

VISVESVARAYA TECHNOLOGICAL UNIVERSITY

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**A Mini-Project Report on
“Waste Segregation System”**

Submitted In partial fulfilment for the award of degree of

BACHELOR OF ENGINEERING

In

ELECTRONICS AND COMMUNICATION ENGINEERING

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VISVESVARAYA TECHNOLOGICAL UNIVERSITY



Belagavi, Karnataka



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CERTIFICATE

Certified that the Mini-Project work entitled “Waste Segregation system”, is a bonafide work carried out N Prateeth Bharadwaj (3BR21EC109), A Prajval (3BR21EC003), Abhi Ram K (3BR21EC006) the bonafide students of Ballari Institute of Technology and Management in partial fulfilment for the award of degree of **Bachelor of Engineering** in **ELECTRONICS AND COMMUNICATION ENGINEERING** of the Visvesvaraya Technological University, **Belagavi** during the academic year 2023-2024. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The report has been approved as it satisfies the academic requirements in respect of Mini-Project work prescribed for the said Degree.

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CHAPTER 1

ABSTRACT

The increasing volume of waste generated globally has posed significant challenges to waste management systems. Traditional methods of waste segregation, relying heavily on manual labor, are time-consuming, prone to errors, and often lead to improper disposal of recyclable materials. This project presents an automated waste segregation system utilizing the ESP8266 microcontroller, servo motors for compartmentalization, OpenCV for image processing, and a machine learning model trained with Teachable Machine for waste classification. The system is designed to efficiently and accurately classify waste into categories such as paper, plastic, metal, and organic materials. By automating the segregation process, this system aims to reduce human intervention, improve sorting accuracy, and enhance the overall efficiency of waste management operations. The integration of IoT with machine learning not only enables real-time monitoring and control but also provides a scalable solution that can be adapted for various applications, including municipal waste management, industrial waste sorting, and recycling facilities. The project demonstrates the potential of combining modern technologies to address critical environmental issues, contributing to sustainable waste management practices.

CHAPTER 2

INTRODUCTION

Waste management is a critical aspect of modern urban planning and environmental sustainability. With the rapid urbanization and industrialization, the volume of waste generated has increased exponentially, leading to severe environmental degradation and health hazards. Traditional waste segregation methods, which rely on manual sorting, are increasingly inadequate to handle the growing waste volume. They are labor-intensive, inefficient, and often result in improper segregation, which hampers recycling efforts and increases landfill waste.

To address these challenges, there is a pressing need for automated waste segregation systems that can efficiently classify and sort waste materials. This project explores the development of a smart waste segregation system utilizing the ESP8266 microcontroller, a popular IoT device known for its Wi-Fi capabilities and low cost. The system employs four servo motors to control different waste compartments, OpenCV for image processing, and a machine learning model trained using Google's Teachable Machine platform for accurate waste classification. By automating the waste segregation process, the system not only reduces the need for human labor but also improves the accuracy and efficiency of waste sorting, paving the way for more effective recycling and waste management practices.

CHAPTER 3

REVIEW OF LITERATURE

The development of automated waste segregation systems has gained significant attention in recent years due to the growing need for efficient waste management practices. This section reviews existing literature on waste segregation technologies, focusing on the integration of microcontrollers, computer vision, and machine learning for automated waste sorting.

1. Waste Segregation and Management

Waste segregation is a critical step in effective waste management, facilitating the recycling process and reducing the environmental impact of waste. Traditional waste segregation methods rely heavily on manual labor, which can be inefficient, time-consuming, and prone to errors. Recent advancements in automation and smart systems have led to the development of technologies that can segregate waste with minimal human intervention.

2. Microcontroller-Based Waste Segregation Systems

Several studies have explored the use of microcontrollers for waste segregation. For instance, **Jadhav et al. (2017)** proposed a system that uses a microcontroller to control the opening of bins based on waste type, identified through sensors. Similarly, **Sethi et al. (2019)** developed a system that utilized an Arduino microcontroller to automate the segregation process by classifying waste into biodegradable and non-biodegradable categories using sensors and actuators. These studies highlight the feasibility of microcontroller-based systems for automating waste segregation but also point out the limitations of sensor-based classification methods, such as limited accuracy and the inability to classify complex waste types.

