to withstand varying environmental conditions and mechanical wear and tear. Materials were chosen for durability, and the design was tested to ensure consistent operation over extended periods.

Despite these challenges, the project successfully delivered a functional prototype capable of accurate waste segregation and IoT-enabled monitoring. The integration of advanced technologies and innovative solutions has demonstrated the potential for scalable, sustainable e-waste management systems that can significantly reduce environmental impact.

1.3 Application

Urban Waste Management Systems: The system can be deployed in urban areas to automate waste segregation in residential, commercial, and industrial zones. This ensures efficient collection, reduces manual labor, and promotes better waste management practices.

Recycling Facilities: Recycling centers can use the system to segregate e-waste and general waste efficiently, enabling faster processing and recovery of valuable materials from e-waste such as metals and reusable components.

Smart Cities: Integrated with IoT-based smart city infrastructure, the system can contribute to real-time waste management and data-driven decision-making for urban sanitation and resource allocation.

Educational Institutions: Schools, colleges, and universities can implement this system for awareness and hands-on learning about waste management, environmental sustainability, and the application of IoT and AI in solving real-world problems.

Corporate Offices and IT Parks: Large corporations and IT hubs generate substantial e-waste. This system can help segregate and manage waste efficiently, contributing to corporate social responsibility (CSR) initiatives and environmental compliance.

Industrial Zones: Industries that generate electronic and non-electronic waste can utilize the system to segregate waste effectively, ensuring proper disposal and adherence to environmental regulations.

Healthcare Facilities: Hospitals and healthcare centers often generate e-waste alongside medical waste. This system can be adapted to segregate e-waste efficiently, ensuring compliance with waste disposal standards.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

TITLE

Design and Development of E-Waste Monitoring, Segregation and Recycling System.

YEAR

2023

AUTHOR

Manas Saha Roy; Md. Nazmul Islam Lusan; Md. Ahadur Rahman Khan; Md. Parvez Khan; Abir Ahmed; Md. Saniat Rahman Zishan.

DESCRIPTION

The rapid growth in electronic device usage has led to a significant rise in electronic waste (e-waste), posing serious environmental challenges. In countries like Bangladesh, limited awareness and inadequate infrastructure result in improper disposal of e-waste, which contains toxic substances such as lead and mercury. Informal recycling methods further exacerbate environmental and health risks, highlighting the need for sustainable solutions.

Automated systems using sensors and conveyor mechanisms have shown promise in efficient waste sorting and segregation. These technologies enhance the precision and speed of processing, while shredding systems extract reusable materials like metals and plastics. Digital platforms for e-waste collection and monitoring are also gaining traction. These systems connect consumers with recycling facilities, incentivizing proper disposal practices and promoting transparency.

A comprehensive e-waste management system integrating sorting, shredding, and digital platforms can transform waste management practices in Bangladesh. Public awareness and technological adoption are crucial to ensure the success of such solutions.

2.2 LITERATURE REVIEW

TITLE

Analysis of IoT based Digital Waste Management Collections Garbage Disposal and its Applications.

YEAR

2024

AUTHOR

K. Periyasamy, Peram Praveen Kumar Reddy, Sonukumar, G. Ramachandran, T. Muthumanickam.

DESCRIPTION

The increasing accumulation of electronic waste (e-waste), laden with hazardous materials like heavy metals and chemicals, presents critical challenges to waste management systems. Simultaneously, the presence of valuable materials such as gold and copper in e-waste emphasizes the need for efficient recovery and recycling practices. In India, the informal handling of e-waste remains widespread, often leading to environmental degradation and health risks. Hence, innovative solutions leveraging IoT (Internet of Things) and digital technologies are gaining momentum to address these challenges.

IoT-enabled waste management systems have demonstrated significant potential in enhancing waste collection and recycling processes. Smart bins equipped with sensors can monitor e-waste levels and trigger automated actions when predefined thresholds are met. Studies have shown that such systems improve the efficiency of collection logistics, reduce human intervention, and lower operational costs. The integration of IoT with mobile applications further facilitates public participation by providing convenient disposal options for end users.

The proposed smart collection system for household e-waste management in India introduces a novel approach by combining sensor-equipped collection boxes, automated scheduling systems, and a user-friendly mobile application. These elements ensure timely waste collection, reduce environmental hazards, and support sustainable recycling practices. The proof-of-concept highlights the feasibility of such systems and their potential to revolutionize waste management in India. With increased adoption, these technologies can significantly improve e-waste management efficiency and contribute to a circular economy.

2.3 LITERATURE REVIEW

TITLE

ElectroSortNet: A Novel CNN Approach for E-Waste Classification and IoT-Driven Separation System

YEAR

2024

AUTHOR

Hasibul Hasan Rupok ,Nahian Sourov, Sanjida Jannat Anannaya, Amina Afroz, Mahmudul Hasan Bipul, Md. Motaharul Islam

DESCRIPTION

Recycling electronic waste (e-waste) is essential for mitigating environmental hazards and recovering valuable resources like gold and copper. Studies highlight the significance of advanced technologies in improving e-waste recycling efficiency. According to the United Nations Environment Programme, a tonne of e-waste contains 100 times more gold than a tonne of gold ore, emphasizing the need for accurate sorting and classification systems.

Machine learning, particularly Convolutional Neural Networks (CNNs), has been widely adopted for image-based classification tasks. Enhanced architectures using attention mechanisms, such as squeeze-and-excitation networks, and residual connections have shown significant improvements in performance by addressing challenges like vanishing gradients and improving contextual understanding. These innovations are critical for accurate classification of heterogeneous e-waste materials.

The proposed ElectroSortNet introduces a novel CNN-based approach tailored for e-waste classification. With a test accuracy of 97.44% on a unique dataset, it outperforms existing architectures, underscoring its robustness. Coupled with an IoT-driven e-waste separation system, the model integrates seamlessly into automated workflows. This system employs conveyor belts and robotic arms to sort e-waste based on ElectroSortNet's classification, providing an efficient and scalable solution.

The ElectroSortNet-backed IoT system represents a transformative step in e-waste recycling, combining machine learning accuracy with automated separation processes. Its application demonstrates the potential for integrating artificial intelligence with IoT to revolutionize sustainable waste management practices.

2.4 LITERATURE REVIEW

TITLE

Smart Trash Management: IoT and Machine Learning Solutions for Effective E-Waste Management

YEAR

2024

AUTHOR

Amit Sharma, Narendra Kumar Swami, Rohit Mittal, Kamal Kant Hiran

DESCRIPTION

The rapid growth in population and urbanization has intensified the challenges of waste management, particularly in the context of electronic waste (e-waste). Improper trash management contributes to environmental degradation and poses serious health risks. Conventional waste collection methods, which involve infrequent pickups, often result in garbage overflow and littering. Addressing these issues necessitates the integration of modern technologies such as the Internet of Things (IoT) and Machine Learning (ML).

IoT-based systems have proven effective in enhancing waste management practices by employing sensors and microcontrollers for real-time monitoring of waste levels. Such systems enable efficient scheduling of waste collection, minimizing the likelihood of garbage overflow. Machine learning models further improve waste classification and prediction of waste accumulation patterns, ensuring optimized operations. Image processing techniques, often integrated into these frameworks, provide precise assessments of disposal site conditions, facilitating data-driven decision-making.

The proposed solution in this study combines IoT and ML for smarter trash management. Using microcontrollers and sensors, the framework calculates the e-waste index of disposal sites via image processing. The inclusion of a hardware prototype demonstrates the practical feasibility of the approach. By promoting clean and pollution-free cities, the system aligns with global goals for sustainable urban development.

This IoT- and ML-driven model offers a transformative method for effective e-waste management, showcasing its potential to address the shortcomings of traditional waste management practices.

2.5 LITERATURE REVIEW

TITLE

An Efficient E-Waste Management System through Energy-Aware Routing and Hybrid Optimization Deep Learning Routing on an IoT-Cloud Platform

YEAR

2023

AUTHOR

Puppala Ramya, V. Ramya, M. Babu Rao

DESCRIPTION

The rapid advancement of technology has led to an exponential increase in electronic waste (e-waste), creating challenges in its effective management. Traditional methods of e-waste classification and routing often demand significant manual labor and resources, underscoring the need for innovative and automated solutions. Research efforts have increasingly focused on integrating IoT, cloud computing, and advanced algorithms to enhance the efficiency of e-waste management systems.

Hybrid optimization techniques have proven effective in solving complex routing and classification problems in IoT-enabled systems. The proposed Fractional Horse Herd Gas Optimization-based Shepherd Convolutional Neural Network (FrHHGO-based ShCNN) represents a novel hybrid approach, combining Fractional Henry Gas Optimization (FHGO) and Horse Herd Optimization Algorithm (HOA). These methods facilitate energy-aware routing and high-accuracy classification of e-waste. The incorporation of feature extraction techniques, such as Gray Level Co-occurrence Matrix (GLCM), Local Gabor Binary Pattern (LGBP), and Histogram of Oriented Gradient (HOG), enhances the system's ability to process diverse datasets.

Implemented on an IUoT-cloud platform, the FrHHGO-based ShCNN system enables seamless data collection from IoT nodes, cloud storage, and routing optimization. The model outperformed existing techniques, including standard Deep Learning and Cuckoo Search-based Neural Networks, achieving superior metrics such as 95% accuracy, 93.4% sensitivity, and 96.7% specificity. Additionally, the system demonstrated energy efficiency with minimal energy consumption of 0.301 J and delay of 0.666 seconds.

