"AUTOMATED WASTE SEGREGATION SYSTEM"

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CERTIFICATE

This is to certify that the project work entitled "**Automated Waste Segregation System**" is a work carried out by **Ms. Anagha Ravishankar (4NI17CS011)**, **Mr. Manas Sharma (4NI17CS034), Ms. R K Chitra (4NI17CS062)** and **Ms. Anvita Murthy (4NI17CS126)** in fulfillment for the project work eighth semester, Computer Science & Engineering, The National Institute of Engineering **(**Autonomous Institution under Visvesvaraya Technological University, Belagavi) during the academic year 2020-2021. It is certified that all corrections and suggestions indicated for the Internal Assessment have been incorporated in the report deposited in the department library. The project work report has been approved in fulfillment as per academic regulations of The National Institute of Engineering, Mysuru.

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ABSTRACT

The key to efficient waste management is to ensure segregation of waste and resource recovery. Waste is usually segregated on the basis of whether it is biodegradable or nonbiodegradable. A major challenge with respect to this is that the waste is not segregated and is thrown into dustbins nonetheless. These end up as huge piles of waste in dump yards, which need to be segregated.

Waste segregation is currently being done manually by the municipal corporation. This results in the unsanitary working conditions for the people who need to perform this task. Despite being provided with the necessary equipment, they run the risk of catching infections from the waste they work with. Automation of this process will be beneficial for the people who work on this, by reducing health hazards.

CHAPTER 1

INTRODUCTION

Machine Learning and Image Classification are technologies that have become very popular in recent times. They have a wide range of applications and are used by major corporate like Google, Amazon, Facebook etc. Machine Learning deals with systems being able to learn from past data. Image Classification refers to identifying which class an object in an image belongs to. Facebook uses image classification to identify people in the images uploaded and tag them based on previous tags.

Recycling is a very important phenomenon in a healthy and green environment. Waste segregation is one of the primary challenges to recycling systems in major cities in our country. In India, 62 million tons of garbage is generated annually. Of these 5.6 million tons of wastes consists of plastic materials. About 60 percent of this is recycled every year. In addition, 11.9 million tons are recycled from 43 million tons of solid waste produced. Though the numbers sound good, a serious problem in the recycling industry is the segregation of waste before recycling or any other waste treatment processes. In India, at present situation waste is not segregated when collected from households. So, a lot of workforce and effort are needed to separate this waste. In addition to this people working in this industry are prone to various infections caused due to toxic materials present in the waste. So, the idea is to decrease the human intervention and make this waste segregation process more productive. The proposed work is aimed to build an image classifier that identifies the object and detects the type of waste material using Convolution Neural Network.

With the rise in pollution levels, segregating waste by classifying it as biodegradable and non-biodegradable is a solution to control pollution. Biodegradable waste refers to the waste that can be decomposed by bacteria and other living organisms. This type of waste can be recycled or used for composting purposes. Non-biodegradable waste refers to the waste that cannot be decomposed like plastic and will remain stagnant to cause more harm to the environment if not treated properly. Therefore, this project aims at building a system that is able to automatically identify and classify wastes to decomposable categories. This is more efficient and faster than manually sorting the waste and classifying them, owing to the colossal amount of waste that is generated on a daily basis. The waste is transported from the bins all over the city to the dump yards, where they are segregated and treated accordingly. Automating this process of segregation provides an edge over doing the same manually as it is much faster and more efficient.

1.1 Machine Learning:

Machine Learning is a branch of computer science that makes it possible for machines to learn from data without being explicitly programmed. Machines can learn to draw conclusions from data, automatically learn to recognize complex patterns and make decisions based on this data.

Common Terminologies:

- **Model/Hypothesis:**

  This is a representation based on the rule learned by the algorithm from the data.
- **Feature:**

  These are individual properties used to make predictions. For predicting the price of a house, features could include number of rooms, area of the house etc. where each of these are features.
- **Target/Label:**

  Target is the variable that has to be predicted. While predicting the price of a house, the target will be price.
- **Training:**

  Training is the process of giving a set of input data along with its corresponding outputs such that the system is able to develop a model which can predict the output for unseen data with a certain level of accuracy.
- **Prediction:**

  After training, the model can now predict the output for previously unseen data.

Classification of Machine Learning Problems:

Machine Learning problems can be classified in several ways. The standard ones include classification on the basis of the **nature of learning of the system** and on the basis of **output produced by the system**.

- **Nature of Learning of the System**:

  There are 2 categories under this type of classification: **Supervised Learning** and **Unsupervised Learning**.

  - **Supervised Learning:** In supervised learning, some sample inputs along with their corresponding outputs are fed into the system and the system is expected to learn a rule that is able to map these inputs onto their corresponding outputs. This process is called training and the accuracy of a system's prediction is known during the testing process. In testing, the system will be given previously unseen data and is expected to predict the output based on the rule developed / learnt by it.

    Examples of supervised learning include Image Classification, Market Prediction, Regression.

  - **Unsupervised Learning:** In unsupervised learning, no labels are given and the algorithm is is expected to identify some patterns in the given data.

    Examples: Clustering, High Dimensional Visualization, Generative Models.

  - **Semi-supervised Learning:** In semi-supervised learning, there is a large amount of input data in which some of them have labels and the rest don't.

  - **Reinforcement Learning:** In reinforcement learning, the algorithm interacts with the environment which is dynamic in nature and takes decisions. In the absence of data, it takes decisions based on experience and is given feedback in terms of either punishments or rewards.

- **Output given by system:**

  - **Classification:** The input data is divided into a number of classes and the algorithm is expected to assign class labels to unseen data.

- **Regression:** In regression, the outputs are continuous and not discrete.

- **Clustering:** In clustering, the given set of inputs is divided into groups. Unlike in classification, the labels and groups aren't known beforehand.

- **Density Estimation:** The task is to find the distribution of inputs in some space.

- **Dimensionality Reduction:** In dimensionality reduction, the inputs are simplified by mapping them onto lower-dimensional space.

1.2 Object Analysis:

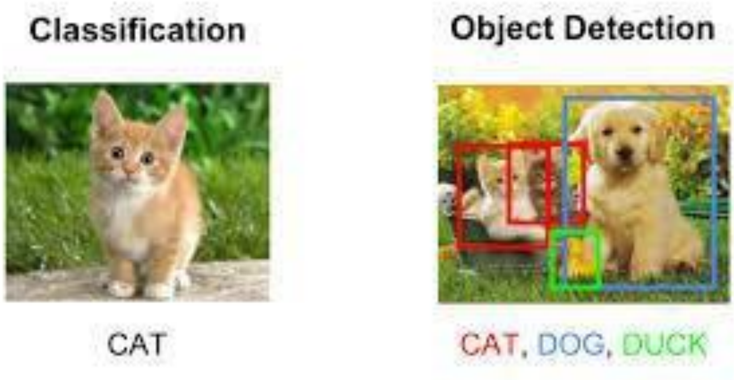
Object Analysis deals with the recognition of objects followed by its classification.

- **Object Detection:**

  Object Detection is a technique by which the algorithm can identify and locate interesting objects in an image. It is a subset of computer vision. Object Detection can thus be used to detect the waste material loaded on the conveyor belt that is captured by the camera.

- **Object Classification:**

  Object Classification deals with classifying the objects detected by the system into predefined classes. The training process for this could include feeding the system with images along with their labels (example: feeding pictures of dogs, cats and other domesticated animals to a system along with labels for each). The system is then given unseen data or previously unseen images and is expected to predict the label or class the object in the image belongs to. The training process can be continued until the system is able to predict satisfactorily. The input fed to the system could be an image or photograph. The output produced by the system could be a class label identifying the class, the object identified by the algorithm belongs to.



Thus, object classification can be used to classify the waste material previously detected as either biodegradable or non-biodegradable by the system.

1.3 Automation:

The amount of waste collected is usually colossal. Making a human monitor the system to run the program for every waste material to detect and classify it would be both tedious and cumbersome. Automating the system such that it has minimum to no human intervention would be ideal. This automation can be achieved such that the algorithm can run continuously and whenever an object is detected, it can be classified accordingly. Automating the process will make the system more efficient, faster and also reduces human intervention.

1.4 Conclusion:

The process of waste segregation after collection is crucial in controlling the pollution. Making this process manual could be time consuming and extremely cumbersome. Automating this process can help efficiently segregate waste using machine learning methods like object detection to detect waste material and object classification to determine if the waste material is biodegradable or non-biodegradable.

CHAPTER 2

LITERATURE SURVEY

[1] **Electronically assisted automatic waste segregation**

Domestic waste disposal is a huge concern these days due to increasing urbanization and increase in the generation of various kinds of wastes. Without proper management and disposal techniques the chemicals and plastic contents dumped is increasing and they do not perish unless treated properly. The treatment of waste includes various processes starting with timely collection and segregation of wastes that are biodegradable and non-biodegradable. Human intervention has been the popular and widely used way of segregation putting health and hygiene at stake. Hence treatment of waste by artificial means would be one of the solutions. A wide range of research has been made in segregation of waste using automation.

A research paper based on the automation of this process explains how a CNN based classifier along with a robotic arm can be used in identifying the waste as biodegradable or not and hence segregation of waste can be achieved. Image Processing with CNNs is used for waste identification which requires training of the model. Using of ultrasonic sensor to detect the vicinity of waste is also employed. An Arduino board is used for controlling the assembly of the setup.

The paper concludes by saying that the scaling up of the assembly and incorporating it in large scale and also including of various classes of waste for making the system more efficient will be included in future work. They also mention about the importance of environmental effects of the robot design which can be both beneficial and detrimental upon the environment. But it is definitely a better alternative compared to manual segregation considering that the robot will not produce any by products that are harmful and can work for long hours provided there is sufficient power supply.

[2] World Bank asserts grim situation of India's waste generation:

India contributes to more than 10% of the world's waste generation, which is considered to be very precarious. Unless concerted measures are initiated this is expected to increase substantially by 2050.

The populous India (1.3 billion populations) generates even more than China's waste generation which is the world's populous nation. While both India and China's waste generation is a fraction of developed countries, as per the studies India's waste generation is expected to increase substantially by 2050 whereas that of China's is expected to be slower.

The continuous innovation, research, up gradation of electronic devices and investments in R&D in the electronic field is contributing to the increased electronic waste generation. With disruptive technologies posing threats to the industry, the companies are resorting to "Innovation" and "automation of new technologies" for survival. While this is moving at lightning speed, the public awareness of hazards of e-waste is moving at a snail pace.

[3] Supreme Court-Intervention:

During July this year, the Supreme Court expressed concern over not meeting the basic requirement of the Solid Waste Management Rules, 2016 by the two third of the states and Union Territories.

Waste management, needless to state needs urgent and immediate attention. The major challenges encountered by India is in the collection, segregation, treatment and recycling of waste. The present management of waste is quite ineffective and inefficient as the waste is dumped into the landfills which not only results in ground water pollution but also at times when space becomes constrained the waste is burnt which causes air pollution due to release of toxic gases. These are quite hazardous as it would greatly influence health related issues which can contribute to respiratory problems, asthma in humans. In addition, this would also influence global warming which is a matter of concern.

India is one of the fastest growing economies and largely leverages "Industrialization" to create employment and per capita income. While all efforts are aimed at making the country to put Industrialization in the growth trajectory, the same importance is not accorded to "Waste Management". The rapid increase in urbanization as a result of industrialization is contributing to generation of solid waste, E waste etc. due to greater utilization of electronic and other allied items.

These wastes may cause potential human health hazard and environmental pollution, if the waste disposal management is not effective. Presently the management of waste is unscientific with lots of manual interventions/involvements. The Solid Waste collection efficiency in India is around 70% (Sharholy et al. 2007), while the same is almost 100% in developed countries. The government's ambitious initiative "Swachh Bharat Mission" aimed at making India a clean country has gained pace and conditions are improving, still a long way to go to reach the levels of the benchmark countries. The major problems in most of the cities/towns/villages presently are dumping of waste in the outskirts which contributes to ground water and air pollution when lit. There is an imminent need to treat the waste properly before disposal. Studies reveal that about 80% of the waste can be recycled or reused while remaining 20% is the real waste which needs to be disposed of with proper means. Conventional and improper techniques currently used for waste segregation is leading to "ineffectiveness" and calls for a major revamp of the system. This study is aimed at describing the current status of municipal solid waste management in different regions of India. Further it summarizes a collective, systematic efforts which improves implementation of legal frameworks, institutional arrangements, financial provisions, technology, operations management, human resource development, public participation and awareness of integrated SWM systems -World Scientific News.