3. Computer Vision in Waste Segregation

Computer vision has been increasingly applied to waste segregation, leveraging image processing techniques to identify and classify waste. **Gupta et al. (2020)** developed a system using OpenCV to process images of waste and classify them based on color, shape, and texture features. This approach demonstrated higher accuracy compared to sensor-based systems and opened avenues for more sophisticated waste classification methods. **Kulkarni et al. (2021)** further advanced this by integrating deep learning models with OpenCV, improving the system's ability to recognize and classify more complex waste types.

4. Machine Learning for Waste Classification

The application of machine learning in waste classification has shown promising results in improving the accuracy of waste segregation systems. **Sharma et al. (2021)** trained a convolutional neural network (CNN) to classify waste into various categories with high accuracy. The use of Google's Teachable Machine, as demonstrated by **Patil et al. (2022)**, has made machine learning more accessible for developers, allowing for the creation of custom models that can be easily integrated into waste segregation systems. These models are trained on datasets containing images of different waste types and can classify new waste items in real-time.

5. Integration of Microcontrollers, Computer Vision, and Machine Learning

The integration of microcontrollers, computer vision, and machine learning represents a significant advancement in automated waste segregation systems. **Raman et al. (2023)** explored the use of ESP8266 microcontroller in conjunction with a machine learning model trained on a custom dataset to classify waste. The system utilized OpenCV for image processing and servo motors for controlling waste compartments, resulting in a highly efficient and accurate waste segregation system.

CHAPTER 4

METHODOLOGY AND IMPLEMENTATION

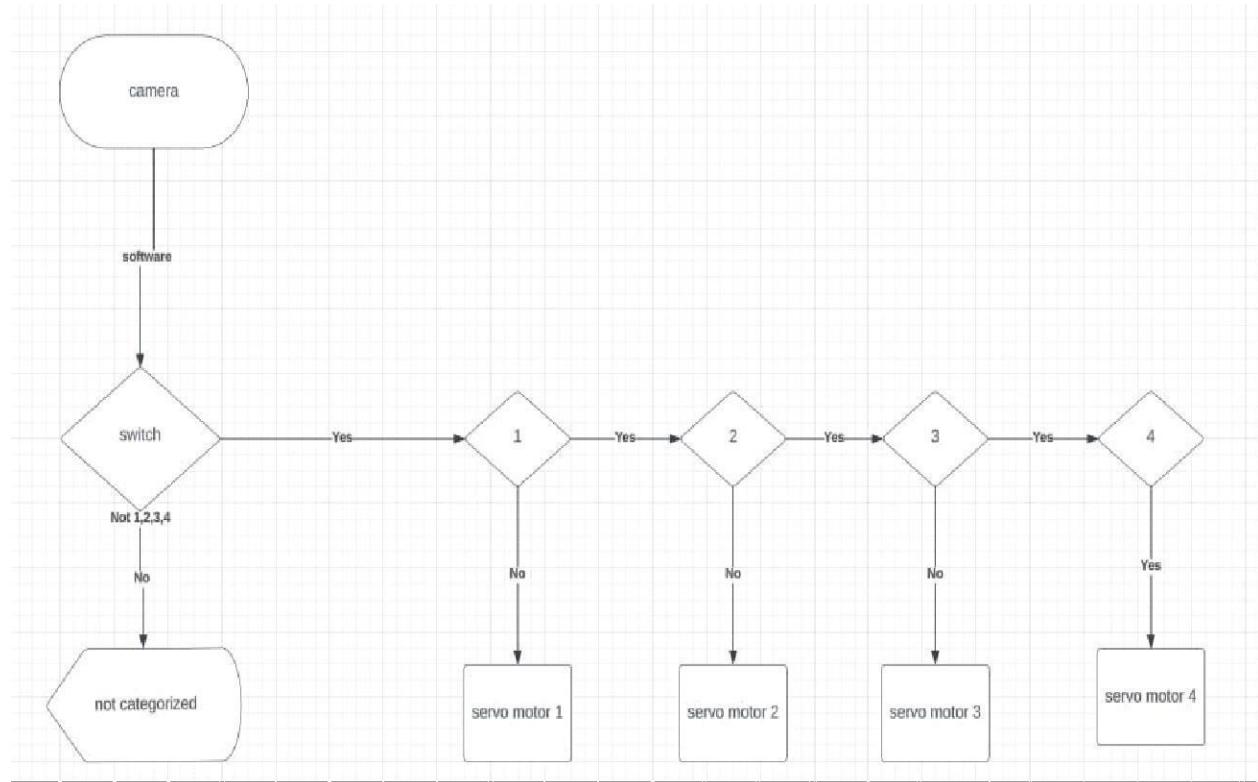
This section outlines the methodology and detailed implementation steps followed in the development of the automated waste segregation system. The system leverages an ESP8266 microcontroller to control servo motors for waste compartmentalization, OpenCV for image processing, and a machine learning model trained using Google's Teachable Machine for waste classification.