This advanced framework promotes the social, environmental, and economic sustainability of e-waste management in emerging economies by reducing manual intervention, minimizing energy consumption, and improving classification precision. The integration of IoT and hybrid optimization algorithms positions this system as a transformative solution for scalable and efficient e-waste management.

2.6 LITERATURE REVIEW

TITLE

IoT-Based Household Electronic Waste Management Systems for Electronic Waste Collection.

YEAR

2023

AUTHOR

Puppala Ramya, V Ramya, M Babu Rao

DESCRIPTION

Managing electronic waste (e-waste), which contains hazardous compounds and valuable metals like gold and copper, is a critical aspect of modern waste management practices. Improper disposal of e-waste poses serious environmental and health risks, emphasizing the need for innovative solutions. While industrialized nations have implemented advanced household e-waste management systems, regions like Andhra

Pradesh lag in adopting robust legislative frameworks and technological solutions. With urbanization and rising electronic consumption, addressing household e-waste in Andhra Pradesh is crucial to advancing smart city initiatives and ensuring sustainable urban development.

IoT-based systems offer transformative solutions for household e-waste collection and recycling. Smart collecting systems equipped with sensors monitor waste levels and automate the disposal process. These systems enhance efficiency by triggering notifications when bins reach 80% capacity, ensuring timely collection and minimizing overflow. The integration of mobile applications provides convenience for users to dispose of household e-waste, promoting public participation and awareness. Additionally, automated back-end servers facilitate the scheduling and dispatch of e-waste collectors, streamlining the entire collection process.

The proposed smart system for Andhra Pradesh incorporates these technologies, offering a comprehensive framework for real-time waste monitoring and collection scheduling. By leveraging IoT and digital tools, the solution addresses key challenges in household e-waste management while fostering community engagement. The successful proof-of-concept demonstrates the feasibility of this approach, underscoring its potential to improve domestic waste management, reduce environmental hazards, and contribute to sustainable development goals in the region.

2.7 LITERATURE REVIEW

TITLE

IoT Based E-Waste Management: Towards a Sustainable Environment.

YEAR

2023

AUTHOR

Atreyi Pramanik, Pranchal Rajput, Srinivas Aluvala

DESCRIPTION

The integration of the Internet of Things (IoT) into e-waste management represents a paradigm shift towards more efficient and sustainable waste management systems. The rise of IoT-based smart solutions leverages interconnected devices and sensors to optimize e-waste collection and processing, addressing both environmental and operational challenges. As electronic waste continues to grow, traditional methods of collection and disposal are increasingly inadequate. IoT offers real-time monitoring, intelligent data analytics, and automation, enhancing efficiency while reducing the environmental impact of improper e-waste management.

One of the key applications of IoT in e-waste management is the monitoring of collection bins and containers using sensors. These devices can track the fill levels of bins, enabling optimized collection routes and minimizing waste overflow. By reducing unnecessary trips and improving logistics, operational costs are significantly lowered, leading to more efficient use of resources. Additionally, the use of RFID tags and sensors ensures enhanced inventory management, allowing for better traceability and accountability throughout the e-waste supply chain. This technology ensures that valuable materials in e-waste, such as metals and rare earth elements, are recovered and recycled effectively.

Furthermore, real-time data analytics enabled by IoT offer valuable insights into e-waste generation patterns, helping manufacturers design products that are more sustainable. By understanding the lifecycle of electronic products and the volumes of waste they generate, manufacturers can improve product design to minimize waste and increase recyclability. This data-driven approach helps promote a circular economy, where products are designed for longevity, reuse, and easy disposal.

In conclusion, IoT-based e-waste management systems represent a promising solution for sustainable environmental practices. The integration of sensors, RFID technology, and data analytics leads to more efficient collection, recycling, and product lifecycle management, driving both environmental and economic benefits. The development of these systems can support smarter, more sustainable cities, and help address the growing global challenge of e-waste.

2.8 LITERATURE REVIEW

TITLE

Leveraging CNN and IoT for Effective E-Waste Management

YEAR

2023

AUTHOR

Ajesh Thangaraj Nadar, Gabriel Nixon Raj, Soham Chandane, Sushant Bhat

DESCRIPTION

The proliferation of electronic devices has led to an exponential increase in electronic waste (e-waste), creating significant challenges in disposal and recycling. E-waste contains a variety of materials, including valuable metals, toxic substances, and complex electronic circuits, making its proper management a pressing issue. Effective recycling requires precise sorting and classification, which has traditionally been labor-intensive and inefficient. However, recent advancements in technologies like the Internet of Things (IoT) and Convolutional Neural Networks (CNNs) offer promising solutions for enhancing e-waste management processes.

IoT enables real-time monitoring and management of e-waste through interconnected devices and sensors, providing accurate data for efficient collection, transportation, and recycling. By integrating IoT with CNN-based object detection, it becomes possible to automate the sorting of e-waste into distinct categories such as circuit boards, sensors, and wires. CNNs, a type of deep learning model, are particularly effective in image-based classification tasks, offering high accuracy in identifying and distinguishing between different types of e-waste materials. This reduces human error and accelerates the sorting process, leading to improved efficiency in recycling operations.

The envisioned system incorporates both a camera and a weighing scale to classify e-waste components. The camera uses object detection to identify individual e-waste items, while the scale assesses the weight of each component, ensuring the correct categorization based on both visual and weight-based attributes. This dual approach allows for more precise sorting, enabling the e-waste to be transferred more efficiently to the appropriate recycling facilities.

In summary, leveraging IoT and CNNs for e-waste management presents a significant advancement in the automation of recycling processes. The integration of smart systems with real-time monitoring, object detection, and weight analysis not only enhances operational efficiency but also supports sustainable e-waste recycling. This approach promises to reduce environmental harm, recover valuable materials, and improve the overall management of e-waste in modern societies.

CHAPTER 3

PROPOSED METHODOLOGY

3.1 Problem Statement

The rapid growth in the use of electronic devices has led to an alarming increase in electronic waste (e-waste), which poses significant environmental and health hazards due to its toxic components. Inadequate segregation and improper disposal of e-waste often result in valuable materials being lost and harmful substances contaminating the environment. Traditional waste management systems rely heavily on manual segregation, which is time-consuming, inefficient, and prone to errors. Additionally, the lack of real-time monitoring and notification systems for waste collection leads to delays, contributing to inefficient waste disposal practices and overflow of bins in urban areas. There is an urgent need for an automated, intelligent, and scalable solution that can classify, segregate, and manage e-waste effectively while integrating with modern IoT frameworks to ensure timely disposal and optimize waste management processes. This project aims to address these challenges by developing a smart e-waste management system that uses image processing and IoT to automate waste segregation, improve classification accuracy, and enable real-time monitoring and notifications.

3.2 Existing Methodology

The conventional approach to e-waste management employs inductive and capacitive sensors to classify and segregate waste based on its material properties. This methodology relies on the fundamental principle that metallic and non-metallic materials exhibit different electrical characteristics, such as inductance and capacitance. The process involves the following steps:

Detection of Material Type:

- **Inductive Sensors:** These sensors are used to detect metallic objects. When metallic waste passes through the sensor’s detection range, it induces a change in the magnetic field, which is measured as a signal to identify metallic e-waste.
- **Capacitive Sensors:** These sensors are used to detect non-metallic materials by measuring changes in capacitance caused by the dielectric properties of materials such as plastics, paper, and glass.

Classification of Waste: Based on the signals from inductive and capacitive sensors, the system classifies the waste as either metallic (e-waste) or non-metallic (general waste). The classification is typically binary and does not account for further differentiation within metallic or non-metallic categories.

Physical Segregation: Once the waste is classified, mechanical systems such as conveyor belts and actuators (e.g., pneumatic pushers or motors) direct the waste to designated bins. Metallic waste is diverted to an e-waste bin, while non-metallic waste is directed to a general waste bin.

Limitations:

- **Limited Classification:** The methodology is restricted to detecting only metallic versus non-metallic waste and cannot identify specific types of e-waste (e.g., circuit boards, batteries, or cables).
- **Accuracy Issues:** Variability in material properties, such as coatings on metals or composite materials, can reduce detection accuracy.
- **Lack of IoT Integration:** Traditional systems do not provide real-time monitoring or notifications for bin status, leading to inefficiencies in waste collection and disposal.
- **Scalability Challenges:** The system's reliance on hardware sensors alone makes it less adaptable for large-scale or multi-category waste management.

While this methodology is effective for basic waste segregation, its limitations in classification accuracy and lack of IoT connectivity necessitate a more advanced solution. The proposed project addresses these gaps by employing image processing and IoT to enhance waste segregation and management processes.

3.3 Proposed Methodology

The proposed methodology for "Efficient E-Waste Management Using IoT" aims to overcome the limitations of traditional sensor-based systems by leveraging image processing, machine learning, and IoT technologies to automate waste classification, segregation, and monitoring. The process is as follows:

1. Image-Based Waste Classification

- **Input Capture:** Waste is placed on a conveyor belt for processing. Instead of using physical sensors to detect material properties, the system captures waste images.
- **Image Processing:** The captured image undergoes preprocessing steps such as grayscale conversion, boundary extraction, and noise removal to prepare it for classification.
- **Machine Learning Classification:** A Convolutional Neural Network (CNN) is employed to classify the waste based on its features.
    - The CNN is trained on a labeled dataset of e-waste and normal waste images.
    - The Levenberg-Marquardt algorithm is used to optimize the training process for faster convergence and higher accuracy.
- **Classification Output:** The system determines whether the waste belongs to the e-waste category or general waste.