The major challenge in India is to bring general awareness of solid waste management which is lacking due to self-motivation and attitude (Nandan et al. 2017). Collective efforts by the public will ease the system like segregation of waste when offered to the municipal authorities by distinguishing the waste type. Besides the waste collection, handling, transportation and disposal of waste needs to be managed effectively keeping human health, environment and safety in overall perspectives. The economic value of the waste is best realized when segregated, which is the basic issue presently haunting the administrations in both urban and rural areas.

CHAPTER 3

SYSTEM ANALYSIS

3.1 Existing system and drawbacks

Every house generates waste. With proper segregation, we can recycle a good amount of this waste and therefore conserve a lot of resources. This waste is directly collected from households in big dumpsters, which is further collected in massive dump yards. Little to no segregation is done at houses and everything is mixed up. In dump yards, municipality workers have to manually segregate this waste using their hands which is quite unhygienic and harmful to their health. These workers work in abysmal environment with lack of protective gear and therefore are in huge risk of falling ill.

3.2 Proposed Solution

In the proposed system, we want to automate this technique of segregation of waste so that with just a little to no human interference, waste can be segregated easily without the need of touching this waste. The segregation is done on basis of the image-processing model that we have developed that classifies waste as either biodegradable or non-biodegradable and sends appropriate signal to Arduino that controls a servo motor that helps in placing the waste in its respective bin hence segregating the waste correctly without any human intervention.

The webcam present on laptop captures the image of the waste and processes the image on the model that we have trained and tested with custom dataset of daily household waste like plastic, paper, textile, vegetables etc. The model then evaluates whether the waste is biodegradable or non-biodegradable and sends appropriate signal to Arduino to segregate the waste.

As not much human intervention is required, this can be very helpful in benefiting with many people standard of living as well as saving the cost as more automation is there.

SYSTEM REQUIREMENTS

3.3 Software Requirements

The software requirements are description of features and functionalities of the target system. These requirements convey the expectations of users from software product.

- Operating System: Windows
- Programming Language: Python
- Arduino Software IDE installed

3.4 Hardware Requirements

Hardware requirements are the requirements of a hardware device. Most hardware only has operating system requirements or compatibility.

- A laptop with integrated Webcam
- Processor: Intel i5
- Arduino UNO
- SG90 TowerPro Servo Motor
- Jumper Cables
- Nvidia Graphics Card

CHAPTER 4

SYSTEM DESIGN

4.1 Introduction

The purpose of the design phase is to plan a solution of the problem specified by the requirements document. This phase is the first step in moving from the problem domain to the solution domain. In other words, starting with what is needed; design takes us towards how to satisfy the needs. The design of a system is perhaps the most critical factor affecting the quality of the software; it has a major impact on the later phases particularly testing and maintenance.

4.2 Architecture Design

Architecture focuses on looking at a system as a combination of many different components and how they interact with each other to produce the desired results. The focus is on identifying the components or subsystems and how they connect. In other words, the focus is on what major components are needed.

The system has a proposed 3-layer architecture:

a) Presentation Layer

b) Service Layer

c) Code Layer

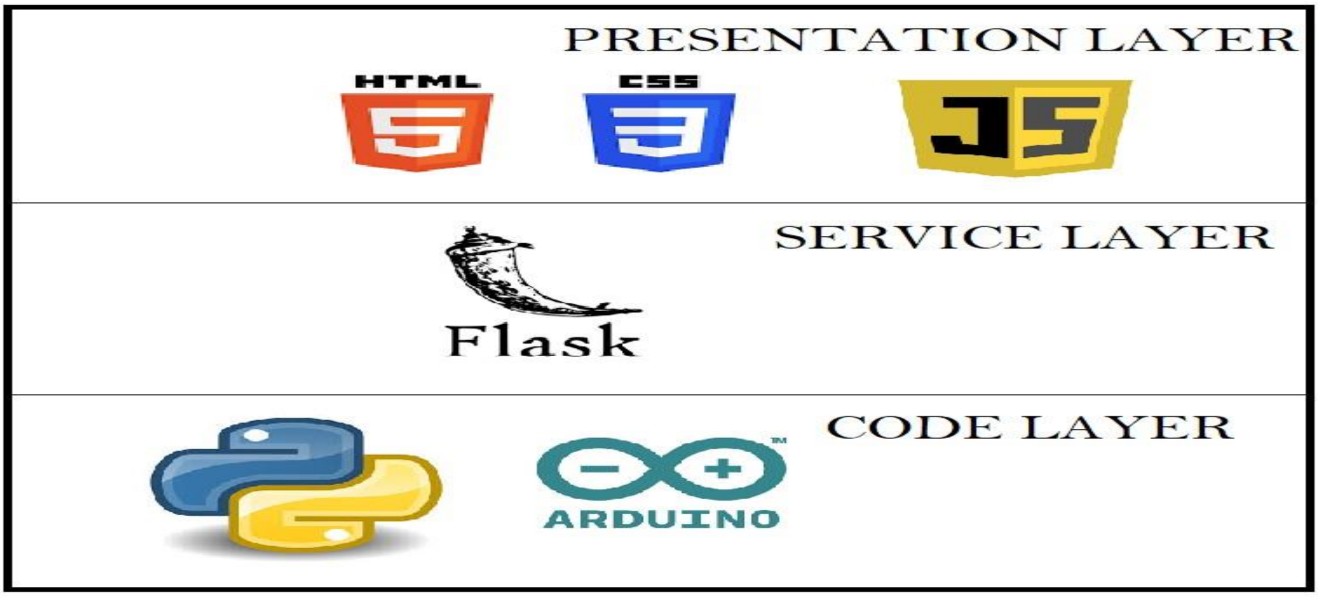


Fig. 4.1 System Architecture

4.3 Architectural Components

1) Presentation Layer:

This is the layer which acts as the frontline for the project, which is visible and interacts with the client. HTML5, CSS3 and JavaScript are used to create the UI for the system. Designing a user-friendly platform with styling and dynamic web pages in order to make the user experience worthwhile is possible due to this.

a) HTML5

HTML5 is a mark-up language used for structuring and presenting content on the World Wide Web. It includes detailed processing models to encourage more interoperable implementations; it extends, improves and rationalizes the mark-up available for documents and introduces mark-up and application programming interfaces (APIs) for complex web applications. For the same reasons, HTML5 is also used as a candidate for cross-platform mobile applications, because it includes features designed with low-powered devices in mind.

b) CSS3 – Cascading Style Sheets

CSS is a style sheet language used for describing the presentation of a document written in a mark-up language like HTML. CSS is a cornerstone technology of the World Wide Web, alongside HTML and JavaScript. CSS is designed to enable the separation of presentation and content. This separation can improve content accessibility, provide more flexibility and control in the specification of presentation characteristics, enable multiple web pages to share formatting by specifying the relevant CSS is a separate file and reduces the complexity and repetition in the structural content.

c) JavaScript

JavaScript is a high-level, just-in-time compiled programming language. It enables interactive web pages and is an essential part of web applications. Majority of the websites use it for client-side page behavior. It has various APIs for working with text, data structures etc.

2) Service layer

The service layer provides services to interconnect the front end and back-end code. This layer provides authentication and security to the system as well.

a) Flask

Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries. It has no database abstraction layer, form validation or any other components where pre-existing third-party libraries provide common functions.

3) Code Layer

This is the most important layer, containing all the backend code that is responsible for running all the tasks which provides the cloud services to the clients. This layer connects to the database and also runs the required services based on the requests.

a) Python

Python is an interpreted, high-level and general-purpose programming language. Python’s design philosophy emphasizes code readability with its notable use of significant whitespace. Its language constructs and object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.

b) Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards. The Arduino IDE supports the languages C and C++ using special rules of code structuring

4.4 Conclusion

This chapter provides the architecture of the system, followed by the detailed description about the architectural components.

CHAPTER 5

DETAILED SYSTEM DESIGN

5.1 Introduction

In detailed design the internal logic of each of the modules are specified. The focus is on designing the logic for each of the modules. In other words, how modules can be implemented in software looked into. A design methodology is a systematic approach to create a design by application of a set of technologies and guidelines.

5.2 System Architecture

Segregation of waste is one of the factors included in law, to make it a better place for the people and the environment. Segregation of waste is important to prevent soil degradation and reduce the burden on cities. Currently in many places across the globe, segregation of waste is done manually in the dump yard by the workers with lack of protective gear.

This unhygienic environment leads to birth of many diseases and illness. Automating this process helps in effective disposals with very minimal human intervention. The automated waste segregation system classifies the waste as bio degradable or non-biodegradable based on image processing considering the factor of color, texture, size, shape and orientation. The waste materials are loaded onto the platform; the web camera captures the picture and sends it as an input for the deep leaning model to perform image processing, classification and detection.

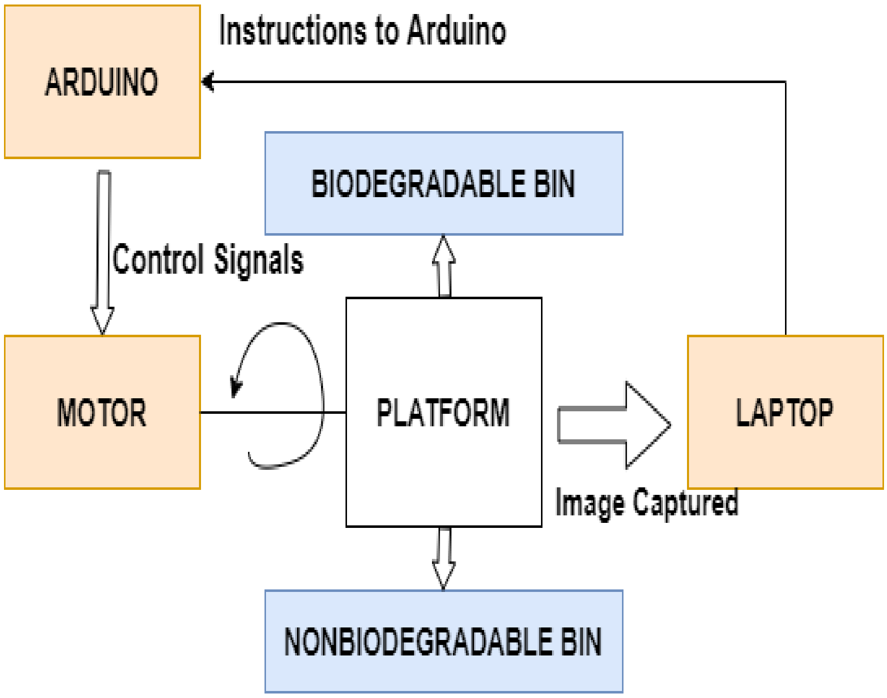


Fig. 5.1 Automated Segregation System Architecture

The Platform rotates according to the signal received from the Arduino fed into the motor. On rotation the waste item is dropped into the respective bin, making it a very efficient and easy form of waste segregation.

The microcontroller after receiving the classification output sends appropriate signals to the gate / gear to rotate to the path based on degradable material type. The heart of the model is the image classifier which controls and makes all the decisions. The model Resnet 34 (Residual Network) involves large number of neural layers that helps in incremental learning [4] and training. The image of the waste material to be classified is captured by the web cam, transformed to 128 x 128 pixels and fed into model for processing. Convolution Neural Network (CNN) model is used in analyzing the captured image to produce corresponding result [5]. CNN tremendously minimizes the preprocessing attempt for an image dataset. It has the capacity to study high-degree abstractions from a raw input data. The signal triggered by the CNN model is fed to the Arduino, to rotate the gears accordingly to the corresponding bio degradable or non-biodegradable pits. The motor drops the waste material to the predicted bin and returns back to the original position to process the next material as shown below.