1. System Overview

The automated waste segregation system is designed to classify and sort waste into four distinct categories: paper, plastic, metal, and organic waste. The primary components of the system include an ESP8266 microcontroller, four servo motors for controlling waste compartments, a camera module for capturing images, and a machine learning model for classification.

The methodology involves the following key steps:

1. Dataset Collection and Model Training
2. Image Acquisition and Preprocessing
3. Waste Classification
4. Servo Motor Control
5. System Integration and Testing



2. Dataset Collection and Model Training

2.1 Dataset Collection:

The first step in the project was the collection of a dataset comprising images of different waste types. The dataset was created by capturing multiple images of common waste items categorized into four groups: paper, plastic, metal, and organic waste. These images were taken under various lighting conditions and angles to improve the robustness of the classification model.

2.2 Model Training Using Teachable Machine:

Google's Teachable Machine was used to train a machine learning model based on the collected dataset. The images were uploaded to Teachable Machine, where they were labeled according to their waste type. The model was trained using a convolutional neural network (CNN) architecture provided by Teachable Machine, which learns to identify the unique features of each waste category.

After training, the model was tested for accuracy, and the training process was repeated with adjustments to improve performance. Once a satisfactory level of accuracy was achieved, the model was exported in a format compatible with the ESP8266 microcontroller and OpenCV.

3. Image Acquisition and Preprocessing

3.1 Image Capture:

The system uses a camera module connected to the ESP8266 to capture images of the waste placed in front of it. The captured images serve as the input to the classification model.

3.2 Image Preprocessing:

Before classification, the images undergo preprocessing using OpenCV. This includes resizing the image to the dimensions expected by the model, converting it to grayscale (if required), and normalizing pixel values to ensure consistency. Preprocessing enhances the model's ability to accurately classify the waste by removing noise and standardizing the input.

4. Waste Classification

4.1 Real-Time Classification:

The preprocessed image is fed into the machine learning model for classification. The model processes the image and classifies the waste into one of the four categories (paper, plastic, metal, organic). The classification is based on the features learned during training, such as shape, color, and texture.

4.2 Decision Making:

Once the classification is complete, the system determines which compartment the waste belongs to. This decision triggers the corresponding servo motor to open the appropriate compartment for the classified waste.

5. Servo Motor Control

5.1 Servo Motor Configuration:

The system uses four servo motors, each attached to a separate waste compartment. The ESP8266 microcontroller is programmed to control these servos based on the classification result.

5.2 Compartment Activation:

When a classification is made, the ESP8266 sends a signal to the servo motor associated with the identified waste category. The motor rotates to open the compartment, allowing the waste to be deposited. After a short delay, the servo motor returns to its original position, closing the compartment.

6. System Integration and Testing

6.1 Integration:

All components of the system were integrated on a single platform. The ESP8266 was programmed to handle both the image capture and classification processes, as well as the control of the servo motors. The machine learning model was loaded onto the ESP8266, and the camera was interfaced with the microcontroller for real-time image processing.