2. Automated Segregation System

- **Conveyor Belt Operation:** A motor-driven conveyor belt moves the waste to the appropriate bin based on the classification result.
- **Bin Segregation Mechanism:**
    - If the waste is classified as e-waste, a servo motor operates to slide the waste into the designated e-waste bin.
    - If classified as normal waste, the conveyor belt continues its operation to dump the waste into the general waste bin.

3. IoT-Enabled Monitoring

- **Hardware Components:**

    - ESP-32 Microcontroller: Central control unit for managing sensors, motors, and IoT communication.
    - Ultrasonic Sensors: Monitor the fill levels of e-waste and general waste bins.
- **IoT Integration:**
    - The system uses the Blynk IoT platform to send real-time notifications to a connected mobile app when any bin is nearing capacity.
    - Data is also uploaded to a cloud server for remote monitoring and analysis.

4. System Feedback and Alerts

- Once a bin is full, the IoT system alerts the user for immediate waste collection.
- The notifications reduce delays in waste disposal, ensuring efficient waste management.

Advantages Over Existing Methodology

- **Enhanced Classification:** Advanced image processing enables the system to identify complex waste categories beyond metallic and non-metallic distinctions.
- **Automation:** Eliminates the need for manual intervention, reducing errors and improving efficiency.
- **Scalability:** The system can be easily scaled to handle additional waste categories by updating the dataset and retraining the model.
- **IoT Integration:** Enables real-time monitoring, proactive notifications, and data-driven optimization for waste collection schedules.

3.4 Flow Chart & Block Diagram

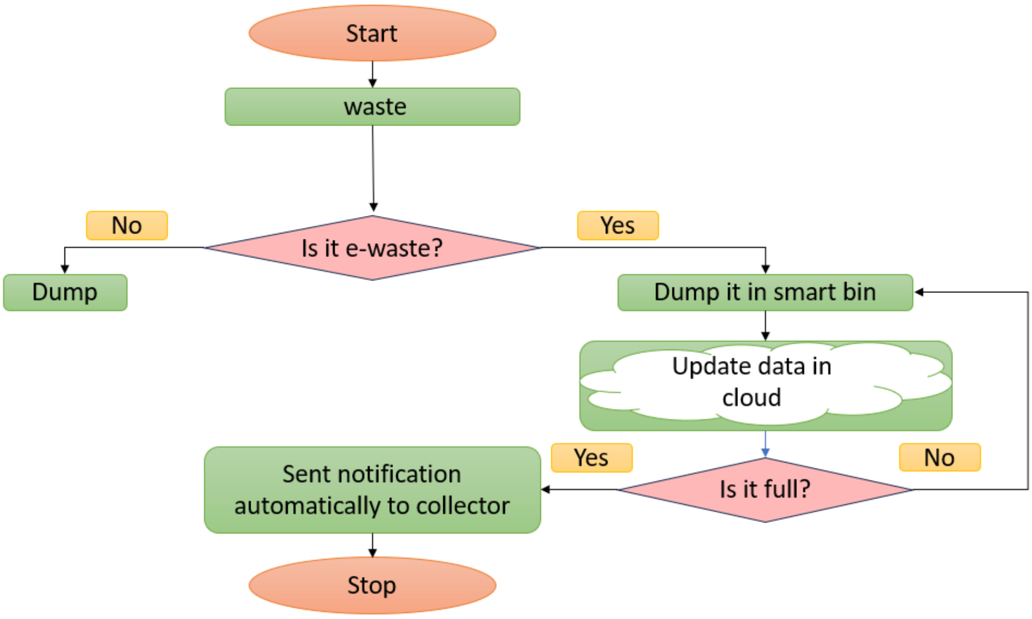

Figure 3.1: Flow chart

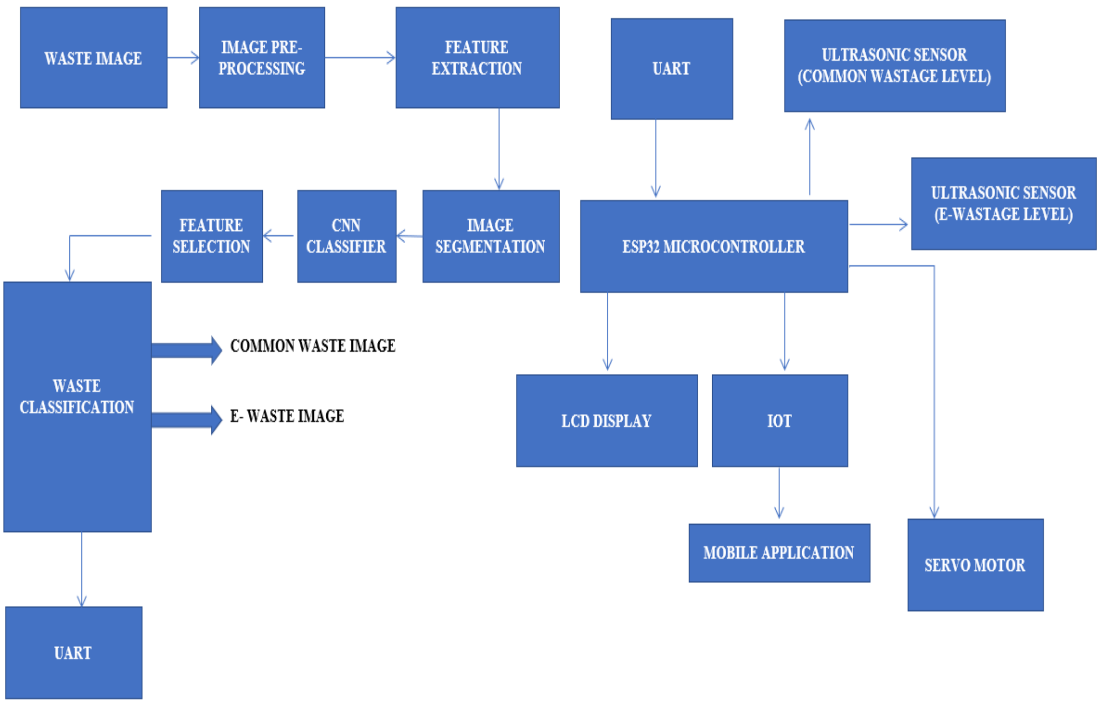

Figure 3.2: Block Diagram

3.5 Hardware Description

3.5.1 ESP-32 Microcontroller: The ESP-32 is a powerful and versatile microcontroller that is highly suitable for IoT applications. It integrates a dual-core processor, rich interfaces, and robust connectivity options, making it the backbone of our project.

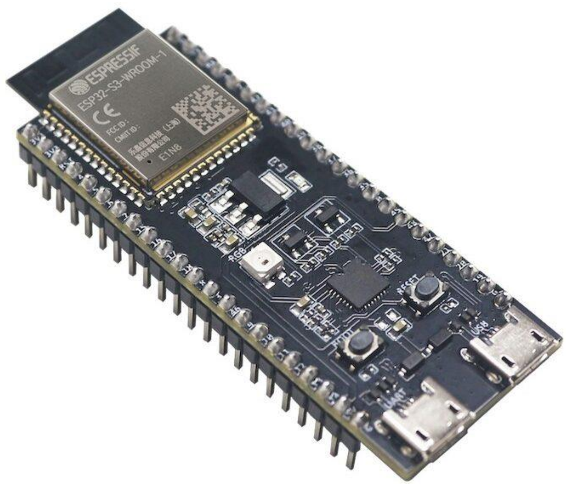

Figure 3.3 ESP-32 Microcontroller

Features:

1. **Processor:**
   The ESP-32 is powered by a dual-core Xtensa LX6 microprocessor, which supports multitasking. This enables simultaneous control of sensors, motors, and IoT communication without performance degradation.
2. **Memory:**
   It includes 520 KB of SRAM and 4 MB of flash memory, allowing it to handle complex programs and data processing.
3. **Connectivity:**

   - **Wi-Fi:** Enables real-time communication with cloud servers for waste bin status updates. Integrated 2.4 GHz Wi-Fi and Bluetooth 4.2 allow real-time communication with cloud platforms like Blynk.

   - **Bluetooth:** Provides additional options for short-range communication or device pairing.

4. **GPIO Pins**: Multiple General-Purpose Input/Output (GPIO) pins are available for interfacing with hardware components like ultrasonic sensors, servo motors, and LCD displays.

