Intelligent Garbage Classification using Deep Learning

(An IBM Project)

In partial fulfillment for the Course

SB8040 - PROFESSIONAL READINESS FOR INNOVATION, EMPLOYABILITY AND ENTREPRENEURSHIP (NAAN MUDHALVAN)

PROJECT REPORT

Submitted by

HEMA HARIHARAN S	**513520104009**
MADHAN RAJ R	**513520104021**
JEEVANANDHAM S	**513520104012**
GURUPRASATH J	**513520104006**

BACHELOR OF ENGINEERING IN

COMPUTER SCIENCE AND ENGINEERING

ANNAI MIRA COLLEGE OF ENGINEERING & TECHNOLOGY,

ARAPAKKAM, RANIPET – 632517

ANNA UNIVERSITY: CHENNAI 600025

MAY – 2023

BONAFIDE CERTIFICATE

Certified that this project report **"INTELLIGENT GARBAGE CLASSIFICATION USING DEEP LEARNING"** is the bonafide work of **"HEMA HARIHARAN S (513520104009), MADHAN RAJ R (513520104021), JEEVANANDHAM S (513520104012), GURUPRASATH J (513520104006)"** who carried out the project work under my supervision.

SIGNATURE

Mrs. A. SATHYA, M.E.,
MENTOR

Dept. of Computer Science and Engineering
Annai Mira College of Engineering and Technology, Arapakkam,
Ranipet - 632517

SIGNATURE

Dr. D. SARAVANAN, Ph.D.,
SPOC

Dept. of Electrical and Electronic Engineering
Annai Mira College of Engineering and Technology, Arapakkam,
Ranipet - 632517

INTERNAL EXAMINER

EXTERNAL EXAMINER

Project Report Format

1. INTRODUCTION

- 1.1 Project Overview
- 1.2 Purpose

2. IDEATION & PROPOSED SOLUTION

- 2.1 Problem Statement Definition
- 2.2 Empathy Map Canvas
- 2.3 Ideation & Brainstorming
- 2.4 Proposed Solution

3. REQUIREMENT ANALYSIS

- 3.1 Functional requirement
- 3.2 Non-Functional requirements

4. PROJECT DESIGN

- 4.1 Data Flow Diagrams
- 4.2 Solution & Technical Architecture
- 4.3 User Stories

5. CODING & SOLUTIONING (Explain the features added in the project along with code)

- 5.1 Feature 1
- 5.2 Feature 2
- 5.3 Database Schema (if Applicable)

6. RESULTS

- 6.1 Performance Metrics

7. ADVANTAGES & DISADVANTAGES

8. CONCLUSION

9. FUTURE SCOPE

10. APPENDIX

- Source Code
- GitHub & Project Video Demo Link
- Screenshots

INTRODUCTION

1.INTRODUCTION

1.1 Project Overview

The project "Intelligent Garbage Classification using Deep Learning" aims to develop a system that can accurately classify different types of garbage based on images. The system utilizes deep learning techniques to train a model that can identify whether an item belongs to categories such as cardboard, glass, metal, paper, plastic, or trash.

1.2 Purpose

The purpose of this project is to address the problem of proper waste management and recycling. By automatically classifying garbage items, the system can assist in sorting and recycling processes, contributing to a more sustainable and eco-friendly environment.