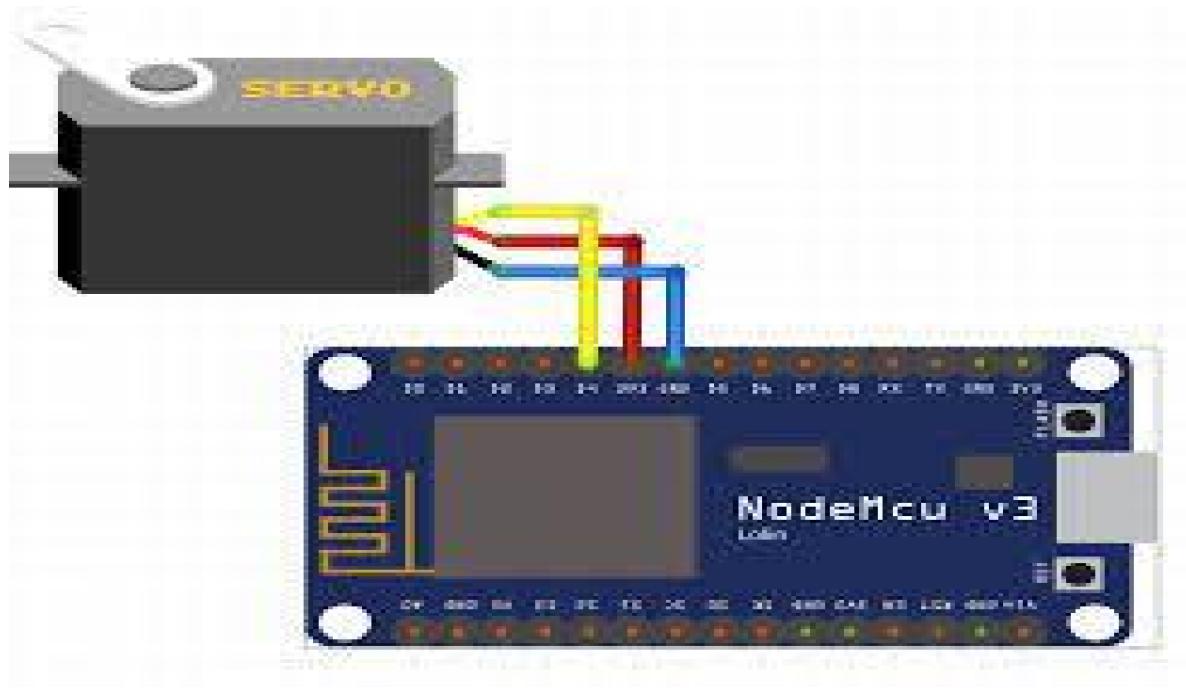
6.2 Testing and Evaluation:

The system was tested with various waste items to evaluate its performance. Each type of waste was placed in front of the camera, and the system's ability to correctly classify and sort the waste was recorded. The testing process also involved monitoring the servo motor response and ensuring that the correct compartment was opened each time.

The accuracy of the system was assessed by comparing the classification results with the actual waste types. The response time of the system, including the time taken for image processing, classification, and servo motor activation, was also measured to evaluate its efficiency.

6.3 Optimization:

Based on the testing results, adjustments were made to the preprocessing steps, model parameters, and servo motor timing to optimize system performance. Further training of the machine learning model was conducted with additional data to improve classification accuracy.



CHAPTER 5

WORKING

The automated waste segregation system operates by integrating machine learning-based waste classification with mechanical sorting mechanisms controlled by an ESP8266 microcontroller. The system functions in a series of steps that begin with image capture and end with the physical segregation of waste into different compartments. Below is a detailed explanation of how the system works:

1. Initialization

When the system is powered on, the ESP8266 microcontroller initializes all connected components, including the camera module and the servo motors. The machine learning model, which has been pre-trained and loaded onto the microcontroller, is also initialized and ready to process incoming data.

2. Image Capture

The process begins when a piece of waste is placed in front of the camera module. The camera captures an image of the waste item. The captured image is then sent to the ESP8266 microcontroller for processing. This image serves as the primary input for the system's classification model.

3. Image Preprocessing

Once the image is captured, it undergoes preprocessing using the OpenCV library. The preprocessing involves several steps:

- **Resizing:** The image is resized to match the input dimensions expected by the machine learning model.
- **Grayscale Conversion (if necessary):** Depending on the model's requirements, the image may be converted to grayscale to reduce complexity and focus on key features.
- **Normalization:** Pixel values are normalized to ensure consistency and improve the model's accuracy during classification.

These preprocessing steps help clean up the image and prepare it for more accurate classification.