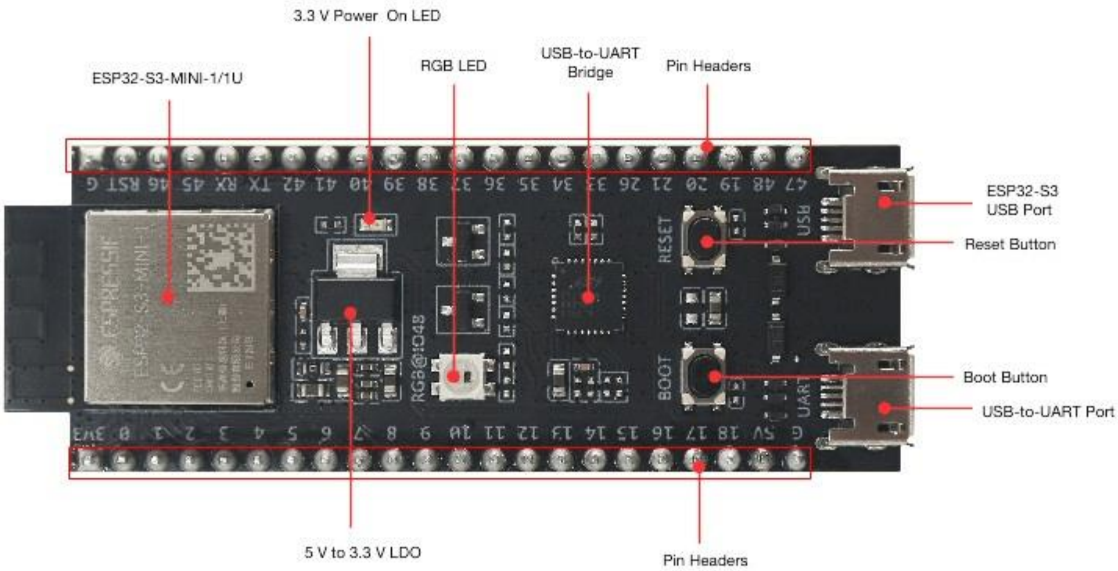

Figure 3.4 ESP-32 Microcontroller Pinout Ports

Role in the Project:

In this project, the ESP-32 serves as the central control unit. It:

- Processes input from the ultrasonic sensors to monitor bin levels.
- Controls the conveyor belt via the DC motor and actuates the servo motor for waste segregation.
- Transmits real-time data to the Blynk IoT platform, enabling notifications when bins are full.

Advantages:

- Compact design and high integration simplify circuit complexity.
- Versatile connectivity enables seamless IoT integration.
- It eliminates the need for additional wireless modules due to built-in Wi-Fi and Bluetooth.
- It supports OTA (Over-The-Air) updates, making it easy to upgrade the system firmware.
- Simple and low-cost communication method.
- Reliable for short-distance communication, particularly within IoT systems.

Challenges:

- Requires precise coding for real-time control and data handling.
- Proper shielding is needed to prevent interference in noisy environments.

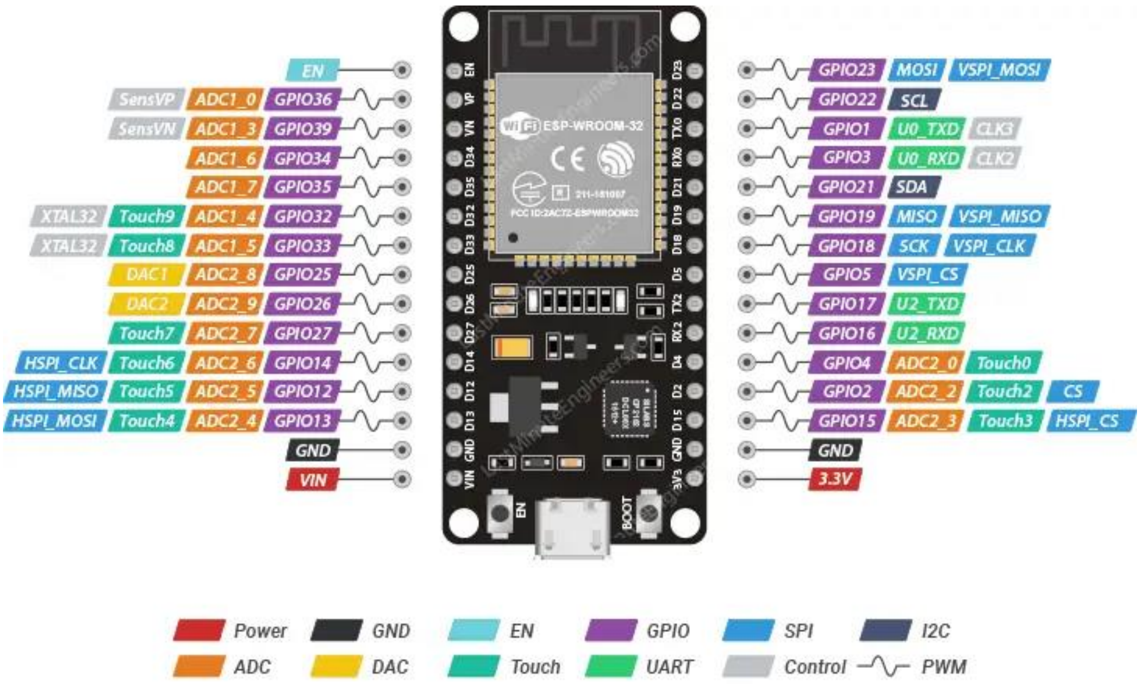

Figure 3.5 GPIO Pins

ESP-32 GPIO Pin Features

1. **Number of GPIO Pins:** The ESP-32 typically has 36 GPIO pins, but not all are available for use as some are reserved for internal functions.
2. **Configurable Functions:**
   - GPIO pins can be configured as digital input or digital output.
   - Some GPIO pins also support analog input (ADC), PWM output, capacitive touch sensing, and special interfaces (e.g., UART, I2C, SPI).
3. **Voltage Levels:** GPIO pins operate at 3.3V logic level, so care must be taken to interface with peripherals designed for 3.3V. A level shifter is needed for 5V devices.

4. **Current Drive Capacity:** Each GPIO pin can source or sink up to 12 mA.
5. **Special Capabilities:** Some GPIOs have pull-up or pull-down resistors, touch sensing capabilities, or are input-only.

3.5.2 UART (Universal Asynchronous Receiver Transmitter)

UART is a hardware communication protocol used for serial communication between devices. It enables the microcontroller to communicate with other components or peripherals.

Figure 3.6 UART Component

Features:

- **Full-Duplex Communication:** Allows simultaneous data transmission and reception.
- **Baud Rate Configurability:** Supports a wide range of baud rates, ensuring compatibility with various devices.
- **Error Detection:** Parity checks and stop bits ensure reliable data transfer.
- **Asynchronous Communication:** UART does not require a clock signal, simplifying hardware design. Data is transmitted using start, stop, and parity bits for reliable communication.

- **Simplicity:** UART operates over just two lines (Tx and Rx), minimizing wiring complexity.

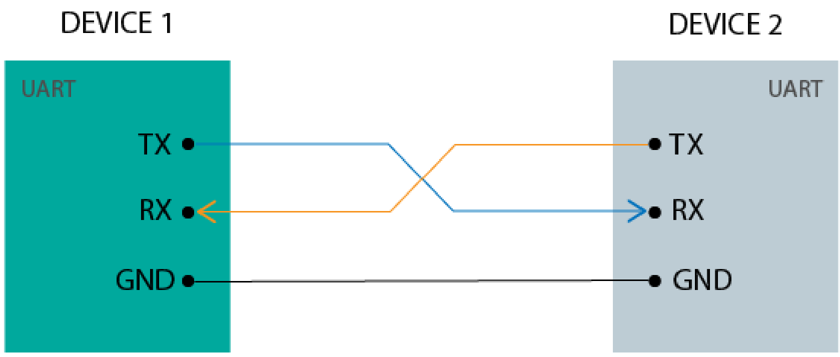

Figure 3.7 UART Data transmission

Role in the Project:

- Enables the ESP-32 to communicate with debugging tools and additional devices during development and testing.
- It ensures smooth data transmission for controlling actuators and receiving sensor data.
- Can be used to interface with external modules, such as GPS or GSM modules, if needed in future expansions.

Advantages

- Simple and low-cost communication method.
- Reliable for short-distance communication, particularly within IoT systems.
- Efficient for low-speed communication in IoT devices.
- Reliable error detection mechanisms ensure data integrity.
- Simple and reliable communication.
- Does not require a clock signal, reducing hardware complexity.

Challenges:

- Limited to short-distance communication.
- Requires precise matching of baud rates between devices.

3.5.3 Ultrasonic Sensor

An ultrasonic sensor is a device that measures distance or detects objects by using ultrasonic sound waves. These sensors operate on the principle of echolocation, similar to how bats navigate in the dark.

The ultrasonic sensor is responsible for monitoring the fill levels of bins in the project. The most common model used is the HC-SR04, which is highly reliable for non-contact distance measurement.

Figure 3.8 Ultrasonic Sensor

Key Components of an Ultrasonic Sensor

1. **Transmitter:**
    - Emits ultrasonic sound waves (typically 20 kHz to 400 kHz).
    - Converts electrical energy into mechanical vibrations.
2. **Receiver:**
    - Detects the sound waves reflected (echo) back from an object.
    - Converts mechanical vibrations back into electrical signals.
3. **Control Circuit:**
    - Generates the electrical signal for the transmitter.
    - Processes the received signal to calculate distance or detect the presence of an object.

Working Principle

1. **Transmission:** The sensor's transmitter emits a burst of ultrasonic sound waves.

2. **Propagation:** These waves travel through the medium (usually air) until they hit an object.
3. **Reflection:** The waves bounce back from the surface of the object toward the sensor.
4. **Reception:** The receiver captures the reflected waves.
5. **Processing:** The time delay between transmission and reception is measured. Using the speed of sound in air (approximately 343 m/s at room temperature), the distance to the object is calculated using the formula:

$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time Delay}}{2}$$

Figure 3.9 Ultrasonic Sensor Pin Connection

Features:

- **Operating Principle:** Emits ultrasonic waves and measures the time taken for the echo to return.
- **High Accuracy:** Can measure distances ranging from 2 cm to 400 cm with minimal error.
- **Compact and Lightweight:** Easy to integrate into small systems.