Fig. 5.2 Waste Classification Setup

Fig. 5.3 Platform Movement after Classification

5.3 Use Case Diagram

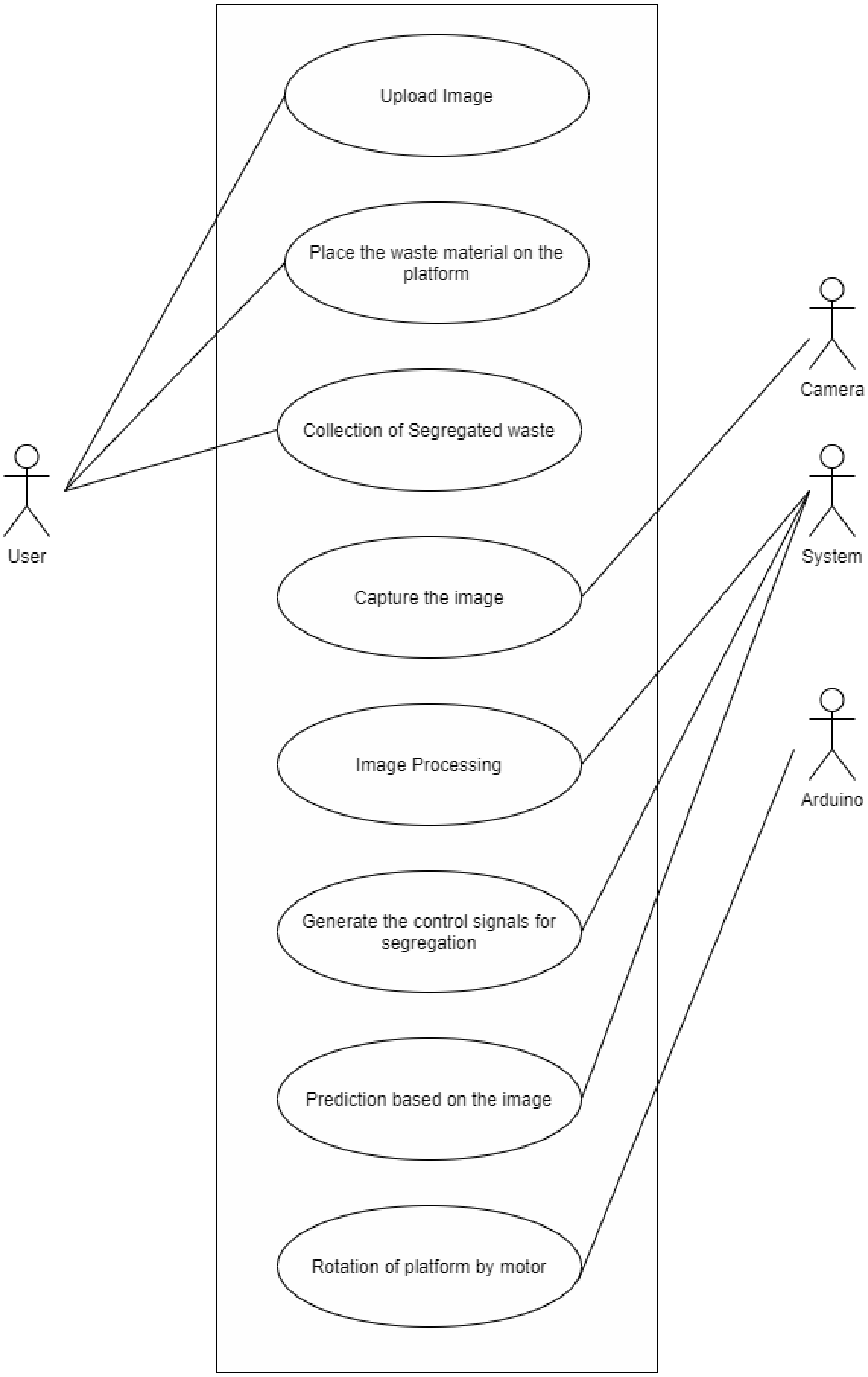


Fig. 5.3 Use Case Diagram

The use case diagram is presented in Fig 5.3. Its purpose is to present the graphical view of the functionality provided by the system in terms of the actors, their goals and any dependencies between those use cases.

Actors:

- User
- Camera
- Backend System
- Arduino Board

The use case diagram consists of four actors who are, the person in charge of the waste segregation and uploading the image, the camera that captures the image, the backend system that performs the object classification and the Arduino board that is in charge of the movement of the platform.

Roles of the actors:

The person in charge of the segregation uploads the image or places the waste materials on the platform. He later needs to collect the segregated waste bins and take it for appropriate disposal grounds.

The camera captures the image placed on the platform that is used for prediction.

The captured/uploaded image is transformed by the backend system. The CNN Model predicts which category the waste material belongs to. Based on the prediction, the backend system sends appropriate signals to rotate the motor in the appropriate direction.

The Arduino board ensures the motor rotates the platform in the correct direction based on the signal it receives from the backend system. The waste falls into the appropriate bin hence performing automated segregation of the waste.

Use Cases:

For user:

- Uploading the image
- Placing the waste material
- Collection of the segregated waste

For camera:

- Capturing the image

For backend system:

- Image processing
- Generating control signal
- Prediction based on image

For Arduino board:

- Rotation of the platform

5.4 Activity Diagram

The activity diagram is presented in Fig 5.4. It represents the order in which a particular task of the system is performed to obtain the result.

The process starts with the user capturing the image of the waste material placed in front of it through the webcam. The captured image is then cropped to 128 x 128 pixels by the backend system. Alternatively, the user can also upload an image to the site for prediction. The image is transformed to 128 x 128 pixels by the backend system. The transformed image is sent to the convolution neural network model for prediction. The model predicts which of the predefined 15 categories the material belongs to and based on this, the backend system classifies it as biodegradable or non-biodegradable.

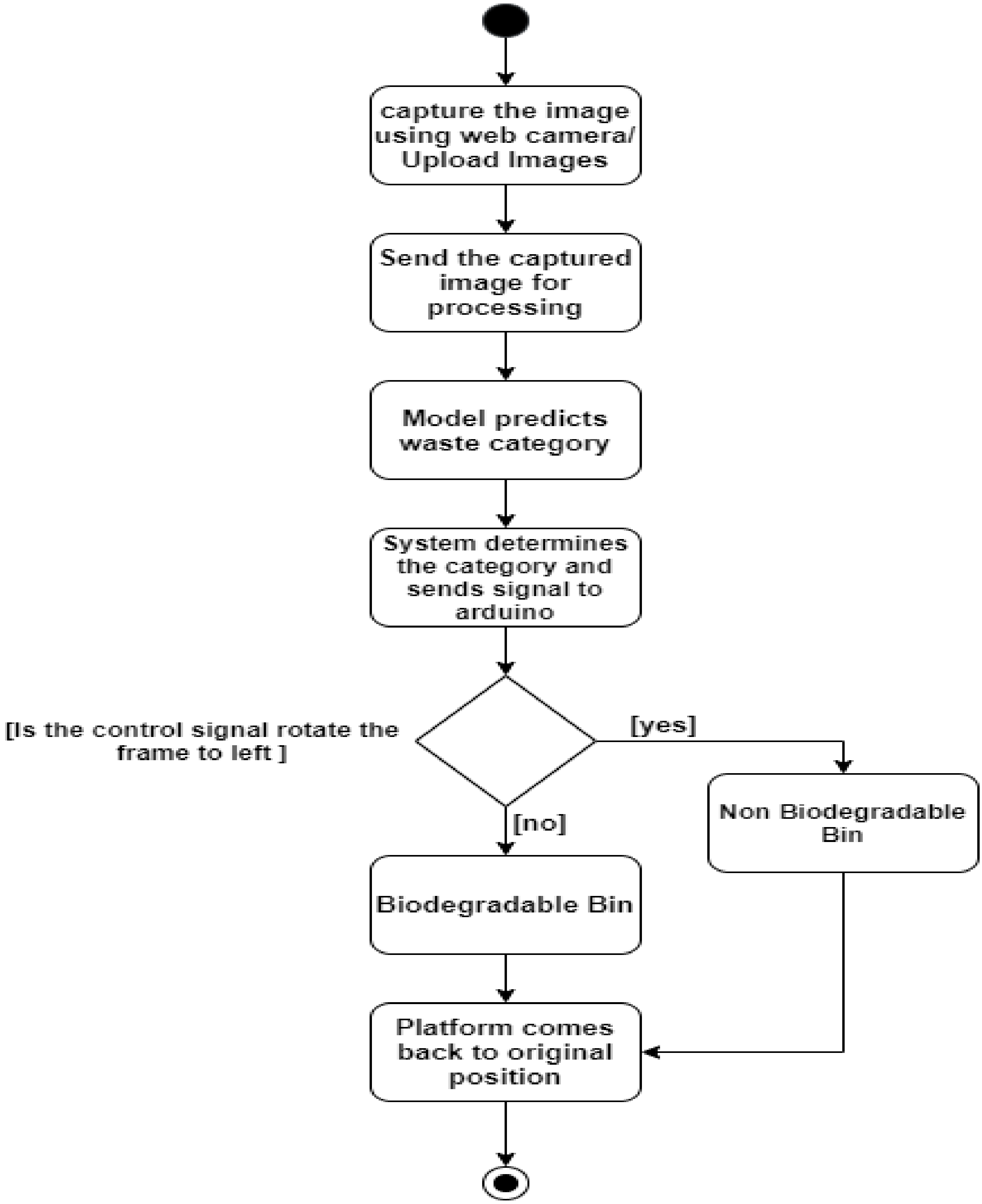


Fig. 5.4 Activity Diagram

Based on the classification, signals are sent to the motor to rotate in the appropriate direction and dump the waste in the appropriate bin. The waste materials are collected and segregated in their appropriate bins making it easy for disposal, ensuring a cleaner and healthier environment. The platform comes back to its original position at the end.

5.5 Sequence Diagram

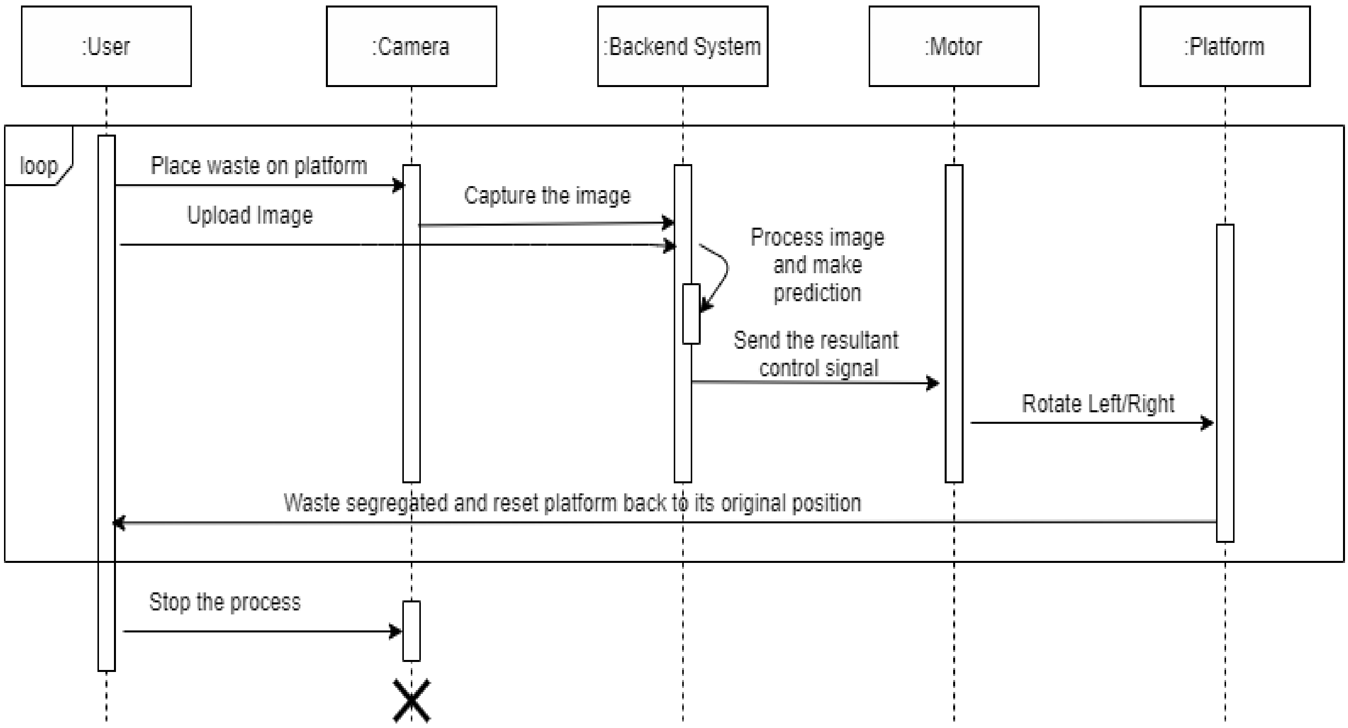


Fig. 5.5 Sequence Diagram

The sequence diagram in Unified Modelling Language (UML), is a kind of interaction diagram that shows how the processes and the objects of the system interact with each other and in what order. The sequence diagram for the system is represented in Fig 4. It shows how each component and process interacts with each other.

Main Objects of the Sequence Diagram:

- User
- Web Camera
- Backend System
- Motor
- Platform

The main sequence of events occurs as follows:

- The user places the item to be classified on the platform and an image is captured using the webcam. Alternatively, the user can upload an image from the device as well for prediction.
- The captured/uploaded image is processed by the backend system and using the model, a prediction is made as to which category the item belongs to.
- According to the category, the backend system classifies it as biodegradable or non-biodegradable.
- The appropriate control signals are generated for the motor to rotate the platform.
- The Platform rotates and the waste material is collected in the appropriate bin.
- The Platform returns to its initial position.
- This process is repeated for all the waste materials in a loop until the user stops the process.