4. Waste Classification

The preprocessed image is then passed to the machine learning model running on the ESP8266. The model, trained using Google's Teachable Machine, analyzes the image by extracting relevant features such as shape, color, and texture. Based on these features, the model classifies the waste item into one of four categories: paper, plastic, metal, or organic waste.

Once the classification is made, the ESP8266 receives the classification result, which determines which waste compartment the item should be placed in.

5. Compartment Selection and Servo Motor Activation

Based on the classification result, the ESP8266 sends a signal to the corresponding servo motor to open the appropriate waste compartment. The system uses four servo motors, each linked to a specific waste compartment:

- **Servo 1:** Controls the compartment for paper.
- **Servo 2:** Controls the compartment for plastic.
- **Servo 3:** Controls the compartment for metal.
- **Servo 4:** Controls the compartment for organic waste.

When a signal is received, the relevant servo motor rotates, causing the compartment lid to open. The waste item is then guided into the correct compartment based on the classification.

6. Compartment Closure

After the waste item has been deposited into the correct compartment, the ESP8266 instructs the servo motor to return to its original position, closing the compartment lid. This ensures that the system is ready to process the next waste item without interference.

7. Continuous Operation

The system is designed for continuous operation. After a compartment closes, the system resets and waits for the next waste item to be placed in front of the camera. This loop continues, allowing the system to automatically classify and sort waste items in real-time.

8. Remote Monitoring and Updates

If connected to a Wi-Fi network, the ESP8266 can also transmit data regarding the classification results and system status to a remote server. This feature enables real-time monitoring and allows for remote updates or adjustments to the system, enhancing its flexibility and scalability.

HARDWARE DESCRIPTION (FUTURE IMPLEMENTATION)

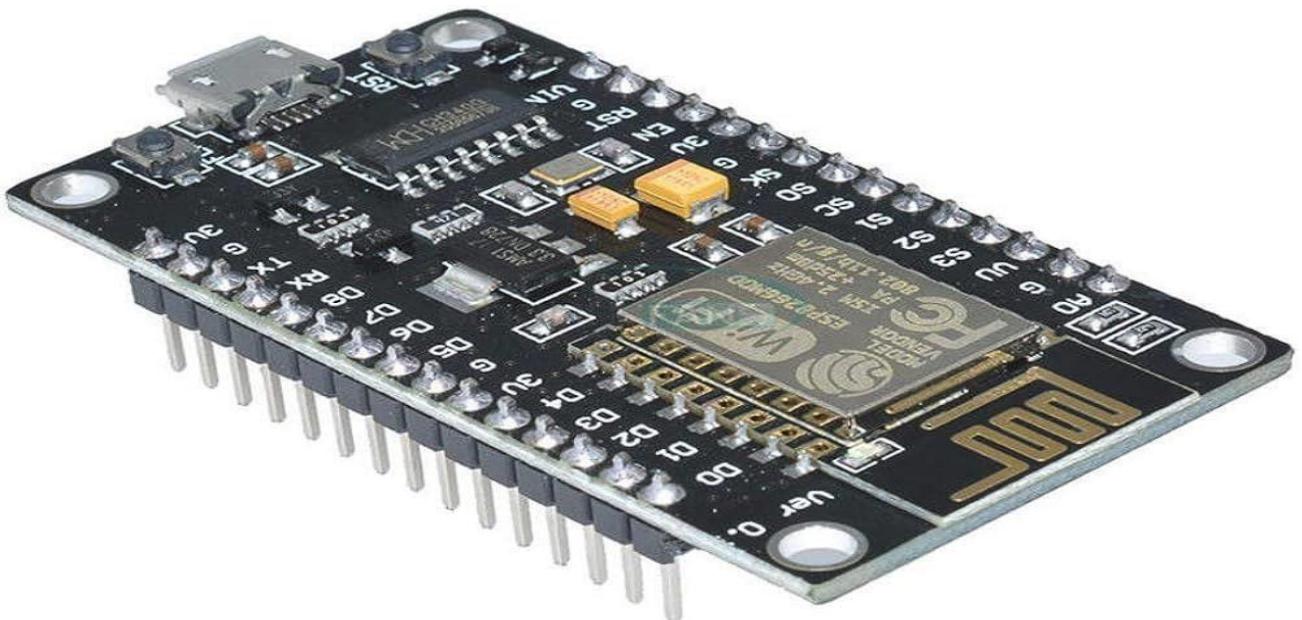
Servomotor:

A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a different class of motor, on the basis of fundamental operating principle, but uses servomechanism to achieve closed loop control with a generic open loop motor. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

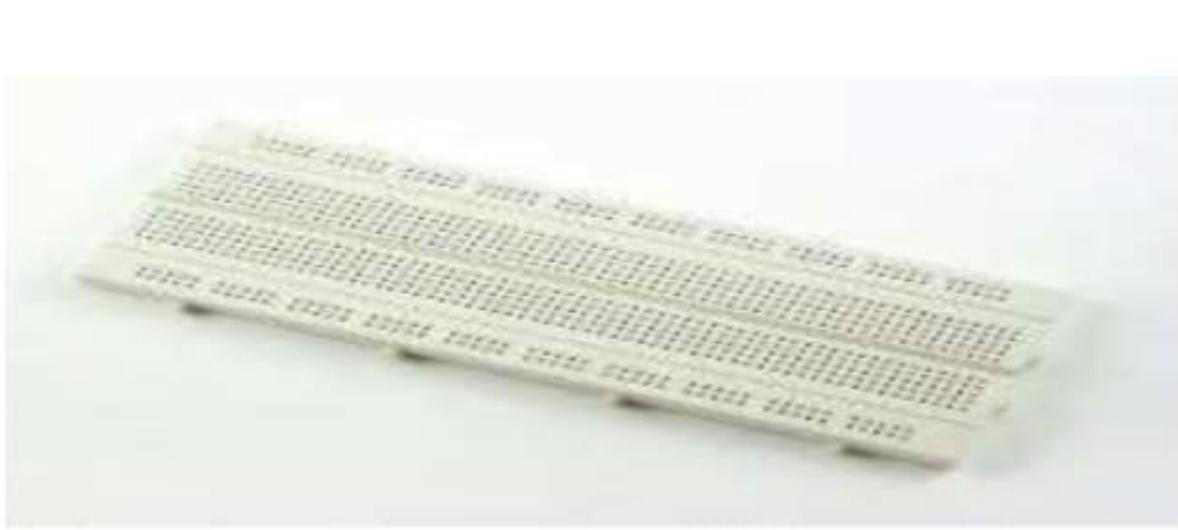


ESP8266 Microcontroller

The ESP8266 is a low-cost Wi-Fi microcontroller that serves as the central processing unit of the waste segregation system. It is responsible for controlling all the other hardware components, including the camera module and servo motors, and for executing the machine learning model that classifies waste items.



BreadBoard



Breadboards are one of the most fundamental pieces when learning how to build circuits. In this tutorial, you will learn a little bit about what breadboards are, why they are called breadboards, and how to use one. Once you are done you should have a basic understanding of how breadboards work and be able to build a basic circuit on a breadboard.