Role in the Project:

The ultrasonic sensor monitors the fill level of the bins (e-waste and normal waste). When a bin is close to being full, the sensor sends data to the ESP-32, triggering a notification to the user via the Blynk IoT platform.

Advantages:

- Non-contact measurement ensures durability and minimal wear and tear.
- Works well in dusty environments typical of waste bins.

Challenges:

- Affected by temperature variations and soft materials that absorb sound waves.
- Proper alignment is necessary for accurate readings.

3.5.4 DC Motor

A DC motor is an electric motor that converts direct current (DC) electrical energy into mechanical energy. Its operation is based on the principle of electromagnetic induction, where a current-carrying conductor in a magnetic field experiences a force.

A DC motor converts electrical energy into mechanical motion, making it a key component for the conveyor belt mechanism.

Figure 3.10 DC Motor

Features:

- Speed Control: Can be easily controlled using Pulse Width Modulation (PWM).
- Compact and Durable: Suitable for applications requiring continuous operation.
- Varied Power Ratings: Available in a range of power ratings to suit different load requirements.

Role in the Project:

The DC motor drives the conveyor belt, moving waste to the classification and segregation zones. The motor's speed is controlled by the ESP-32 to synchronize with the waste classification process.

Advantages:

- Simple and reliable operation.
- Easily interfaced with microcontrollers.

Challenges:

- Requires a motor driver circuit for safe operation.
- Generates noise and heat during prolonged use.

3.5.5 Servo Motor

A servo motor is a rotary or linear actuator designed for precise control of angular or linear position, speed, and acceleration. It combines a motor with a sensor for position feedback and a controller to regulate its motion. Servo motors are widely used in robotics, CNC machines, and automation systems due to their precision and reliability.

Features:

- **High Precision:** Capable of positioning within a fraction of a degree.
- **Compact Size:** Suitable for small spaces.
- **Feedback Mechanism:** Includes built-in encoders for accurate positioning.

Role in the Project:

The servo motor slides the waste into the appropriate bin based on the classification result from the image processing system.

Advantages:

- Precise and repeatable movement.
- Simple control using PWM signals.

Challenges:

- Limited rotational range (usually 0° to 180°).
- Sensitive to voltage fluctuations.

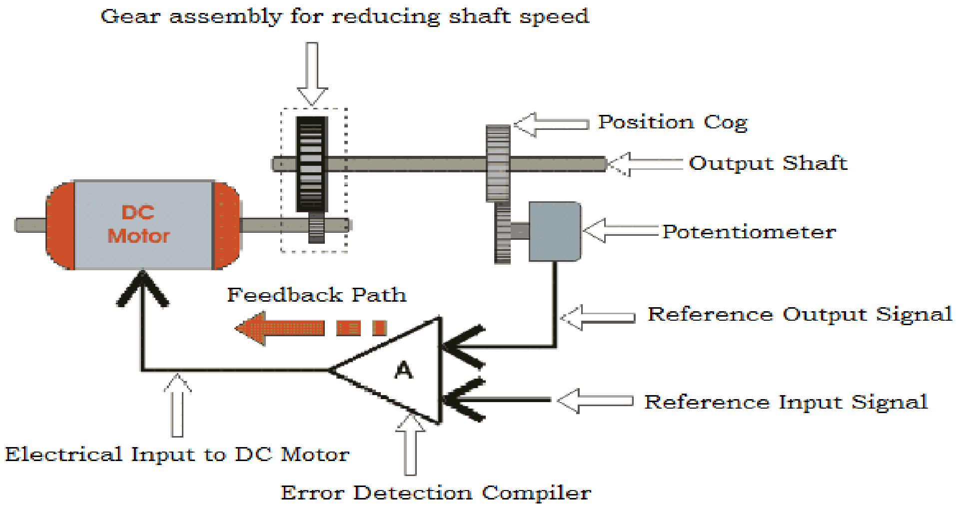

Figure 3.11 Servo Motor

3.5.6 LCD

An LCD (Liquid Crystal Display) is a flat-panel display technology that uses liquid crystals to control light modulation and create visible images or text. These displays are energy-efficient, lightweight, and commonly used in electronic devices such as smartphones, TVs, digital clocks, and instrumentation.

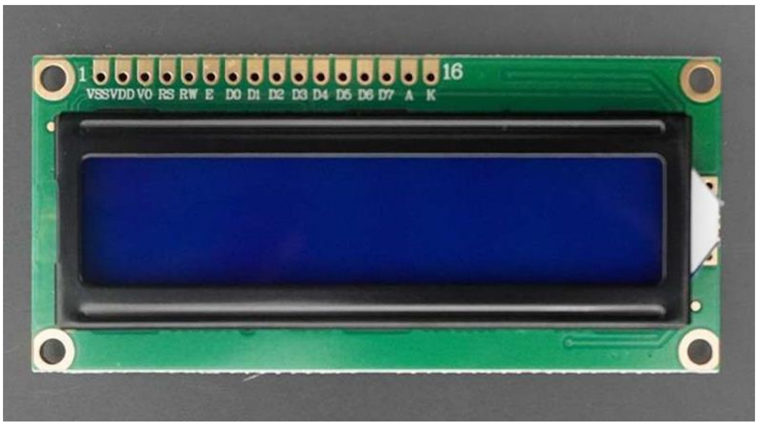

Figure 3.12 LCD

Features:

- **Multi-Line Display:** Typically supports 16x2 or 20x4 characters.
- **Low Power Consumption:** Ideal for battery-operated systems.
- **Customizable Display:** Allows display of text and simple graphics.

Role in the Project:

The LCD displays key system information, such as bin status, waste classification results, and operational messages for the user.

Advantages:

- Simple interface with microcontrollers.
- Provides real-time feedback.

Challenges:

- Limited visibility under bright light.
- Requires precise timing for data transmission.

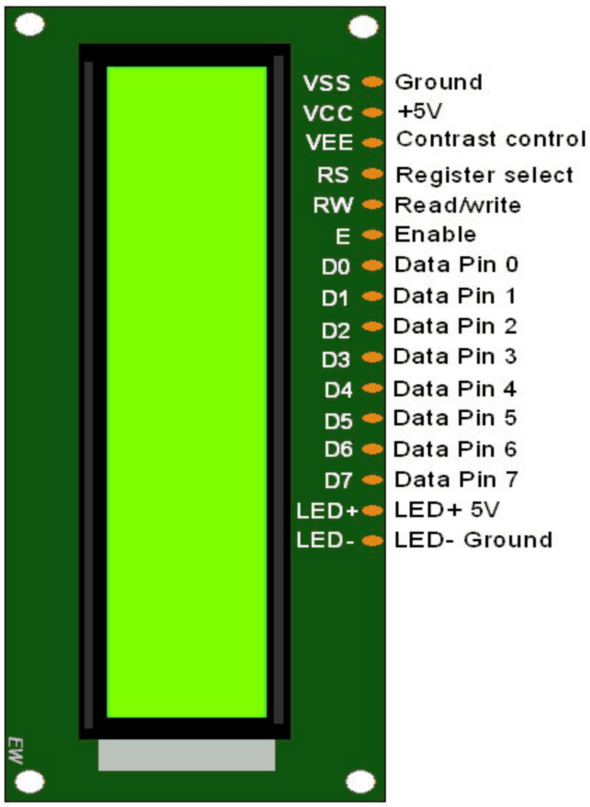

Figure 3.13 LCD Pin Diagram

3.5.7 Conveyor Belt

A conveyor belt is a continuous moving surface used for transporting waste from the input stage to the segregation zone.

Features:

- **Durable Material:** Made of rubber or synthetic materials to withstand heavy loads.
- **Adjustable Speed:** Can be controlled to match the processing rate.
- **Modular Design:** Easy to install and maintain.

Role in the Project:

The conveyor belt moves waste along the classification system. Based on the classification, the belt directs waste to the appropriate bin.

Advantages:

- Increases automation and efficiency.
- Reduces manual handling of waste.

Challenges:

- Requires regular maintenance to prevent wear and tear.
- Proper alignment is essential to prevent slippage.

3.5.8 Power Adapter

A power adapter provides the required electrical power for the system components.

Features:

- **Voltage Regulation:** Converts mains electricity to a stable DC output.
- **Multiple Outputs:** Provides different voltage levels for various components.
- **Overload Protection:** Prevents damage to connected devices.

Role in the Project:

The power adapter supplies stable power to the ESP-32, motors, sensors, and other hardware components.

Advantages:

- Reliable and consistent power supply.
- Protects components from power surges.

Challenges:

- Requires proper matching of voltage and current ratings with the components.
- Bulky adapters may limit portability.

3.6 Software Description

3.6.1 MATLAB

MATLAB is a powerful programming and numerical computing platform that excels in handling matrix operations, signal processing, and image processing. Its Image Processing Toolbox offers a wide range of tools and functions to analyze, manipulate, and interpret images.

Role in the Project

- MATLAB is used to classify waste into e-waste and normal waste using image processing techniques.
- The classification involves analyzing features such as shape, texture, and edge boundaries to identify the type of waste.