5.6 Data Flow Diagram

A data flow diagram (DFD) is a graphical representation of the "flow" of data through an information system. DFDs can also be used for the visualization of data processing. On a DFD, data items flow from an external data source or an internal data store to an internal data store or an external data sink via an internal process. A context-level data flow diagram shows the interaction between the system and external agents which acts as data sources and data sinks. On the context diagram (also known as the 'Level 0 DFD') the system's interactions with the outside world are modeled purely in terms of data flows across the system boundary. The context diagram shows the entire system as a single process and gives no clues as to its internal organization. Context level DFD is exploded to level 1 DFD, which shows all processes at the first level of numbering, data stores, external entities and the data flows between them. The purpose of this level is to show the major and high-level processes of the system and their interrelation. The Level-0 Data Flow Diagram is shown as given below.

This Data Flow Diagram represents an abstract and precise view of the flow of data within the entire system or application.

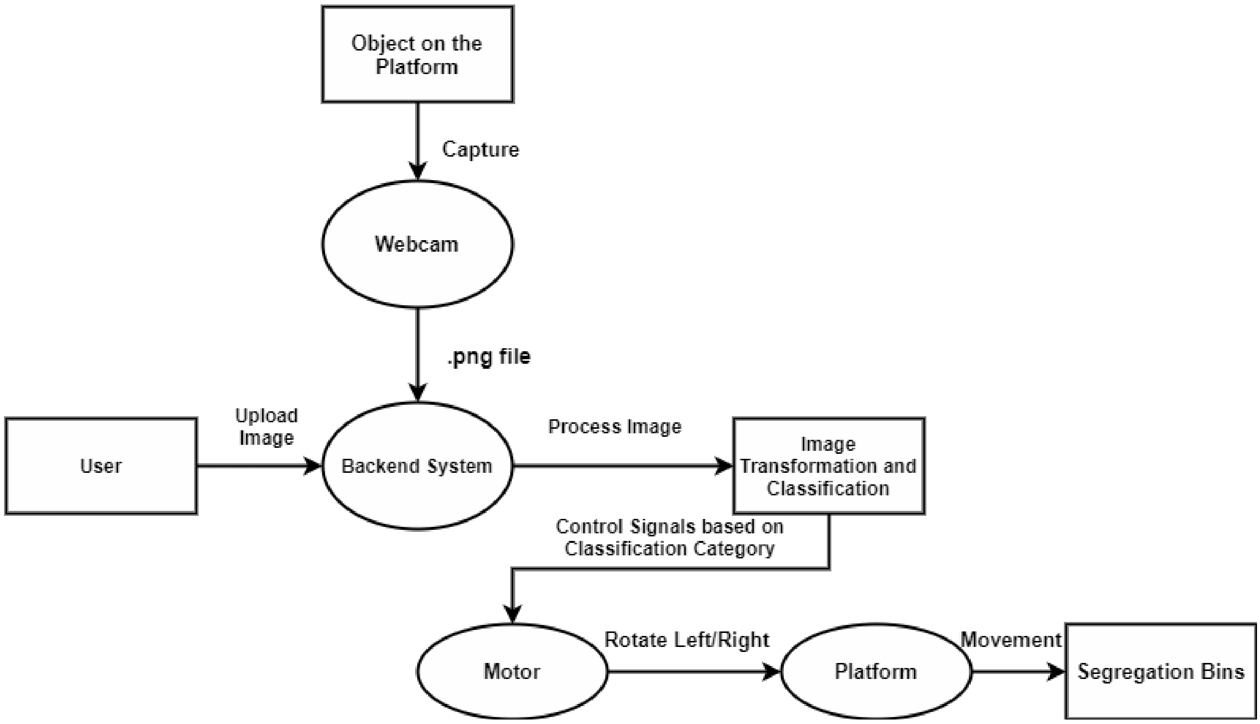


Fig. 5.6 Level 0 Data Flow Diagram

The object on the platform is captured by the web camera. This is of '.png' format. The captured image is sent to the backend system, where it is cropped and transformed to 128 x 128 pixels. Alternatively, the user can upload an image, which the backend system transforms to 128 x 128 pixels. The transformed image is then sent to the neural network model for prediction. The model classifies the image under one of the 15 predefined categories. The category is finally mapped onto one of the two final categories i.e., biodegradable and non-biodegradable using a static dictionary.

Appropriate control signals are generated for the same and sent to the motor for the rotation of the platform. The platform rotates accordingly, dumping the material into the appropriate bin.

CHAPTER 6

IMPLEMENTATION

6.1 Introduction

System implementation is the phase where ideas and vision are implemented in the real world. The implementation phase is a significant phase in the development of the project. In this phase the system designs are transformed into the language specific programs such that the requirements given in the software requirements specification are satisfied. It also provides information on the various stages of implementation of the project and gives a detailed information of the methodology and different tools used. This phase entails actual implementation of ideas that were described in the analysis and design phase. The technique and the methods that are used for implementing the software must support reusability, ease of maintenance and should be well documented.

6.2 Overview of the Implementation Process

The project was divided into three phases for the purpose of implementation. Each phase had a different technology used. Phase I included training our model using convolutional neural network which is a class of deep neural networks. Phase II included building and testing the prototype model using Python and Arduino IDE on a Windows machine. Phase III of the project included creating a user interface for the working of the model.

6.3 Main Aim of Implementation

The main aim of the implementation is to create an automated waste segregation system that performs the task of segregating it into two categories namely biodegradable and non-biodegradable in real time and dumps the waste into the appropriate bin.

6.4 Tools and Technologies used

a. Python

Python is a high level, interpreted programming language. Due to its simplistic syntax and high code readability, it is the perfect programming language for performing complex tasks such as machine learning, deep learning etc. There are a large number of libraries available in Python for the purpose of applications such as Scikit-learn for machine learning, PyTorch for neural networks etc.

Python was used to build the entire system and test its functionality on a Windows machine. The advantage of using Python is the large number of libraries available to perform the task. Python scripts were written to perform the object detection and segregation based on it.

Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries. It has no database abstraction layer, form validation or any other components where pre-existing third-party libraries provide common functions. Flask was mainly used for creating the front-end web application for the automated waste segregation system.

b. fastai

We have used the fastai framework of the PyTorch library for training the model. **fastai** is a deep learning library which provides practitioners with high-level components that can quickly and easily provide state-of-the-art results in standard deep learning domains, and provides researchers with low-level components that can be mixed and matched to build new approaches. It aims to do both things without substantial compromises in ease of use, flexibility or performance. This is possible thanks to a carefully layered architecture, which expresses common underlying patterns of many deep learning and data processing techniques in terms of decoupled abstractions. These abstractions can be expressed concisely and clearly by leveraging the dynamism of the underlying Python language and the flexibility of the PyTorch library.

c. Scikit-learn

Scikit-learn is a machine learning library for Python. It consists of various classification, regression and clustering algorithms for various machine learning applications and can be interoperated along with other Python libraries such as SciPy and NumPy.

Scikit-learn can also be used for image classification and segmentation tasks that are compute intensive. Using the Scikit-learn library along with fastai, the datasets have been trained to produce the waste segregation model.

Sklearn confusion matrix returns the values of the Confusion matrix. A confusion matrix also known as an error matrix, is a summarized table used to assess the performance of a classification model. The number of correct and incorrect predictions are summarized with count values and broken down by each class. Generally, we'll evaluate our machine learning model based on some predetermined metrics that we decide to use. When it comes to building classification models, we most likely use a confusion matrix and related metrics to evaluate your model. Confusion matrices are not just useful in model evaluation but also model monitoring and model management.

d. Matplotlib

Matplotlib is a cross-platform, data visualization and graphical plotting library for Python and its numerical extension NumPy. A Python matplotlib script is structured so that a few lines of code are all that is required in most instances to generate a visual data plot.

Seaborn is a Python data visualization library based on matplotlib. It provides a high-level interface for drawing attractive and informative statistical graphics. This library has been used to plot graphs underneath matplotlib.

e. OpenCV

OpenCV is the huge open-source library for the computer vision, machine learning and image processing and now it plays a major role in real-time operation which is very important in today's systems. By using it, one can process images and videos to identify objects, faces or even handwriting of a human. When it integrated with various libraries such as NumPy, python is capable of processing the OpenCV array structure for analysis. To Identify image pattern and its various features we use vector space and perform mathematical operations on these features.

In our system, this library is used to transform the images into particular sizes for training the model which facilitates rotation and cropping of the images fed.

6.5 Development Environments Used

a. Jupyter Notebook

The Jupyter Notebook is an open-source web application that you can use to create and share documents that contains live code, equations, visualizations and text. It is an interactive computational environment, in which you can combine code execution, rich text, mathematics, plots and rich media. It was mainly used for training the model and plotting the graphs and matrices.

b. Sublime Text

Sublime Text is a shareware cross-platform source code editor with a Python application programming interface. It natively supports many programming languages and markup languages and functions can be added by users with plugins, typically community-built and maintained under free-software licenses. This editor was mainly used for the Python programming for the system.

c. Arduino IDE

The Arduino Integrated Development Environment is a cross-platform application that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. We used this for programming the Arduino board.

6.6 Major Phases of Implementation

6.6.1 Phase I

In this phase the model was trained using Convolutional Neural Network where the fastai framework of the PyTorch library was used. The reason for using PyTorch compared to other libraries like TensorFlow where you have to first define an entire computational graph before you can run your model, PyTorch allows you to define your graph dynamically. PyTorch is also great for deep learning research and provides maximum flexibility and speed. Many other libraries like NumPy, Pandas, Scikit-learn, Matplotlib, Seaborn were used for the training of the model.

Two models were considered for training with different accuracies and one was chosen based on some parameters that helps in the good performance of the system. The model was converted to a PKL file by the pickle module and migrated to Python for using the model for prediction.

Implementation Brief

- Create destination folders for data subset and the waste type and move the data to training and validation folders.

- Then an 'ImageDataBunch' object was created which is special to the fastai software. This object pulls together all our train data and validation data and performs the necessary transformations to the images. The ds_tfms is specifying the transforms.

Tfms = get_transforms (do_flip=True, flip_vert=True)

data = ImageDataBunch.from_folder (path, ds_tfms=tfms, bs=16)

- In fastai, the model being trained is called a ‘learner’. A learner is a general concept that can learn to fit a model. We are using the cnn_learner which will use the ResNet34 architecture.

Learn = create_cnn (data, models.resnet34, metrics=error_rate)

- Once the learner was created, we used the fit_one_cycle method to train the model on our data set for 10 epochs.

Learn.fit_one_cycle (10, max_lr=5.13e-03)

- The results showed an accuracy of 93.20%.

6.6.2 Phase II

The second phase of the project implementation was the programming of Arduino that helps in the manual classification of wastes into the appropriate bin which is automated based on the object. The Arduino board was programmed by sending serial data from Python to Arduino for the mechanical movement of the SG90 TowerPro Servo Motor which turns left for biodegradable waste and right for non-biodegradable waste.

The Arduino was connected to the motor and programmed as well to control its movement. This comprises the hardware part of the project that does the segregation of the wastes mechanically using the Arduino, motor and a platform on which the wastes are kept.

Implementation Brief

- Below snippet of the code performs attaching the motor to pin 3 of the Arduino (attach) and opens a communication medium between the two at port 9600 (begin) and sets the Arduino in the appropriate position for the waste materials to be placed on it (write).

myservo.attach(3);

Serial.begin(9600);

myservo.write(60);

- The ‘myByteArray’ variable reads the value written in the communication port by the Python script.

myByteArray = Serial.read();

- Below snippet of code tilts the platform to the left and right and brings it back to the initial position.

```
If(myByteArray == '1')
{
  for(i=59; i!=20; i--)  #tilts the platform left
  {
    myservo.write(i);
   delay(50);
  }
 if(myByteArray=='2')  #brings the platform to initial position
  {
    myservo.write(60);
  }
if(myByteArray=='0')
{
  for(i=61; i!=100; i++)  #tilts the platform right
  {
   myservo.write(i);
   delay(50);
  }
```

- The line of code below loads the model into the variable ‘learn’ from the ‘export.pkl’ file which is migrated to Python.

learn = load_learner(path,’export.pkl’)

- The class of the waste is predicted by the below line of code.

pred_class,pred_idx,outputs = learn.predict(open_image(filename))

- The ‘b_nb’ variable has the prediction class of the waste which is imported for movement of the platform based on it.

If str(pred_class) in biodegradable:

b_nb = 'biodegradable'

else:

b_nb = 'nonbiodegradable'

6.6.3 Phase III

The third and final phase of the project was creating a front-end web application using Python's Flask framework. A simple user interface was created, keeping in mind that the end user for the application should not face any difficulty in operating the application. The user interface allows us to capture the image kept on the platform that will be segregated into respective bins after capturing or an image can also be uploaded and the application will show the results of the prediction based on the model trained. The image capturing will be from a computer system that has a web camera and the image captured will be submitted for prediction. The Arduino board is connected to the computer system which is in turn connected to the motor that makes the movement of the platform to which it is connected and the waste falls into the appropriate bin.