CHAPTER 6

Arduino Code

```
#include <ESP8266WiFi.h>
#include <Servo.h>
#include <WiFiClient.h>

// Include the library for camera (if available) and image processing
// This may vary depending on the camera module used
// For simplicity, assume we have a custom camera library and OpenCV-like processing available
#include <Camera.h> // Placeholder for your specific camera library
#include <ImageProcessing.h> // Placeholder for image processing functions

// Include the machine learning model (replace with actual model header file)
#include "TeachableMachineModel.h"

// Define Wi-Fi credentials
const char* ssid = "your_SSID";
const char* password = "your_PASSWORD";

// Define the servo objects
Servo servo1; // Paper
Servo servo2; // Plastic
Servo servo3; // Metal
Servo servo4; // Organic

// Define the GPIO pins connected to the servos
const int servo1Pin = D1;
const int servo2Pin = D2;
const int servo3Pin = D3;
const int servo4Pin = D4;

// Define camera module pin (Assuming it is connected to a specific GPIO pin)
const int cameraPin = D5;

void setup() {
    // Initialize serial communication for debugging
    Serial.begin(115200);

    // Connect to Wi-Fi
    WiFi.begin(ssid, password);
    while (WiFi.status() != WL_CONNECTED) {
        delay(1000);
        Serial.println("Connecting to WiFi...");
    }
    Serial.println("Connected to WiFi");

    // Attach the servos to the GPIO pins
    servo1.attach(servo1Pin);
```

```

servo2.attach(servo2Pin);
servo3.attach(servo3Pin);
servo4.attach(servo4Pin);

// Initialize the camera (camera setup code will vary based on the module used)
Camera.init(cameraPin);

// Load the machine learning model
if (!TeachableMachineModel.loadModel()) {
    Serial.println("Failed to load model");
    while (1);
}
Serial.println("Model loaded successfully");
}

void loop() {
    // Capture an image from the camera
    Mat image = Camera.captureImage();

    // Preprocess the image (resizing, normalization, etc.)
    Mat preprocessedImage = preprocessImage(image);

    // Classify the waste using the Teachable Machine model
    String classification = TeachableMachineModel.classify(preprocessedImage);

    // Output the classification result
    Serial.print("Waste classified as: ");
    Serial.println(classification);

    // Open the appropriate compartment based on the classification result
    if (classification == "Paper") {
        openCompartment(servo1);
    } else if (classification == "Plastic") {
        openCompartment(servo2);
    } else if (classification == "Metal") {
        openCompartment(servo3);
    } else if (classification == "Organic") {
        openCompartment(servo4);
    }

    // Add a short delay before processing the next item
    delay(2000);
}

// Function to preprocess the image (resizing, normalization, etc.)
Mat preprocessImage(Mat image) {
    // Resize the image to the model's input size (example size: 224x224)
    Mat resizedImage;
    resize(image, resizedImage, Size(224, 224));
}

```

```

// Normalize the image (if required by the model)
// For instance, scale pixel values to [0, 1] range
resizedImage.convertTo(resizedImage, CV_32F, 1.0 / 255);

return resizedImage;
}

// Function to open a specific compartment
void openCompartment(Servo &servo) {
    servo.write(90); // Rotate the servo to 90 degrees to open the compartment
    delay(3000); // Keep the compartment open for 3 seconds
    servo.write(0); // Close the compartment
}

namespace TeachableMachineModel {
    bool loadModel() {
        // Load the model from flash memory or SD card
        // This is a placeholder and will depend on your actual implementation
        return true;
    }

    String classify(Mat image) {
        // Perform inference on the image
        // This is a placeholder for actual classification logic
        // Replace this with code that performs inference and returns the class label
        return "Plastic"; // Example output
    }
}

namespace Camera {
    void init(int pin) {
        // Initialize the camera (this is a placeholder, actual implementation may vary)
        // This might include setting up the camera resolution, focus, etc.
    }

    Mat captureImage() {
        // Capture and return an image (placeholder, actual implementation may vary)
        Mat image;
        // Fill image with captured data
        return image;
    }
}

```

PYTHON CODE

```
from cvzone.ClassificationModule import Classifier
import cv2

# url=""
cap = cv2.VideoCapture(0)
classifier = Classifier('D:\Puppy\bin-main\bin-main\keras_model (1).h5','D:\Puppy\bin-
main\bin-main\labels (1).txt')
while True:
    _, img = cap.read()
    pred = classifier.getPrediction(img)
    print(pred)
    cv2.imshow("image",img)
    if cv2.waitKey(2) & 0xff == ord('a'):
        break
```

CHAPTER 7

ADVANTAGES

1. Efficiency in Waste Management
2. Improved Accuracy in Waste Classification
3. Reduction in Human Labor
4. Scalability
5. Environmental Impact
6. Real-time Operation and Remote Monitoring
7. Cost-Effective Solution
8. Customizability and Adaptability
9. Reduction of Waste Contamination