Key Functions and Techniques Used

1. **Image Acquisition:**
   - Images of waste are fed into MATLAB as input
   - The imread() function is used to load images for processing.
2. **Preprocessing:**
   - Conversion of images from RGB to grayscale using rgb2gray().
   - Noise reduction and filtering using Gaussian or median filters.
3. **Feature Extraction:**
   - Edge detection using Sobel or Canny methods with edge() function.

- Boundary extraction to analyze contours for object detection.

4. **Classification Algorithm:**
    - A Convolutional Neural Network (CNN) is trained to classify waste based on its features.
    - MATLAB's Deep Learning Toolbox is used, leveraging the Levenberg-Marquardt algorithm for efficient training and high accuracy.
5. **Decision Making:** Based on classification results, MATLAB provides commands to control the conveyor belt and actuators.

Advantages

- Simplifies complex mathematical computations.
- Provides an extensive library for image processing and machine learning tasks.

Challenges and Solutions

- **Challenge:** Large datasets required for training CNN models.
  Solution: Use pre-trained networks or synthetic data augmentation to improve results.

3.6.2 Arduino IDE

The Arduino Integrated Development Environment (IDE) is an open-source software platform used to write, compile, and upload code to microcontrollers. It is widely used for programming ESP-32 and other development boards using Embedded C/C++.

Role in the Project

- The Arduino IDE is used to write and upload firmware for the ESP-32, enabling it to interface with sensors, motors, and the IoT platform.
- It handles real-time tasks such as motor control, bin monitoring, and data transmission to the Blynk IoT platform.

Key Code Modules

1. **Sensor Interfacing:** Reads distance data from ultrasonic sensors using digitalRead() and calculates bin fill levels.
2. **Motor Control:** Implements Pulse Width Modulation (PWM) for controlling the speed of DC motors and positioning of servo motors using analogWrite().
3. **Communication:**
    - Establishes Wi-Fi connectivity with the ESP-32 using the WiFi.h library.
    - Sends notifications to the cloud server when bins are full using Blynk.virtualWrite().
4. **Decision Logic:**
    - Processes input from MATLAB or sensors to classify waste and direct it to the correct bin.
    - Logic is implemented with conditional statements in Embedded C.

Advantages

- Lightweight and easy-to-use platform with a rich library ecosystem.
- Compatible with multiple hardware components, making it ideal for embedded applications.

Challenges and Solutions

- **Challenge:** Limited memory for complex tasks.
  Solution: Optimize code by using efficient data structures and functions.

3.6.3 Blynk IoT Platform

Blynk is a popular IoT platform that allows developers to build applications for remote monitoring and control of devices. It is highly customizable and supports integration with microcontrollers like the ESP-32.

Role in the Project

- Blynk is used to monitor the status of bins and notify users when they are full.

- It provides a mobile app interface where users can track waste levels in real-time.

Key Features Used

1. **Device Integration:**
    - The ESP-32 communicates with the Blynk Cloud using the Blynk.h library.
    - Data from sensors is transmitted to the cloud and displayed on the mobile app.
2. **Real-Time Notifications:** Blynk sends push notifications to users when either the e-waste or normal waste bin is full.
3. **Dashboard Customization:**
    - The app dashboard is customized to display waste levels, system status, and classification results.
    - Widgets like LED indicators, Value Displays, and Buttons are used.
4. **Cloud-Based Storage:** Data from sensors is logged in the cloud for further analysis and optimization of waste management.

Advantages

- Simplifies IoT application development with minimal coding.
- Offers cross-platform support for Android and iOS.
- Provides real-time insights into system operations.

Challenges and Solutions

- **Challenge**: Wi-Fi instability can disrupt communication.
  Solution: Implement reconnection logic in the ESP-32 code to maintain connectivity.

Integration of Software Tools in the Project

- MATLAB performs advanced image processing and classification tasks.

- Arduino IDE ensures efficient hardware control and communication with peripherals.
- Blynk provides a seamless interface for monitoring and notifying users, closing the IoT loop.

3.7 Workflow

3.7.1 Detecting Waste

- **Objective:** Detect the presence of waste on the conveyor belt.
- **Process:**
  1. **Ultrasonic Sensor Monitoring:**
     - The ultrasonic sensor mounted above the conveyor belt detects the presence of an object (waste).
     - When an object is detected, the sensor sends a trigger signal to the ESP-32 microcontroller.
  2. **Conveyor Belt Activation:**
     - The conveyor belt motor is activated to transport the waste under the camera or toward the next processing step.

3.7.2 Waste Separation

This step involves the analysis and classification of waste using image processing techniques.

Image Conversion

- **Objective:** Prepare the captured waste image for processing.
- **Process:**
  1. Load the image manually from the PC .
  2. Convert the image from RGB to grayscale using MATLAB’s rgb2gray() function.
  3. Perform normalization and filtering to reduce noise and enhance image quality.

Morphological Operation / Boundary Extraction

- **Objective:** Highlight the key features of the waste object.
- **Process:**
  1. Use morphological operations like erosion, dilation, and opening to remove noise and enhance features.
  2. Extract boundaries using edge detection methods (e.g., Canny or Sobel algorithms).

Neural Network

- **Objective:** Classify the waste as e-waste or normal waste.
- **Process:**
  1. Feed the processed image into a Convolutional Neural Network (CNN) model trained on e-waste and normal waste datasets.
  2. The CNN analyzes the image and determines its category.
  3. The Levenberg-Marquardt algorithm is used to optimize the network for high accuracy.

E-Waste or Normal Waste

- **Objective:** Determine the waste type and trigger the appropriate action.
- **Process:**
  1. If classified as e-waste, the servo motor redirects the waste into the e-waste bin.
  2. If classified as normal waste, the conveyor belt transports the waste to the normal waste bin.

3.7.3 Collecting Waste in Smart Bins

- **Objective:** Ensure proper collection and tracking of waste.
- **Process:**
  1. Bins are equipped with ultrasonic sensors to monitor their fill levels.

2. When a bin reaches a predefined fill level, the sensor sends a signal to the ESP-32.

3. Data is logged and sent to the cloud for IoT-based monitoring**.**

3.7.4. Notification to Phone (IoT)

- **Objective:** Notify users about bin status.
- **Process:**
  1. The ESP-32 microcontroller sends data to the Blynk IoT platform using Wi-Fi.
  2. A notification is sent to the user's smartphone via the Blynk app.
  3. The dashboard displays real-time waste levels, bin status, and system operations.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Simulation Result

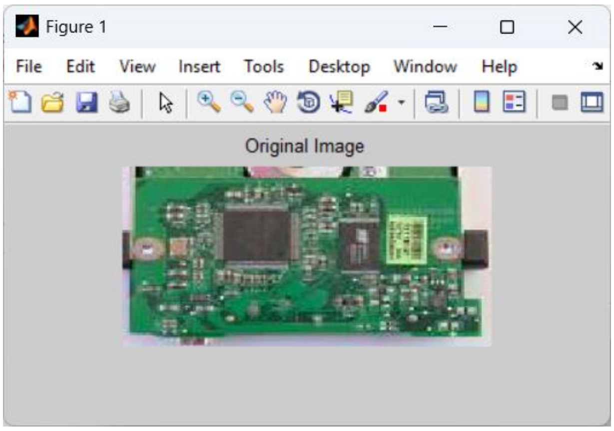

Figure 4.1 Original Image

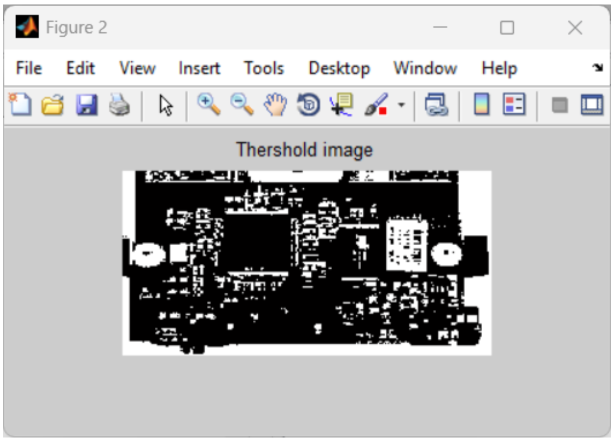

Figure 4.2 Threshold Image

Result: Threshold conversion effectively highlighted the shape and size of the waste objects, making them easier to segment and analyze in subsequent steps.

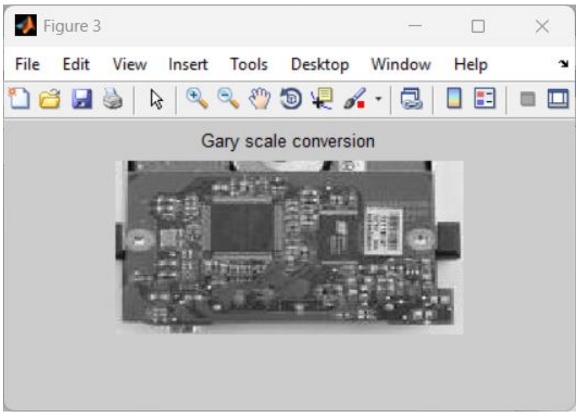

Figure 4.3 Gray Scale Conversion

Result: Grayscale images retained important intensity variations, which were crucial for detecting edges and contours in boundary extraction.