6.7 Project Implementation of Object Classification

6.7.1 Datasets and Data Collection

The images used withinside the proposed project is collected from image scrapping the internet and Kaggle sources. Large dataset consisting of 2566 images are used to train and test the network. The custom CNN structure calls for a huge dataset and additionally takes a number of times to train.

Pre-educated models conquer those troubles as its weights are already optimized while training on the open-source ImageNet dataset [6, 7]. Though the models can't acquire 100% accuracy, its miles constructed to acquire the quality viable classifier and to decrease the mistakes to the most viable extent. Before these datasets are put into training, the images are transformed and flipped in all directions to help the model analyze all the angles of the image. Initially an aspect ratio of 64 x 64 pixels was considered which yielded poorer results due to decreased pixel density, hence doubling the ratio to 128 x 128 pixels provided much better consistency and accuracy.

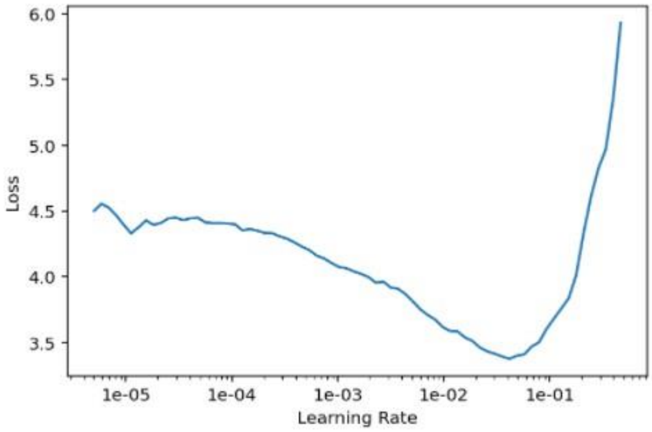
Class	Dataset count
Plastic Items	589
Kitchen waste, Wood and Leaves	210
Pen, Paper and Glass	649
Bags and Cardboards	461
Wrappers, Cans and Thermocol	385
Masks, Straws and Teabags	272
Total Training Images	**2566**

Table. 6.7.1 Details of Dataset

We have come up with two types of models for hyper parameter tuning. They are multi-category classifier and Binary classifier. The details of the two are described below.

6.7.2 Multicategory Classification

On capturing a colored image, we will be dealing with 128x128x3 values because of the RGB (Red, Green, Blue) color scheme. The input layer of the neural network cannot handle multi-dimensional matrices hence we pass these as values instead [12]. The neural network processes the image through several hidden layers, with the last layer having the number of neurons equal to that of the number of output classes. The convolution layer tries to extract the features and patters of the images with their filters [8]. The training sets are fit into 16 batch sizes. The multi-category model detects and classifies images into 15 categories (namely Kitchen residues, Plastic Items, Wooden Objects, Leaves, Pen, Paper, Glass Items, Bags, Cardboards, Wrappers, Cans, Thermocol, Masks, Straws and Teabags). A mapping sheet is created in python to map the classified categories of object into bio degradable and non-biodegradable. This produces an accuracy of 93.20%.

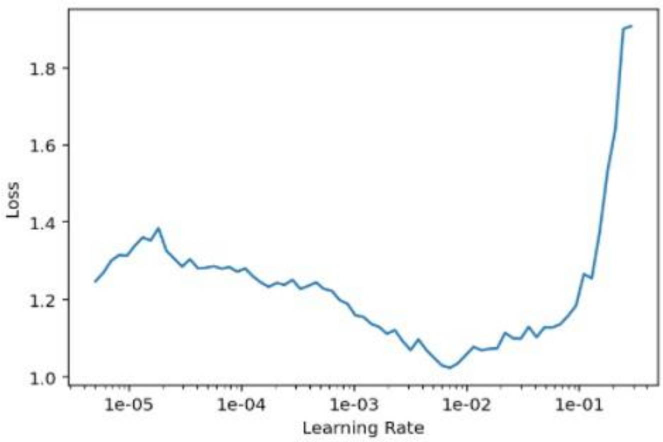


epoch	train_loss	valid_loss	error_rate	time
0	2.260442	1.247620	0.362089	06:15
1	1.539887	1.126818	0.284904	06:58
2	1.464088	1.209851	0.347333	07:39
3	1.419997	1.195878	0.356413	08:04
4	1.188988	0.894306	0.266742	08:18
5	1.029430	0.846909	0.276958	07:13
6	0.881278	0.742034	0.236095	07:00
7	0.737905	0.676393	0.215664	06:55
8	0.553446	0.618100	0.208854	06:55
9	0.498629	0.598658	0.203178	06:59

Fig. 6.7.2 Loss vs. Learning rate and Epoch table for Multi-category Classifier

6.7.3 Binary Classifier

A binary classifies works in the same way as that of multi-category classifier except that the last neural network layer has only two neurons. It detects and classifies images into 2 categories only (bio degradable and non-biodegradable).



epoch	train_loss	valid_loss	error_rate	time
0	0.643156	0.327526	0.124287	08:01
1	0.512411	0.261195	0.087799	08:14
2	0.434168	0.292800	0.117446	08:23
3	0.336641	0.214236	0.083238	07:04
4	0.328208	0.224546	0.088940	07:02
5	0.292002	0.170757	0.053592	06:56
6	0.258069	0.146538	0.055872	07:05
7	0.206562	0.132689	0.050171	06:35
8	0.180382	0.137168	0.047891	04:49
9	0.199128	0.134085	0.049031	04:49

Fig. 6.7.3 Loss vs. Learning rate and Epoch Table for Binary Classifier

Even though this model produced an accuracy of 95.09%, it is difficult to debug and handle misclassified objects. With this intention in mind proceeding with the multi-category model would be a better choice.

CHAPTER 7

SYSTEM TESTING

7.1 Introduction

The aim of Software Testing is to detect defects or errors by testing the components of programs individually. It is done to check the functionality of the software and whether the software created by the developer is performing the way it was intended to and giving the desired output. Thus, testing is a set of activities which can be planned in advance and conducted systematically.

During testing, the components are combined to form a complete system. At this particular stage, testing is carried out to demonstrate that the function meets the required functional goals, and does not behave in abnormal ways. The test cases are chosen to assure the system behavior can be tested for all combinations. Accordingly, the expected behavior of the system under different combinations is given. Therefore, test cases are selected which have inputs and the outputs on expected lines. For testing software, various test strategies are to be used such as unit testing, integration testing and system testing. Our project was put through intensive testing methods to ensure efficiency and accuracy.

7.2 Purpose of Testing

Testing accomplishes a variety of things, but most importantly it measures the quality of the software that is being developed. This view presupposes there are defects in the software waiting to be discovered and this view is rarely disproved or even disputed. Several factors contribute to the importance of making testing a high priority of any software development effort. These include:

- Reducing the cost of developing the program.
- Ensuring that the application behaves exactly as we explain to the user for the vast majority of programs, unpredictability is the least desirable consequences of using an application.
- Reducing the total cost of ownership. By providing software that looks and behaves as shown in the documentation, the customers require fewer hours of training and less support from product experts.
- Developing customer loyalty and word-of-mouth market share.

7.3 Types of Testing

7.3.1 Unit Testing:

Unit testing focuses verification on the smallest unit of software design, the software component or module. Using the component level design description as a guide, important control paths are tested to uncover errors within the boundary of the module. The unit testing is a white box-oriented testing.

Test Case ID	**Test Case Name**	**Test Case Description**	**Status**
TCU01	Import libraries	Import of the following libraries • fastai • Sklearn, NumPy, Pandas	Success
TCU02	Test Camera working	Test the working of the camera module to capture images.	Success
TCU03	Image Transformation < 128 pixels	Testing image transformation function when a user uploads an image smaller than the required size (128*128)	Success
TCU04	Image Transformation > 128 pixels	Testing image transformation function when a user uploads an image larger than the required size (128*128)	Success
TCU05	Image Processing and Classification	Test for Successful Classification of the images	Success
TCU06	Arduino Testing	Test whether the control signals are in line with the classification output.	Success
TCU07	Motor Testing	Check for the equality of the motor rotation and control signal.	Success
TCU08	Platform Rotation for biodegradable materials	Check for platform to rotate towards its right side	Success

TCU09	Platform Rotation for non-biodegradable materials	Check for platform to rotate towards its left side.	Success
TCU10	Platform to return back to idle state.	Check for platform to return back to its original position	Success
TCU11	Front End Display	Display output of the object classification type.	Success
TCU12	Upload Image	Testing if the image is successfully uploaded to the website for processing	Success
TCU13	Classification Accuracy	Testing if the accuracy of the model meets its standards	Failed Initially
TCU14	Crop image function	Checking the crop function working to ensure the cropped image contains the object to be detected.	Failed for few images.

Table 7.1 Unit Testing for Automated Segregation System

First of all, the module interface is tested to ensure that the information properly flows into and out of the program until under test. Then the local data structure is tested to ensure the data stored temporarily maintains its integrity during all steps in an execution. Boundary conditions are tested to ensure that the module operates properly at boundaries established to limit or restrict processing. All independent paths through the control structure are exercised to ensure that all statements in a module have been executed at least once. And finally, all errors handling paths are tested. In this project the testing is done according to bottom-up approach. Starting with smallest and lowest level modules and processing one at a time. For each module a driver and corresponding stubs were also written. If any errors found they were corrected immediately and the unit was tested again.

7.3.2 Integration Testing:

Integration testing is a systematic technique for constructing the program structure while at the same time conducting tests to uncover errors associated with the integration process. The objective is to take unit tested components and build a program structure.

Integration testing is a logical extension of unit testing. In its simplest form, two units that have already been unit tested are combined into a component and the interface between them is tested. A component, in this sense, refers to an integrated aggregate of more than one unit. The idea is to test combinations of pieces and eventually expand the process to test the modules with those of other groups. During the integration process, the software needs to be continuously tested to eradicate errors or software bugs. Eventually all the modules making up a process are tested together. Any errors discovered when combining units are likely related to the interface between units. This method reduces the number of possibilities to a far simpler level ofanalysis.

In this software, the bottom-up integration testing approach has been used, starting with the smallest and lowest level modules and proceeding one at a time. In this testing approach, small clusters of modules of the software were formed and integrated upwards till the main function of the software was finally integrated.

Test Case ID	TCI01
Test Case Name	Integration Object Classification
Description of Test Case	Integration of the web camera output and the neural network model. Maintaining the flow of images into the system for the model to accordingly act on it.
Feature being tested	Real time object classification
Sample Input	Real time image a waste item (Plastic wrapper)
Expected Output	Object to be classified into non-biodegradable category.
Obtained Output	Object successfully classified as non-biodegradable
Status	Success

Table 7.2 Integration Testing for Object Classification

Test Case ID	TCI02
Test Case Name	Integration testing for platform rotation
Description of Test Case	Integration of the model output through Arduino to the motor, by generating appropriate control signals for the motor to rotate the platform accordingly.
Feature being tested	Rotation of the platform in sync with the classification output
Sample Input	A biodegradable object (leaves)
Expected Output	The platform to rotate towards the biodegradable bin.
Obtained Output	Platform rotated towards right side (biodegradable bin)
Status	Success

Table 7.3 Integration Testing for Platform Rotation

Test Case ID	TCI03
Test Case Name	Integration Python model and Arduino board
Description of Test Case	Integration Python model and Arduino board at port 9600.
Feature being tested	Appropriate flow of data through the port.
Sample Input	Real time image a waste item.
Expected Output	Appropriate control signal output.
Obtained Output	Signal output generate accordingly.
Status	Success

Table 7.4 Integration Testing for Python Model and Arduino Board

Test Case ID	TCI04
Test Case Name	Integration Training model and image prediction
Description of Test Case	Integration of the Trained model to classify unseen images.
Feature being tested	Real time object classification using trained dataset
Sample Input	The weights of the images from the trained model.
Expected Output	Classify the unseen image correctly.
Obtained Output	Unseen image classified correctly
Status	Success

Table 7.5 Integration Testing for Training Model and Image Prediction Method

7.3.3 System testing

System testing is the testing process in which the complete system, as a whole, is tested for the main functionality. The system is tested to ensure that all the units that have been integrated satisfies the main system requirements. This testing process helps in removing the overall bugs and improves quality and assurance of the system. The proper functionality of the system is concluded in system testing. The whole system is evaluated in this system testing, with all the main modules being tested.

7.3.4 User Testing

User testing is the process wherein the built application is tested by the users of the application. This ensures that the application built is robust and has all the necessary functionality. Two main user testing methods have been utilized

Alpha Testing

It is virtually impossible for a software developer to foresee how the user will really use a software program. Instructions for use may be misinterpreted, strange combinations of data may be regularly used, output that seemed clear to the tester may be unintelligible to a user in the field, etc.