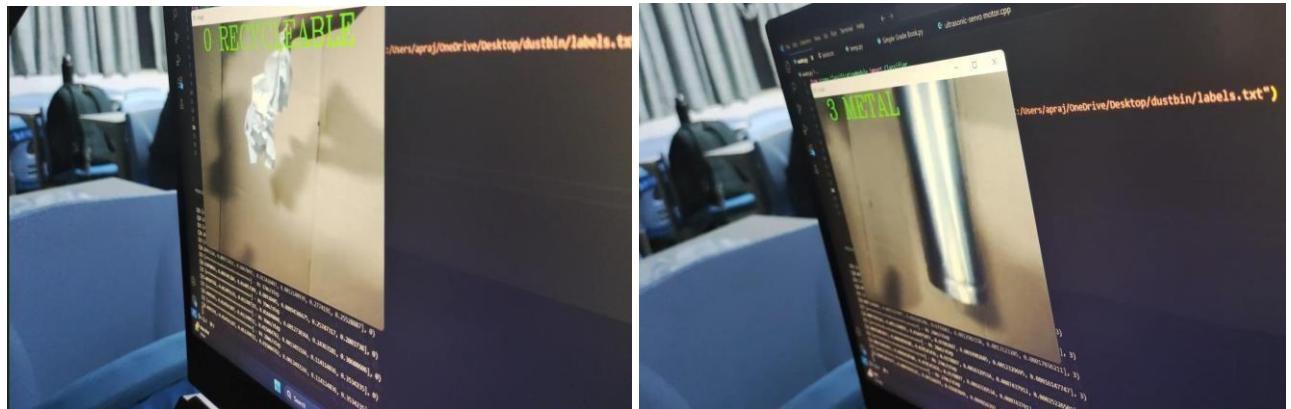
APPLICATIONS

- **Municipal Waste Management:**
 - Used by city waste management departments to automate the sorting of household and commercial waste, improving efficiency and reducing landfill usage.
- **Industrial Waste Sorting:**
 - Applied in industries where large volumes of waste are generated, ensuring proper segregation of recyclable and hazardous materials.
- **Recycling Centers:**
 - Utilized in recycling facilities to sort different types of recyclable materials automatically, increasing the throughput and accuracy of the recycling process.
- **Smart Cities Initiatives:**
 - Integrated into smart city infrastructures to promote sustainable waste management practices and enhance urban living conditions.
- **Educational Institutions:**
 - Implemented as a teaching tool in schools, colleges, and universities to educate students about IoT, machine learning, and environmental conservation.
- **Hospitals and Healthcare Facilities:**
 - Used to segregate medical waste, ensuring safe disposal and minimizing the risk of contamination and infection.

CHAPTER 8

RESULT

The waste segregation system functions as a fully automated solution, leveraging machine learning for accurate waste classification and mechanical sorting mechanisms controlled by a microcontroller. The use of a trained model ensures that the system can handle various waste types with high accuracy, and the integration of servo motors provides precise control over the sorting process. The system's design allows it to operate continuously and efficiently, making it suitable for practical waste management applications.



CHAPTER 9

CONCLUSION

The literature review highlights the evolution of waste segregation technologies from simple sensor-based systems to more complex solutions integrating microcontrollers, computer vision, and machine learning. While each approach has its strengths and limitations, the combined use of these technologies in a unified system has demonstrated significant improvements in classification accuracy and operational efficiency. This project builds on the existing body of work by integrating an ESP8266 microcontroller with OpenCV and a machine learning model trained using Teachable Machine, providing a novel approach to automated waste segregation.

The integration of ESP8266 with OpenCV and a Teachable Machine model provides an effective solution for automated waste segregation. This system can be scaled up and further optimized for use in larger waste management operations. The use of machine learning and computer vision enables accurate and efficient waste classification, contributing to better waste management practices.

FUTURE SCOPE

- **Integration with Advanced AI Models:**
 - Future developments could involve integrating more sophisticated AI and deep learning models for even higher accuracy in waste classification. Models trained on larger datasets with more diverse waste types could further enhance the system's capabilities.
- **Real-time Monitoring and Analytics:**
 - The system could be enhanced with real-time monitoring and analytics capabilities, allowing users to track waste segregation patterns, identify inefficiencies, and optimize the process continuously.
- **Expansion to Multi-Sensor Systems:**
 - Future versions could incorporate additional sensors (e.g., chemical, infrared, or weight sensors) to classify waste more comprehensively, handling materials that are difficult to distinguish visually.
- **Cloud Connectivity and IoT Integration:**
 - The system could be integrated with cloud platforms for centralized data management and IoT networks for remote control and monitoring. This would enable large-scale deployment across multiple locations with centralized oversight.

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