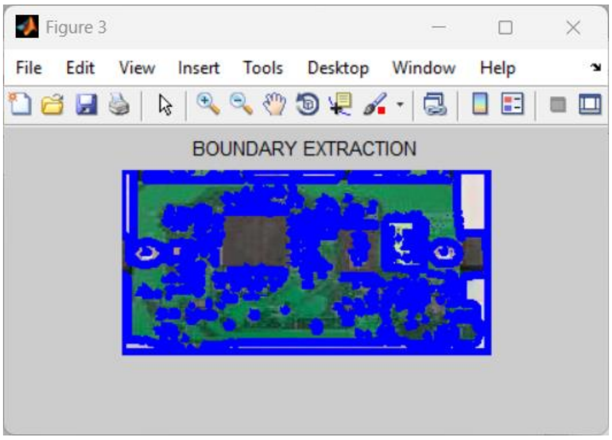

Figure 4.4 Boundary Extraction

Result: Object boundaries were clearly extracted, providing essential shape and structural information for the classification model.

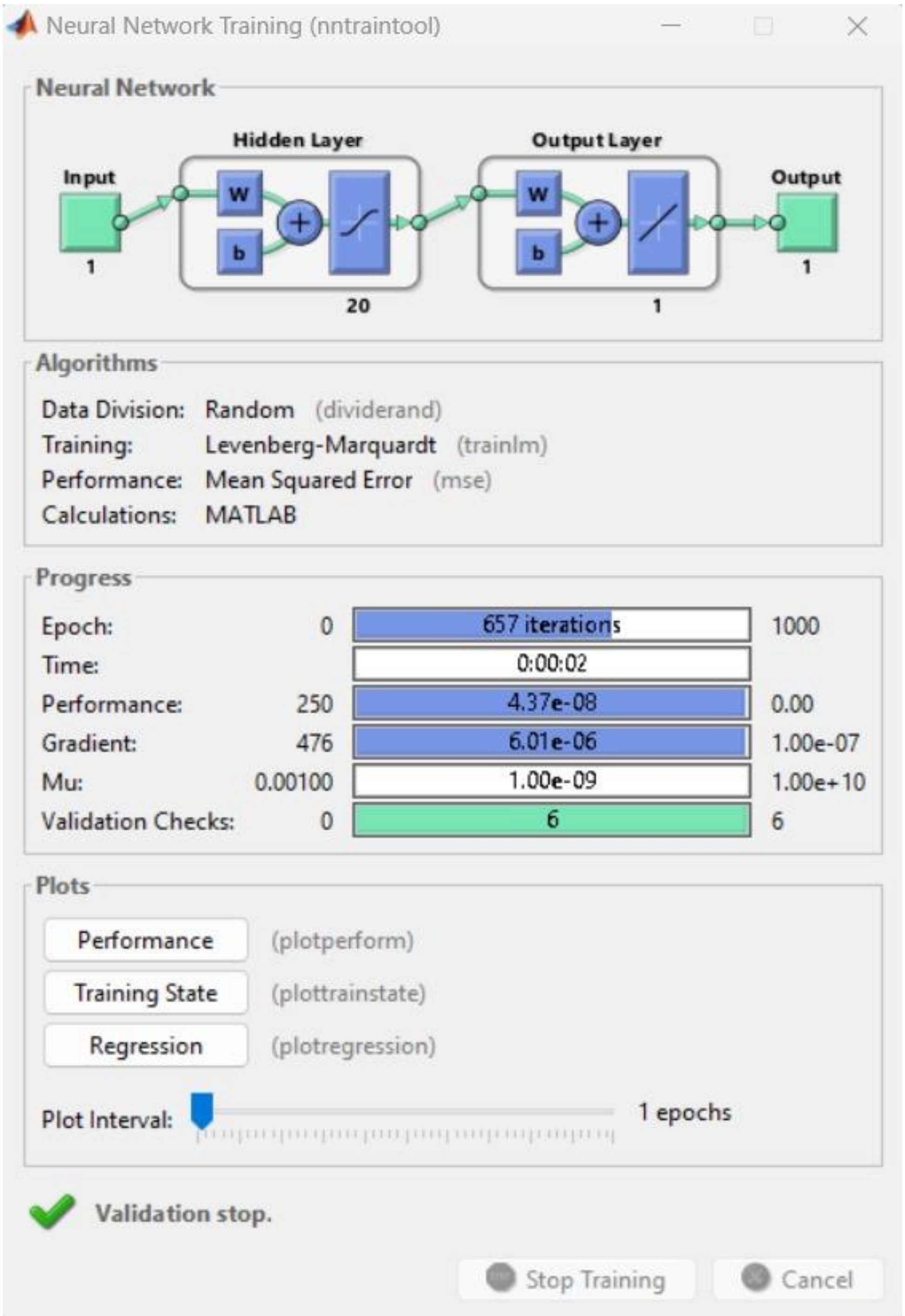

Figure 4.5 Neural Network

Result: The trained CNN model achieved an accuracy of over 90% in classifying waste as e-waste or normal waste, demonstrating effective feature learning and robust classification capabilities.

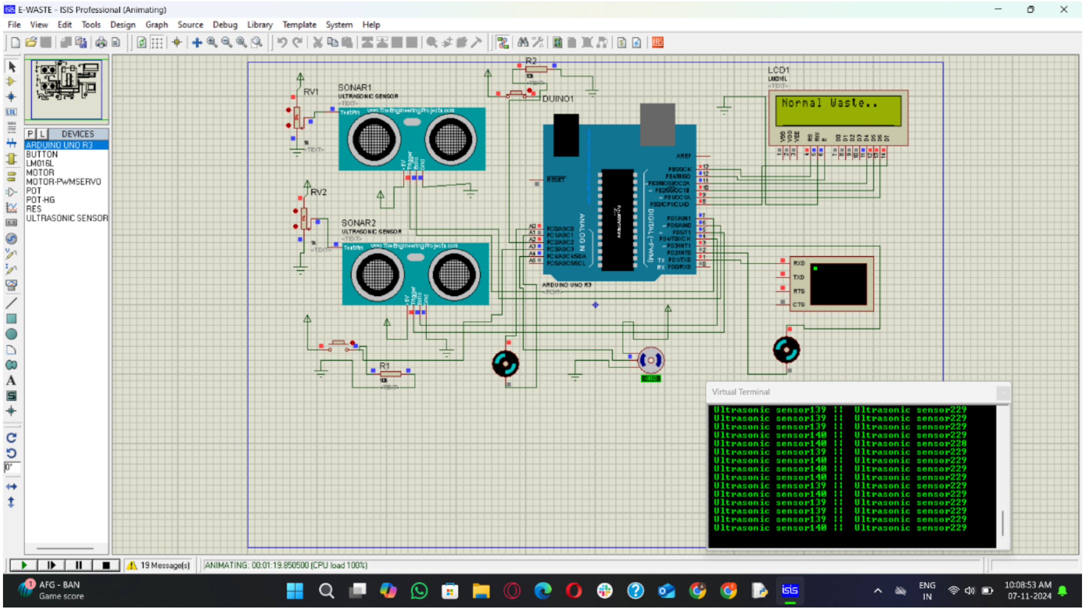

Figure 4.6 Normal Waste

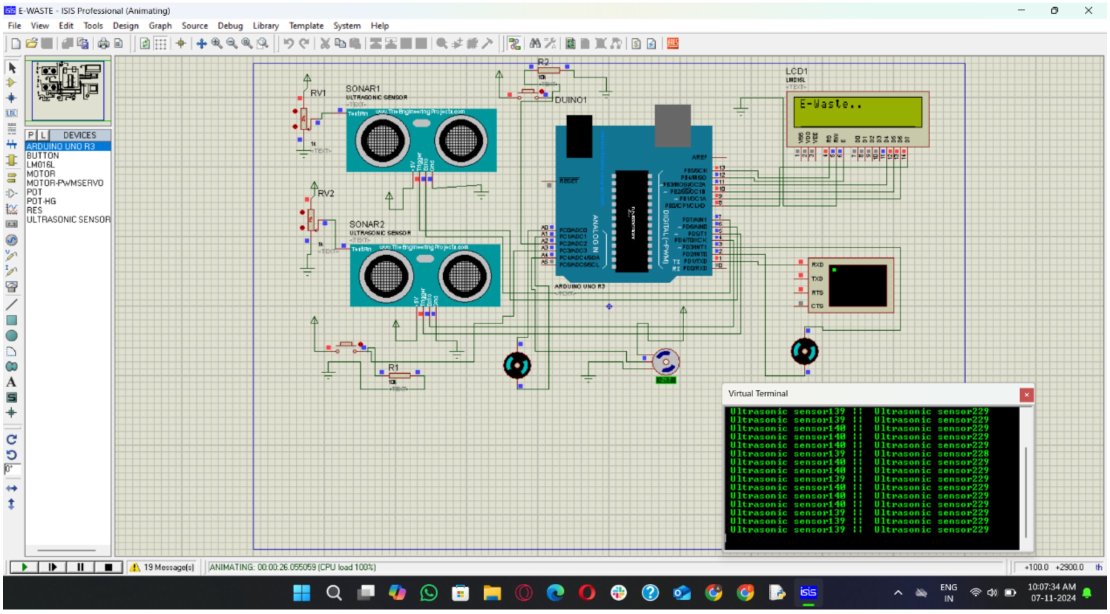

Figure 4.7 E-Waste

Result: The Proteus simulation successfully demonstrated the functionality of the waste detection and classification system. The system activated the appropriate mechanism to direct the waste to the corresponding bin, validating the separation process effectively.