IDEATION & PROPOSED SOLUTION

2.IDEATION & PROPOSED SOLUTION

2.1 Problem Statement Definition

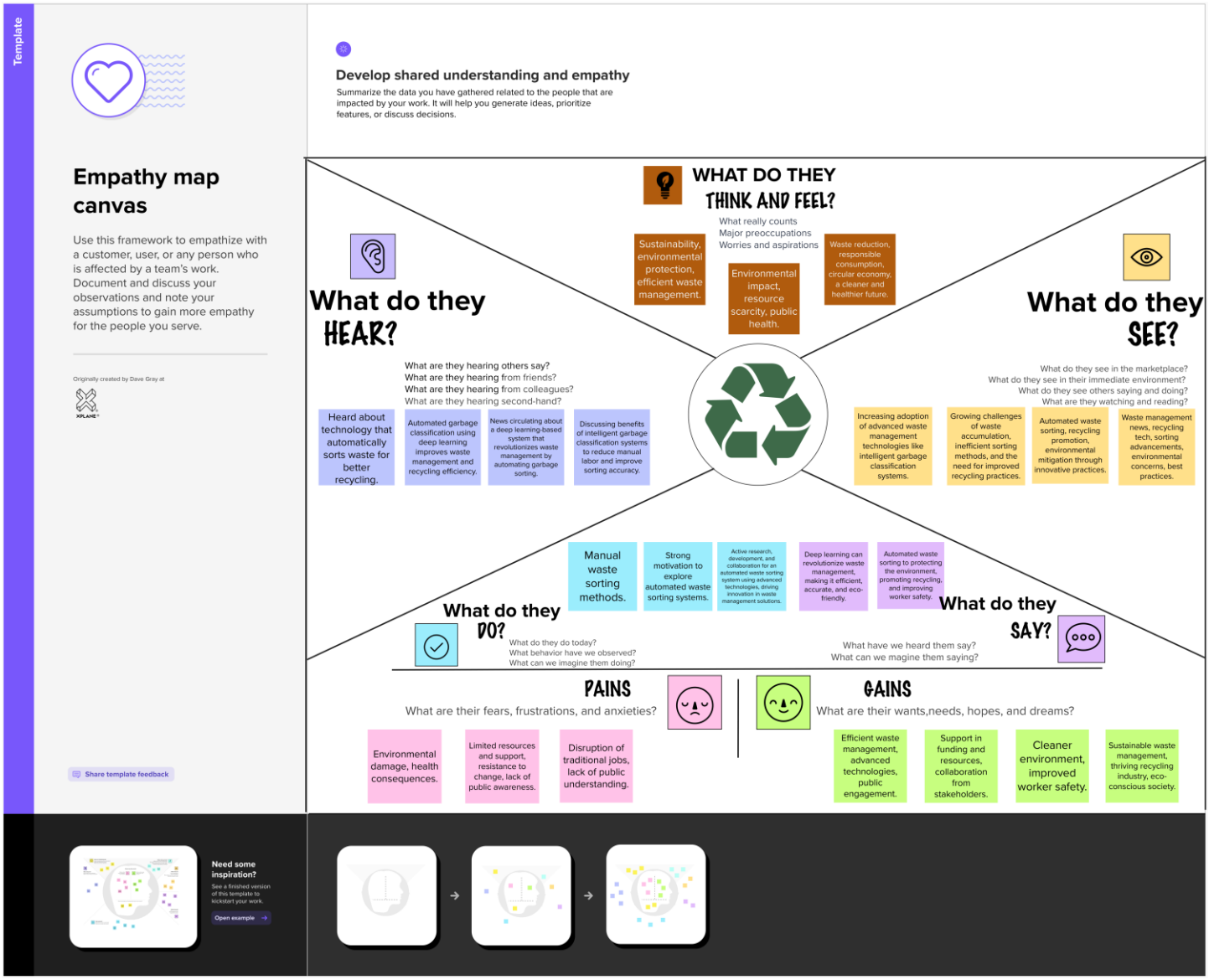
The problem addressed by this project is the difficulty in accurately classifying different types of garbage manually. Manual sorting can be time-consuming and prone to errors, leading to improper waste management practices.

Problem Statement (PS)	I am (Customer)	I'm trying to	But	Because	Which makes me feel
PS-1	Waste management worker	Accurately classify different garbage	Manual sorting is time-consuming	It leads to inefficiency and errors in waste management	Frustrated and inefficient
PS-2	Recycling facility owner	Efficiently sort and recycle garbage	No automated garbage classification	Manual sorting is inefficient and unreliable	Overwhelmed and hindered
PS-3	Environmental activist	Promote proper waste management	Lack of technology for garbage sorting	Inadequate waste management harms the environment	Concerned for the environment
PS-4	Municipality	Improve waste management practices	Inaccurate manual garbage classification	Inefficient waste management affects the community	Struggling with waste issues
PS-5	General public	Contribute to a sustainable environment	Difficulty identifying recyclable items	Lack of awareness and guidance for recycling	Unsure about proper disposal
PS-6	Waste collection company	Optimize garbage collection routes	Inefficient route planning	Ineffective routing leads to delays and inefficiency	Inefficient and unproductive

PS-7	Educational institutions	Teach students about proper waste management	Limited practical examples and resources	Students lack hands-on experience with waste management	Limited understanding and engagement
PS-8	Packaging industry	Ensure accurate sorting of packaging materials	Lack of standardized classification methods	Inconsistent sorting affects recycling efficiency	Challenged in sustainable packaging efforts
PS-9	Research organizations	Conduct accurate waste composition studies	Manual sorting is prone to errors	Inaccurate data affects research outcomes	Hindered in waste analysis
PS-10	Waste management consultants	Provide effective waste management solutions	Limited automated tools for waste analysis	Lack of efficient solutions hinders waste management	Limited ability to offer optimal solutions

2.2 Empathy Map Canvas

The empathy map canvas helps in understanding the users' perspectives and needs. It considers the thoughts, feelings, actions, and motivations of the users involved in waste management and recycling processes.