When a software is built for a customer, a series of acceptance tests are conducted to enable the customer to validate all the requirements. Conducted by the end-user, rather than software engineers, an acceptance test can range from an informal test-drive to a planned and systematically executed series of tests.

In fact, acceptance testing can be conducted over a period of weeks or months, thereby uncovering cumulative errors that might degrade the system over time. If software is developed as a product to be used by many customers, it is impractical to perform formal acceptance tests with each one. Most software product builders use a process called Alpha testing to uncover errors that only the end user seems to find.

The alpha test is conducted by end-users, in the presence of the developers. The software is used in a natural setting with the developer “looking over the shoulder” of typical users and recording errors and usage problems. Alpha tests are conducted in controlled environments.

Alpha testing was conducted for our application system by giving the Android App to the users, and allowing them to perform object detection and face recognition. The testing was performed in the presence of the developers and the results were recorded.

Beta Testing

Once the application system is developed and tested thoroughly, the product should be ready for deployment and use by the end customer. However, it may not be the case many of the times, as the system may still have errors that were never encountered or resolved. These errors may not be encountered by the software developer during the software development or testing phase. However, these hidden errors may be encountered by the users who use the application.

To handle and eradicate these kinds of errors or software bugs, Beta testing is carried out. Beta testing is the phase where the user is given the developed application. The user uses the application and provides his reviews and feedback along with errors encountered (if any). For this reason, Beta testing is called user acceptance testing (UAT) or end user testing. The developer does not need to be present while the user tests the application. Once the application is successfully tested, it can be finally deployed.

CHAPTER 8

RESULTS AND DISCUSSION

The two key concerns for the classifier were the small size of the dataset creating insufficient training atmosphere and an overfitting model because of less data [9]. Image Scraping and debugging of misclassified images are performed to combat these problems. On adopting the multi-category classifier, the next step is to assess the performance of the developed model using some evaluation metrics. Accuracy is the most commonly used and best output metric to compare various models. It is a simple ratio of correctly predicted samples to total number of samples.

$$\textbf{Accuracy} = \frac{\mathbf{TP} + \mathbf{TN}}{\mathbf{TP} + \mathbf{TN} + \mathbf{FP} + \mathbf{FN}}$$

Where TP = True Positives, TN = True Negatives, FP = False Positives, FN = False Negatives [10]. True positive and True negatives are correctly predicted samples whereas False Positives and False Negatives are incorrectly predicted values.

We need to minimize False Positives and False Negatives to build a better model [11]. A confusion matrix is a table often used to define a classification model's output on a collection of test data for which the true values are known. It enables the output of an algorithm to be visualized as depicted in Figure 5.

The final output of the multi-category classifier after mapping and capping are two outputs, one as biodegradable and the other as non-biodegradable. After successful training, this model can classify different types of dry waste real time images available in the dumpster before segregation.

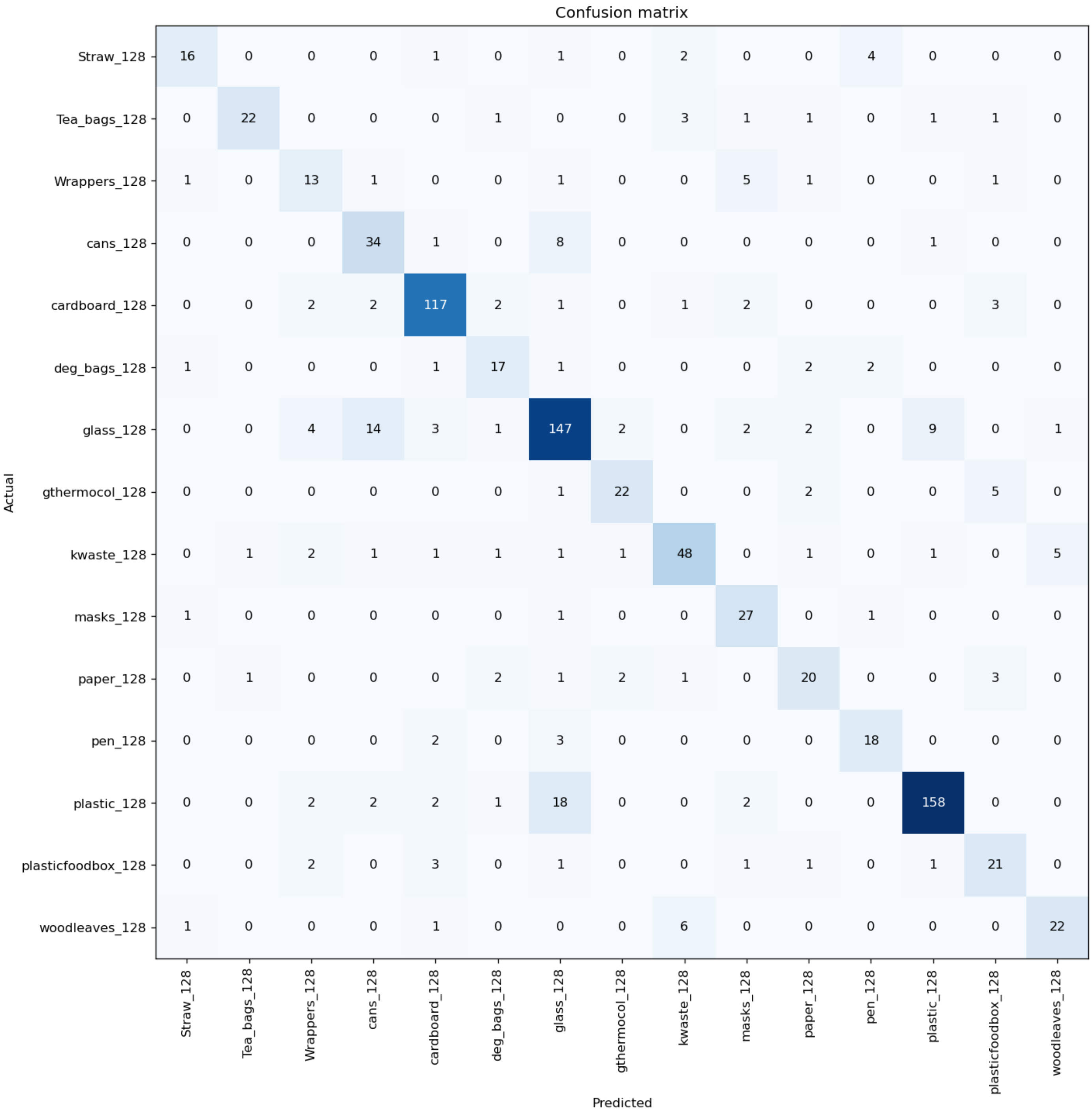


Fig. 8 Confusion Matrix for Multi-category Classifier

CONCLUSION

The proposed system for automated waste segregation aims to provide an easy and cost-effective solution in handling problems in waste management. It uses a CNN network to categorize different wastes. The model helps in avoiding waste segregation manually to some extent and there is a huge scope for improvement for the system.

Our model can detect the type of waste (biodegradable or non-biodegradable) through image processing then the microcontroller controls the bin and motor movements and the waste will be dumped in its respective bin without any human intervention. Hence the model can work on its own which can help in quicker segregation of huge amount of waste.

The separation process of the waste will be faster and intelligent using our system without or reducing human involvement. If more image is added to the dataset, the system accuracy can be improved.

This system gives a solution for situations where large quantities of waste are to be segregated and the objects can be categorized by look only. In situations like these, an automated waste segregation system can do the work without any effort and with high efficiency and accuracy and human effort can be diverted into more difficult segregation tasks which can help in getting control of the waste we produce and properly handle them.

The proposed model gives more priority to low cost, maintainability and accuracy which can be enhanced with the help of future advancements in electronic hardware and cloud technologies.

FUTURE ENHANCEMENTS

- The waste materials can be segregated into biodegradable and non-bio degradable more efficiently by using a larger dataset for training of the model. The current system is able to segregate only dry waste. Further improvement should be able to segregate wet wastes as well.
- The proposed system is able to take one item at a time which can be further improved so that multiple items can be segregated in real time which will help to reduce both human efforts and overall time.
- The model can be trained further in order to detect hidden items in waste. Advance electronic sensors can be used to reduce the time lapse between communications among different parts of model.
- Future work can include scaling up the assembly to incorporate large scale waste handling. The CNN classifier engine will be modified to include more classes of waste for improving the efficiency of the system.
- The discarded things can be processed to extract or recover materials in an effective way and resources or convert them to energy as usable heat, electricity, or fuels. The large-scale introduction of automatic waste management in villages, platforms, hospitals, industries, etc.
- Real time monitoring and controlling of waste management by using Internet of Things (IoT). A prediction system by analysing the given data to predict the variation in the amount of waste and to adjust the timing of management.
- A feature where user can provide feedback regarding wrong prediction of a certain object so that it can be used to train the model based on the feedback for correct prediction in the future.