4.2 Hardware Result

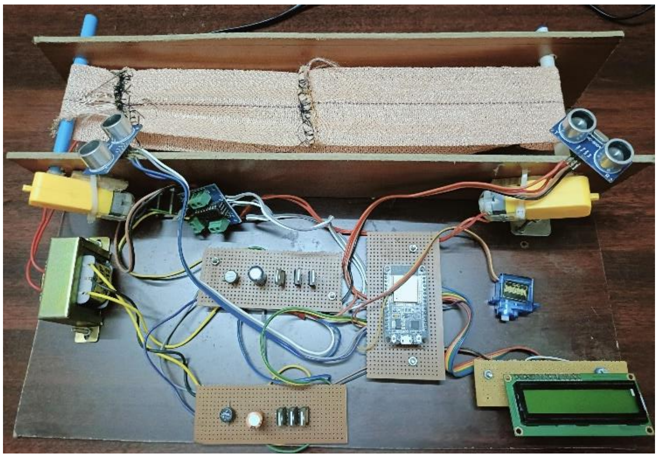

Figure 4.8 Hardware Prototype

Result: The physical prototype effectively demonstrated the real-time classification and segregation of waste into e-waste and normal waste categories. Upon placing an item on the conveyor, the system accurately identified the type of waste using image processing and activated the corresponding servo motor to divert the item into the correct bin. The ultrasonic sensor monitored bin levels and triggered notifications via the Blynk IoT platform when bins reached capacity. This proved that the system works well and can help manage waste automatically.

4.3 Discussion

The project, "Efficient E-Waste Management Using IoT," demonstrates a comprehensive approach to addressing the growing issue of electronic and general waste segregation. By integrating image processing techniques with IoT-enabled hardware, the system provides an automated and intelligent solution for classifying and managing waste. The classification process leverages MATLAB's image processing capabilities, which utilize advanced techniques such as grayscale conversion, boundary extraction, and neural network-based classification. This ensures reliable differentiation between e-waste and normal waste, minimizing errors in waste sorting.

The Arduino IDE was instrumental in programming the ESP-32 microcontroller, which served as the core hardware component. The ESP-32 efficiently handled real-time inputs from sensors, controlled motors for waste redirection, and communicated bin status to the IoT cloud. The use of the Blynk IoT platform added a layer of user interactivity by enabling real-time monitoring and notifications via smartphones. This ensures timely action, such as emptying bins before they overflow, thereby promoting cleaner and more efficient waste management.

While the system performed as expected during testing, certain challenges were encountered. For instance, the reliance on manual image input instead of real-time camera feeds was a limitation that affected the scalability of the system. Additionally, variations in lighting and object placement could potentially affect classification accuracy. These challenges highlight areas for future improvement, such as integrating real-time image acquisition using a camera module and employing advanced pre-trained models for better robustness in classification. The hardware components, including ultrasonic sensors, DC motors, and servo motors, worked seamlessly to implement the mechanical aspects of the project. The conveyor belt system effectively transported waste, and the smart bins with ultrasonic sensors accurately detected fill levels.

Overall, the project successfully demonstrated the feasibility of automating e-waste and normal waste segregation using IoT. The integration of software and hardware elements not only improves efficiency but also paves the way for scaling the solution to industrial-level applications. Future enhancements, such as optimizing image processing algorithms, integrating solar-powered hardware can further improve the system's effectiveness and sustainability.

CHAPTER 5

CONCLUSION

The "Efficient E-Waste Management Using IoT" project combines image processing techniques with IoT-enabled hardware to efficiently classify waste into e-waste and normal waste. The system uses MATLAB-based classification using neural networks for high precision, while an Arduino-controlled ESP-32 microcontroller manages hardware operations. The Blynk platform allows real-time monitoring of bin statuses and alerts users when bins are full, ensuring timely disposal. The use of ultrasonic sensors, motors, and smart bins demonstrates the potential for scalable waste management systems. Despite challenges like manual image input and stable internet connectivity, the project promotes sustainable practices and highlights the potential of technology in tackling environmental challenges. Future upgrades, such as real-time image acquisition and advanced classification algorithms, could further enhance the system's efficiency and suit large-scale industrial adoption.

CHAPTER-6

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The rapid growth of technology and the growing reliance on electronic gadgets have resulted in a large increase in electronic garbage (e-waste). The inclusion of dangerous elements such as lead, mercury, and cadmium makes improper e-waste handling a severe environmental and health risk. Effective e-waste sorting and disposal have become crucial for reducing its environmental impact while also permitting the recovery of valuable materials such as gold, silver, and copper. Traditional methods of e-waste management frequently rely on manual segregation, which is time-consuming, error-prone, and inefficient. This has generated an essential need for an automated, intelligent solution to address the issue.

This project, "Efficient E-Waste Management Using IoT," addresses this issue by creating a system that uses image processing techniques and IoT-enabled hardware to automate the separation of e-waste from regular waste. The system intends to transform waste management operations by enhancing classification accuracy, eliminating manual involvement, and assuring timely waste collection and disposal.

The suggested system combines image analysis for waste identification, a conveyor belt mechanism for physical separation, and IoT monitoring and alerting. Waste images are analyzed and identified using MATLAB's convolutional neural network (CNN), with the training process optimized by the Levenberg-Marquardt algorithm. Servo motors and a conveyor belt guide classified waste to the right bins, ensuring accurate segregation. The hardware solution is built around an ESP-32 microcontroller, which controls sensors and motors and communicates with the cloud-based Blynk IoT platform to notify users when bins are full.

Efficient E-Waste Management Using IOT

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Abstract - Efficient E-Waste Management Using IoT is a project that automates the identification and separation of waste into e-waste and general waste categories using image processing techniques. The system leverages IoT technology to improve waste handling efficiency and address environmental challenges posed by improper e-waste disposal. The implementation involves image analysis in MATLAB, using convolutional neural networks (CNNs) trained with the Levenberg-Marquardt algorithm for waste classification. Based on the results, a conveyor belt system directs the waste to appropriate bins with the help of servo motors. Key hardware components include an ESP-32 microcontroller, ultrasonic sensors, and DC motors. The system also integrates the Blynk IoT platform to notify users when bins are full, ensuring prompt waste collection. This project demonstrated reliable waste classification, effective bin usage, and automated notifications, significantly reducing manual intervention while enhancing waste management efficiency. The system's integration with cloud storage allows for real-time data monitoring, improving operational transparency. Advanced image preprocessing techniques, such as noise reduction and contrast enhancement, further refine classification accuracy. By minimizing human error in waste segregation, the project enhances recycling efficiency, promoting sustainable environmental practices. The project's holistic approach to waste management aligns with global sustainability goals, making it a promising solution for modern waste processing systems.

Keywords - IoT, Image Processing, Convolutional Neural Network (CNN), MATLAB, Blynk Platform, Smart Bin, Waste Classification, Morphological Operations, Neural Network Optimization.

I. Introduction

A. *Overview*

This paper addressing the growing issue of electronic waste (e-waste) has necessitated innovative solutions to ensure proper waste management and recycling. E-waste contains hazardous materials that, if not disposed of responsibly, can harm the environment and human health. Traditional methods of waste segregation are manual, inefficient, and prone to errors, which makes automation a crucial step toward sustainable waste management.

The proposed project, "Efficient E-Waste Management Using IoT," focuses on developing an automated system to classify and separate e-waste from normal waste. The system leverages advanced image processing techniques in MATLAB to analyze and classify waste materials. A convolutional neural network (CNN) is employed to identify waste types based on predefined characteristics. Once classified, the system uses a conveyor belt mechanism controlled by an ESP-32 microcontroller to direct waste to appropriate bins. IoT technology is integrated via the Blynk platform to monitor the status of bins in real-time and notify users when bins are full.

The hardware implementation includes ultrasonic sensors to detect bin levels, servo motors to guide waste into designated bins, and an LCD display to provide system status updates. This comprehensive approach not only improves the efficiency of waste management but also minimizes human intervention. The system's modular design makes it scalable and suitable for both domestic and industrial applications, ensuring its adaptability to various waste management scenarios. By integrating image processing, IoT, and hardware automation, this project addresses the limitations of existing waste management systems and provides a sustainable, efficient solution. The system promotes environmental protection by facilitating proper e-waste recycling and disposal, thereby contributing to a cleaner and healthier planet.

B. *History*

This journal provides a comprehensive overview of recent advancements in the concept of automated waste management systems emerged with the advent of sensor-based technologies and machine learning. Early methods focused on the use of inductive and capacitive sensors to identify metallic and non-metallic materials. These systems, while innovative, were limited in their ability to handle complex waste types, such as e-waste, which often contains a mix of materials.

With advancements in technology, image processing and machine learning algorithms have become instrumental in

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To: ASHWIN M <ashwin.82104008@sritcbe.ac.in>

Dear **M. Ashwin, G. Yogiraj, S. Srihari**

Greetings from the NCEE 2025 Organizing Team – SRIT

Thank you for submitting your paper to our conference. We are pleased to inform you that your paper titled **" EFFICIENT E-WASTE MANAGEMENT USING IOT"** has been **accepted** based on our eligibility and review criteria. We acknowledge your participation in the conference and look forward to your presence at the conference.

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We look forward to your participation in NCEE 2025!

Best regards,

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NCEE 2025 Organizing Team
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