CHAPTER 9

APPENDIX

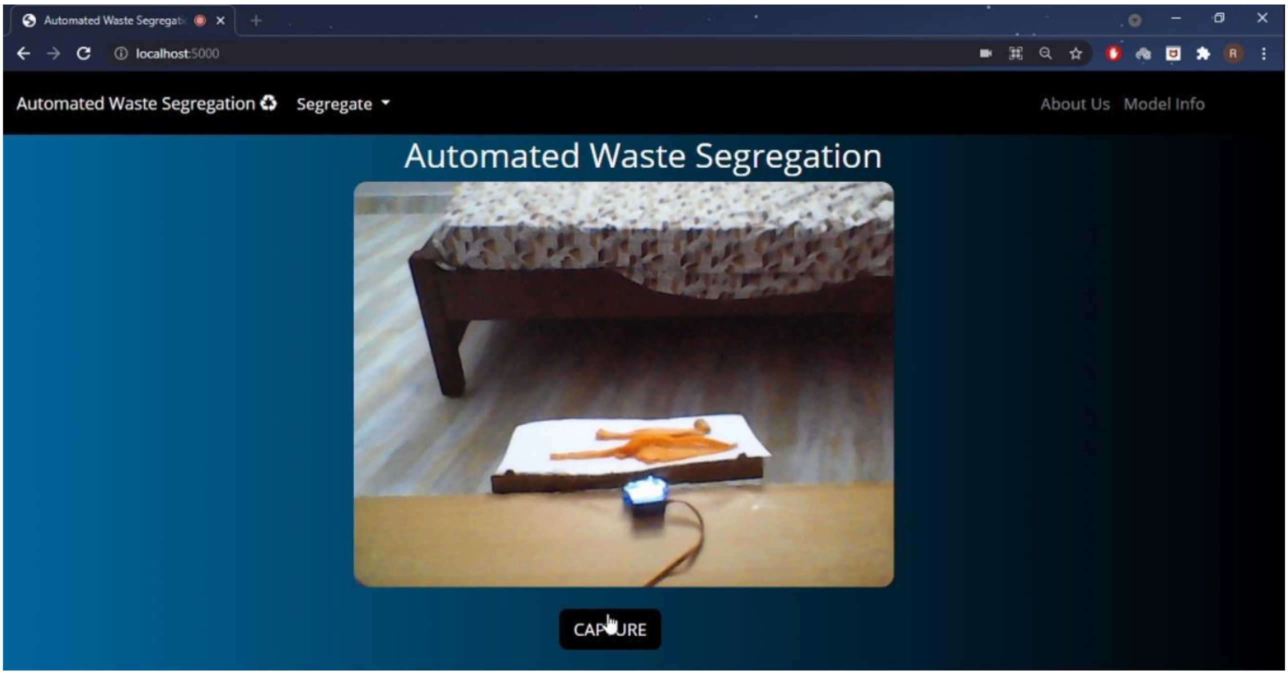


Fig. 9.1 Landing page

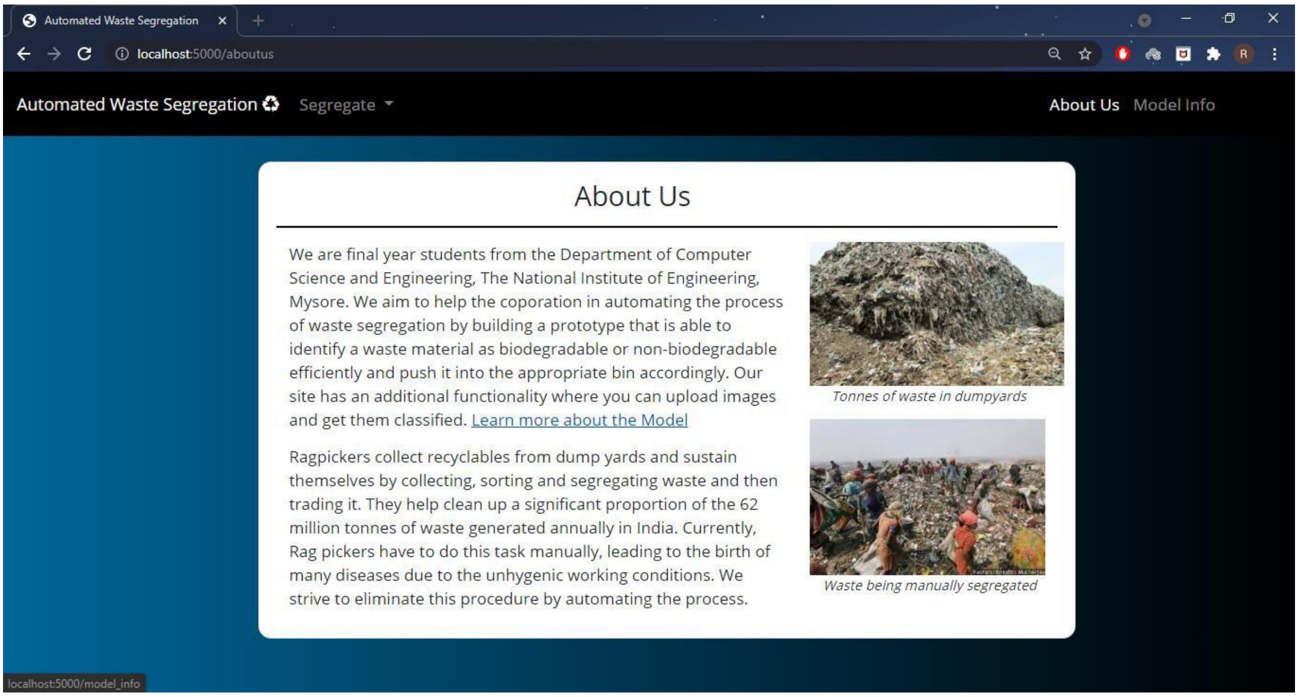


Fig. 9.2 About page

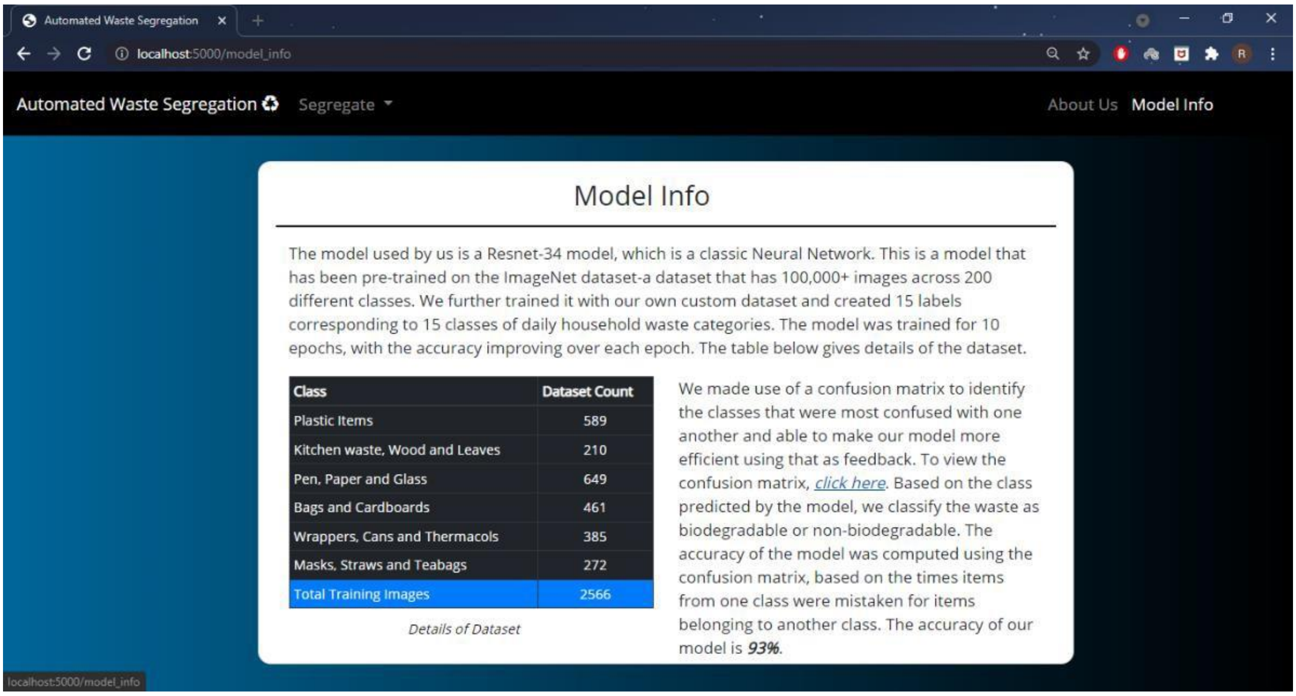


Fig. 9.3 Model Information page

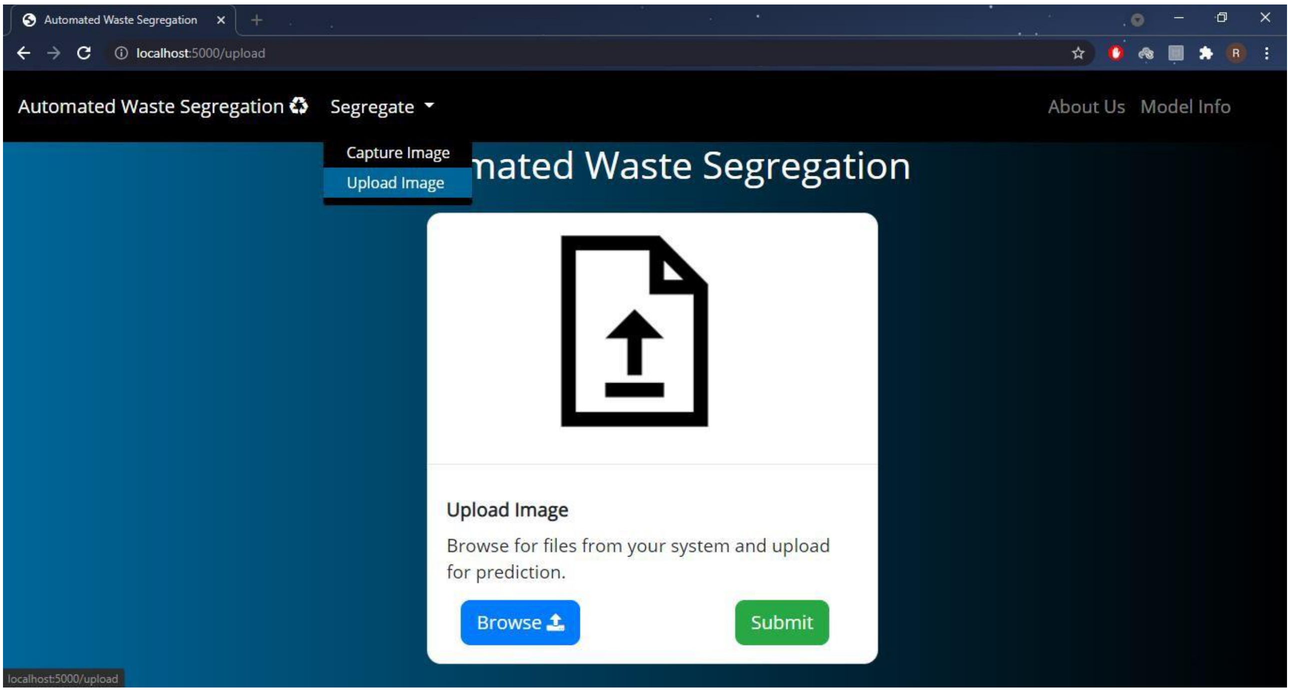


Fig. 9.4 shows two ways of inputting image for waste detection

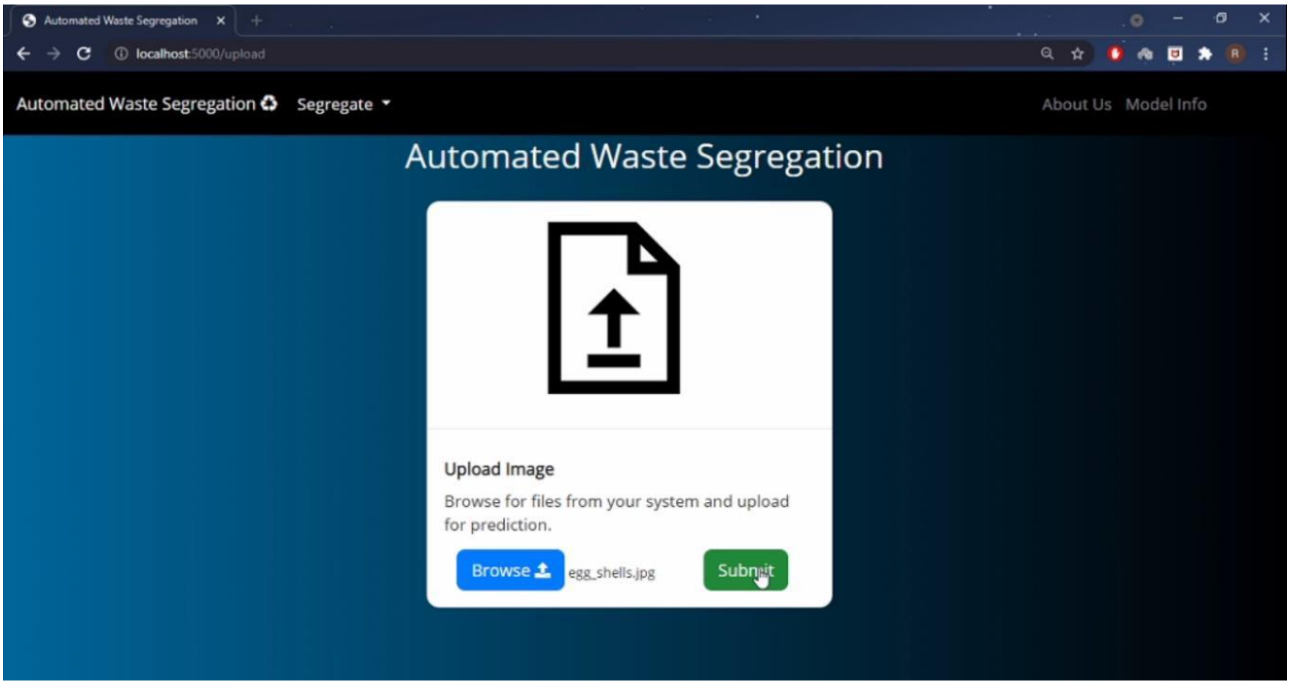


Fig. 9.5 Image upload

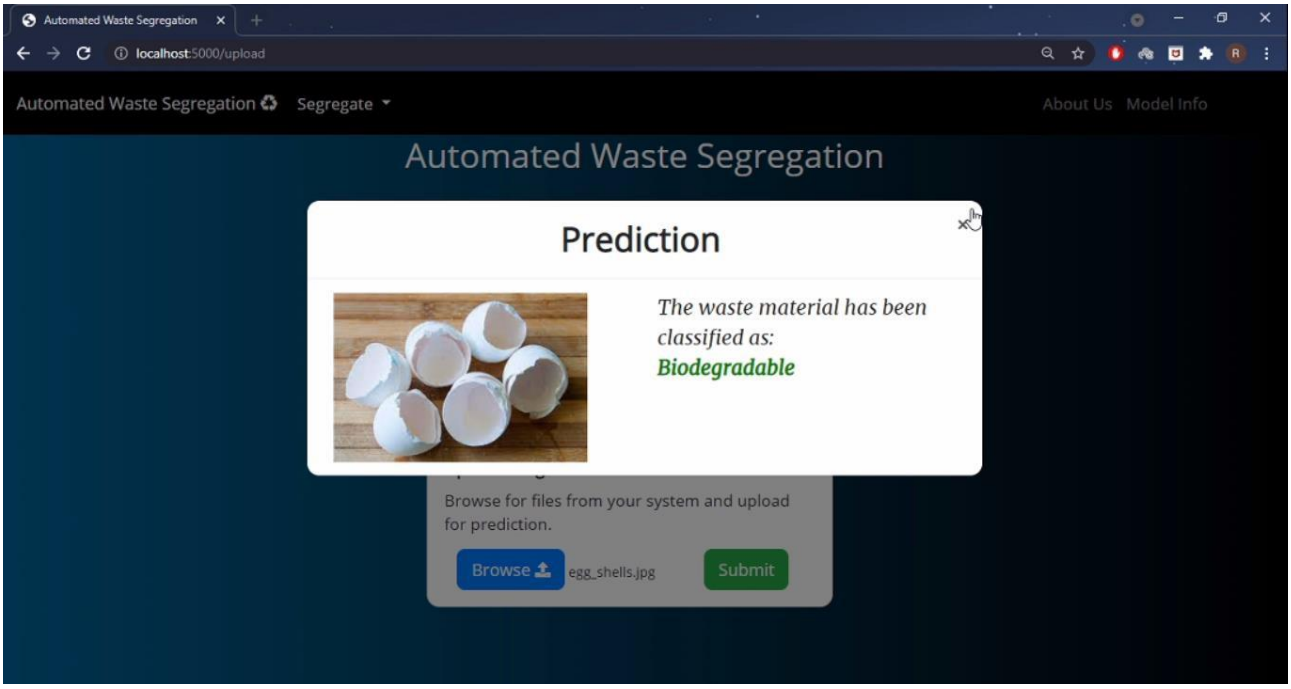


Fig. 9.6 Prediction Result for Biodegradable Object

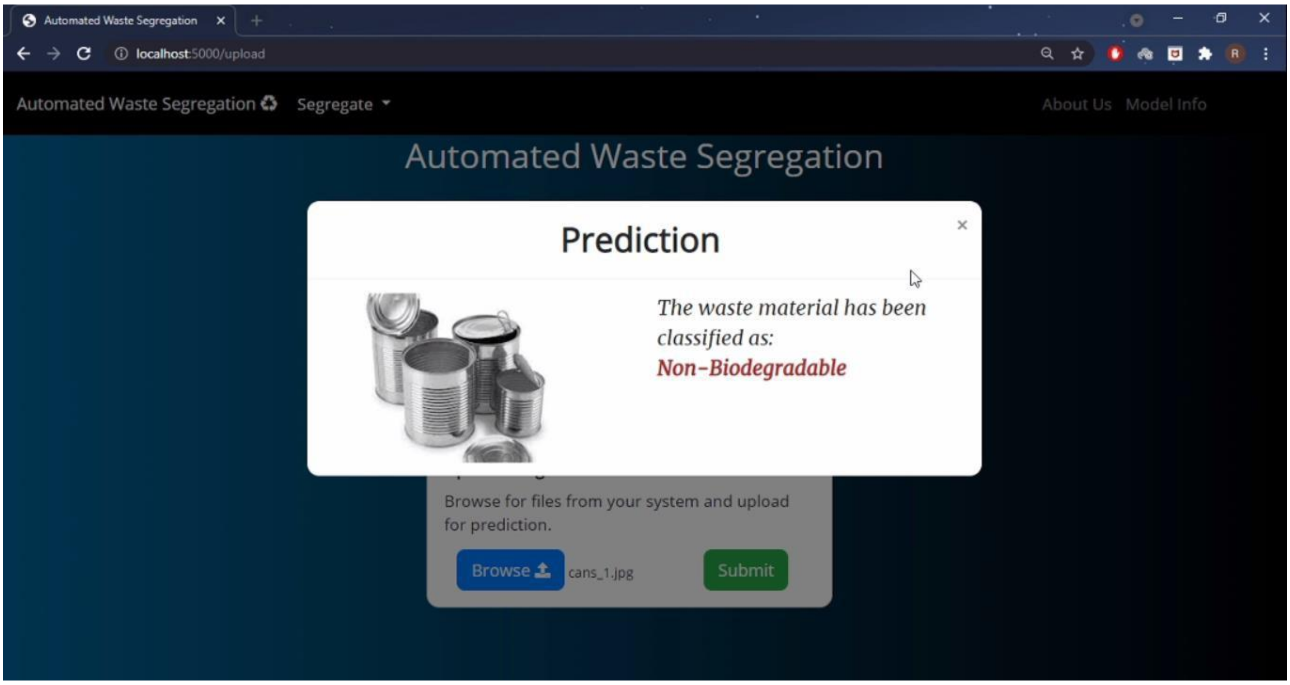


Fig. 9.7 Prediction Result for Non-biodegradable Object

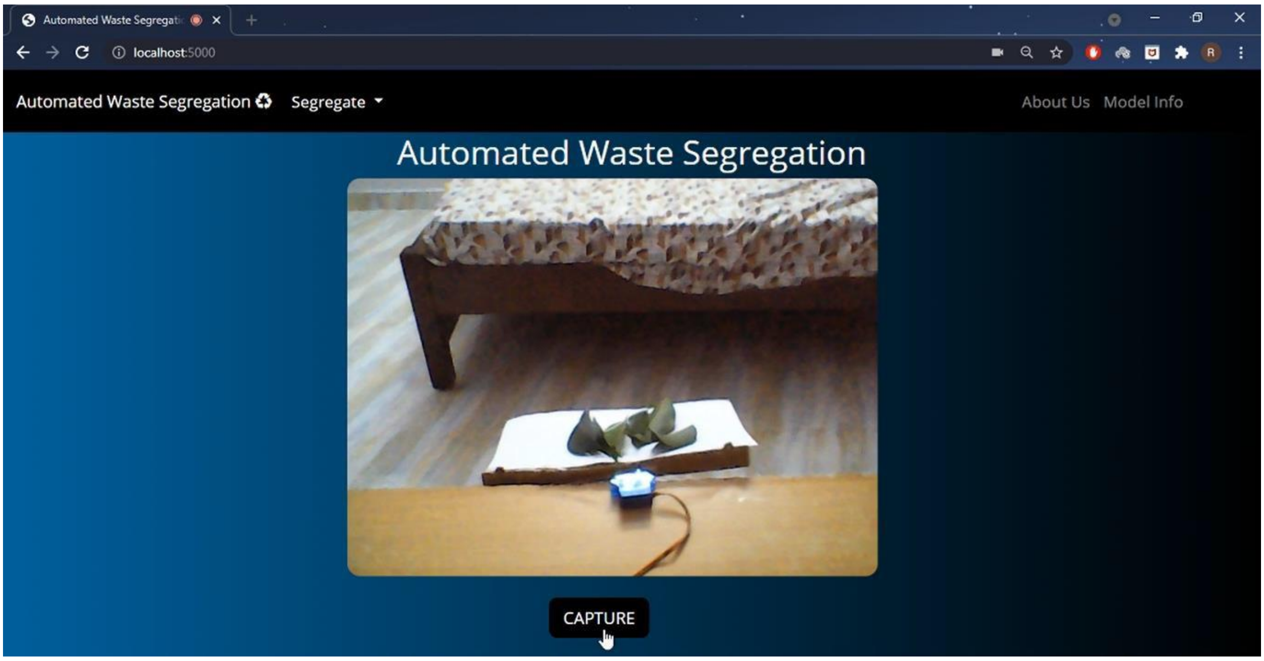


Fig. 9.8 Capture Image

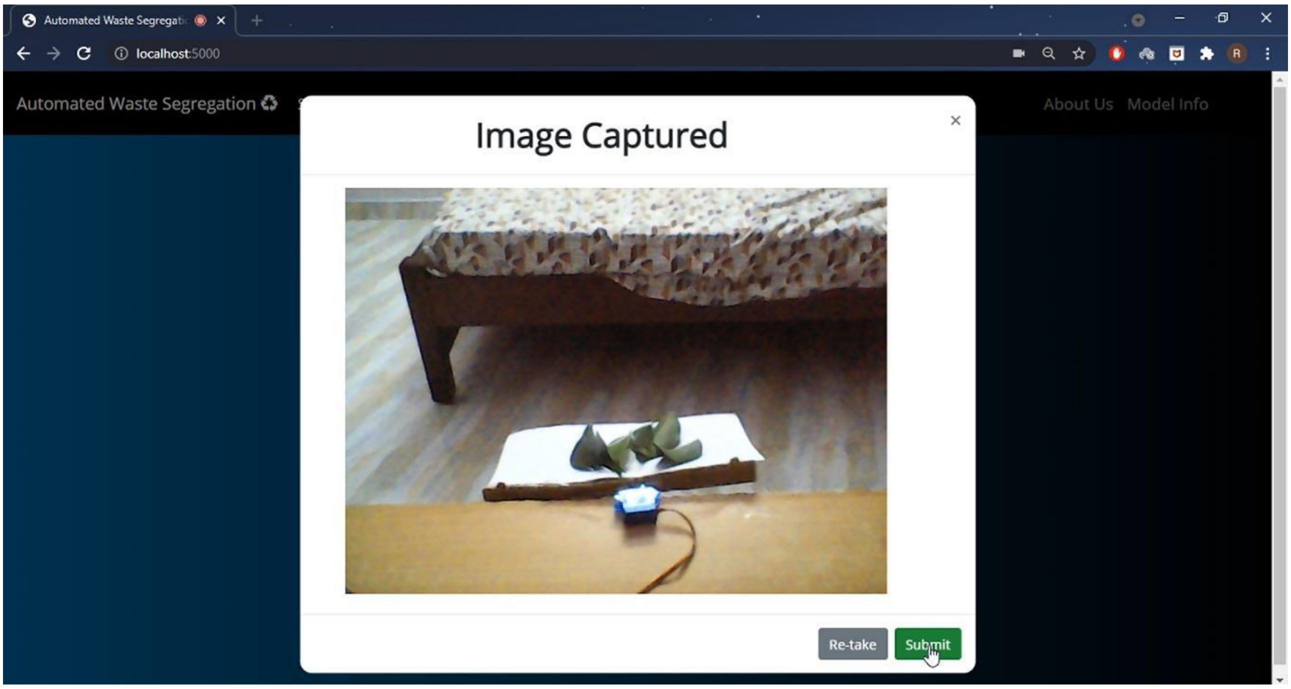


Fig. 9.9 Captured Image for Submission and Prediction

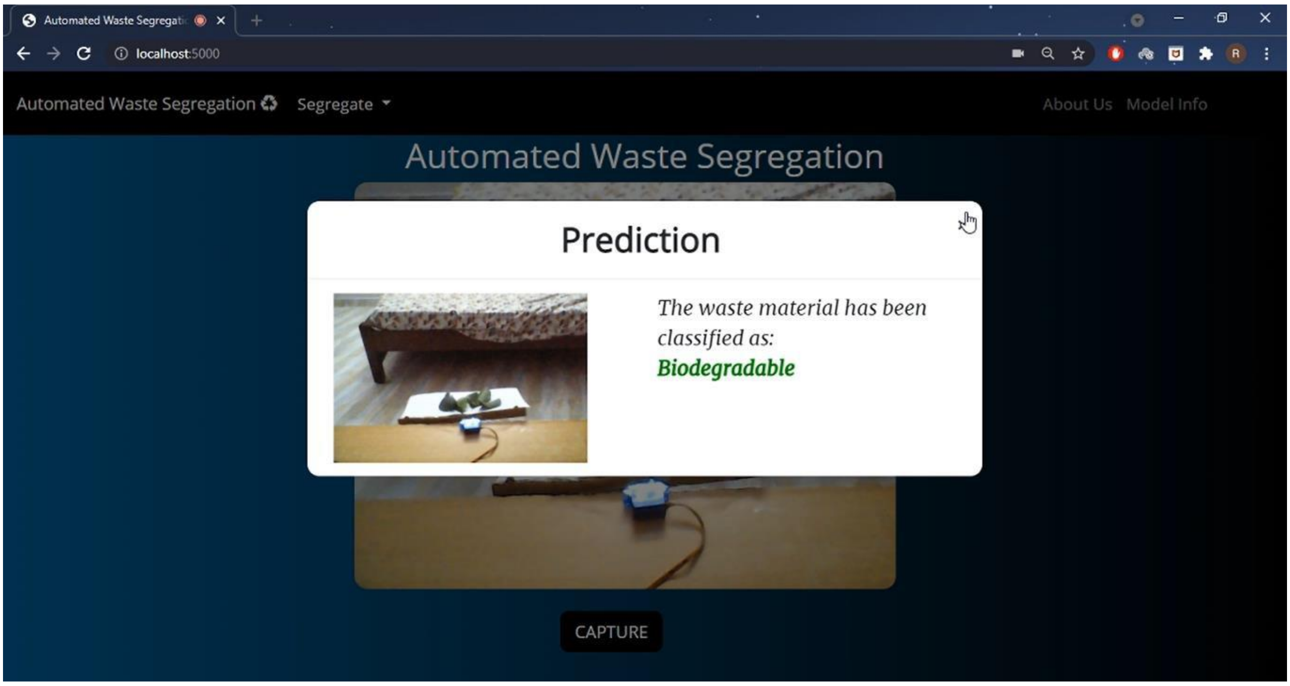


Fig. 9.10 Prediction Result for Captured Image

Fig. 9.11 Biodegradable object falling into the appropriate bin

Fig. 9.12 Non-biodegradable object falling into the appropriate bin

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