2.3 Ideation & Brainstorming

Through ideation and brainstorming sessions, the project team identified the use of deep learning techniques and image classification as a potential solution to automate garbage classification.

2

Brainstorm

Write down any ideas that come to mind that address your problem statement.

10 minutes

TIP

You can select a sticky note and hit the pencil [switch to sketch] icon to start drawing!

HEMA HARIHARAN S

- Managing and disposing of solid waste in a responsible and sustainable manner
- Addressing waste management challenges in densely populated urban areas.
- Sustainable waste management strategies for a better future.
- Promoting the reuse and conversion of waste materials into valuable resources
- Properly disposing of waste materials that cannot be recycled or reused.
- Utilizing monitoring systems to track and manage waste levels, enabling timely collection and disposal.
- Safeguarding public health by managing waste in a way that reduces risks and exposure to hazardous materials.
- Applying optimization algorithms to minimize collection routes, time, and fuel consumption.
- Safeguarding public health by effectively managing and disposing of waste materials.

MADHAN RAJ R

- Utilizing advanced technology solutions for intelligent garbage collection
- Safely handling and disposing of hazardous waste materials to prevent harm to human health and the environment.
- Analyzing data collected from waste management processes to identify patterns and optimize operations.
- Protecting the natural environment through proper waste management practices
- Encouraging the reuse and recycling of waste materials to reduce environmental impact.
- Embracing innovative approaches and technologies to revolutionize waste management practices.
- Implementing automated systems to streamline garbage collection and sorting operations.
- Encouraging collaboration among stakeholders to implement effective waste management solutions.
- Identifying cost-saving opportunities through efficient waste management practices.

JEEVANANDHAM S

- Separating different types of waste materials for effective recycling and disposal.
- Embracing a circular economy approach by promoting the recycling and reutilization of waste materials.
- Raising public awareness about the importance of proper waste disposal and recycling.
- Minimizing pollution and its harmful effects on air, water, and soil.
- Developing an integrated system that optimizes various aspects of garbage collection and waste management.
- **Engaging and involving various stakeholders, including government, residents, and businesses, in waste management efforts.**
- Categorizing waste into different components based on their recyclability and disposal requirements.
- Adhering to and enforcing waste management regulations and policies.
- Promoting a circular economy by emphasizing waste reduction, recycling, and resource recovery.

GURU PRASATH J

- Optimizing garbage collection processes to reduce time, cost, and environmental impact.
- Streamlining processes to maximize resource utilization and minimize waste.
- Providing educational programs to inform and educate communities about waste management best practices.
- Protecting the natural environment through proper waste management practices.
- Harnessing advanced technologies to improve waste management practices and efficiency.
- Encouraging the development of innovative technologies and solutions for waste management challenges.
- **Fostering sustainable waste management practices that balance economic, social, and environmental considerations.**
- Maximizing the use of available resources through efficient waste management processes.
- Encouraging active participation and involvement of the public in waste management initiatives.

3

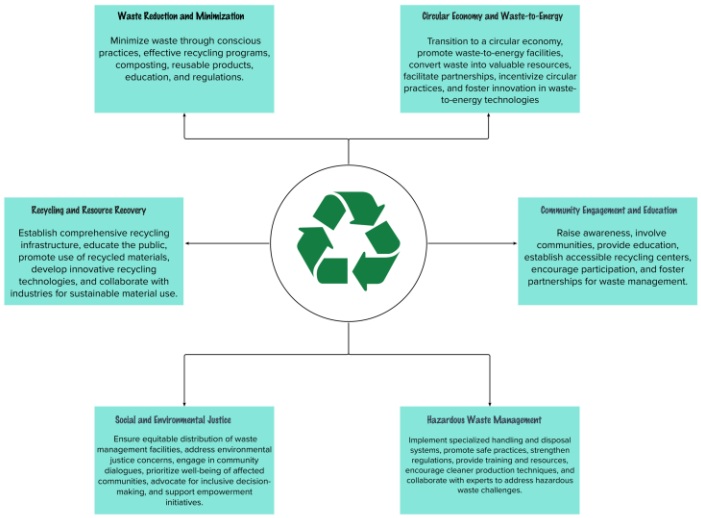
Group ideas

Take turns sharing your ideas while clustering similar or related notes as you go. Once all sticky notes have been grouped, give each cluster a sentence-like label. If a cluster is bigger than six sticky notes, try and see if you and break it up into smaller sub-groups.

20 minutes

TIP

Add customizable tags to sticky notes to make it easier to find, browse, organize, and categorize important ideas as themes within your mural.



4

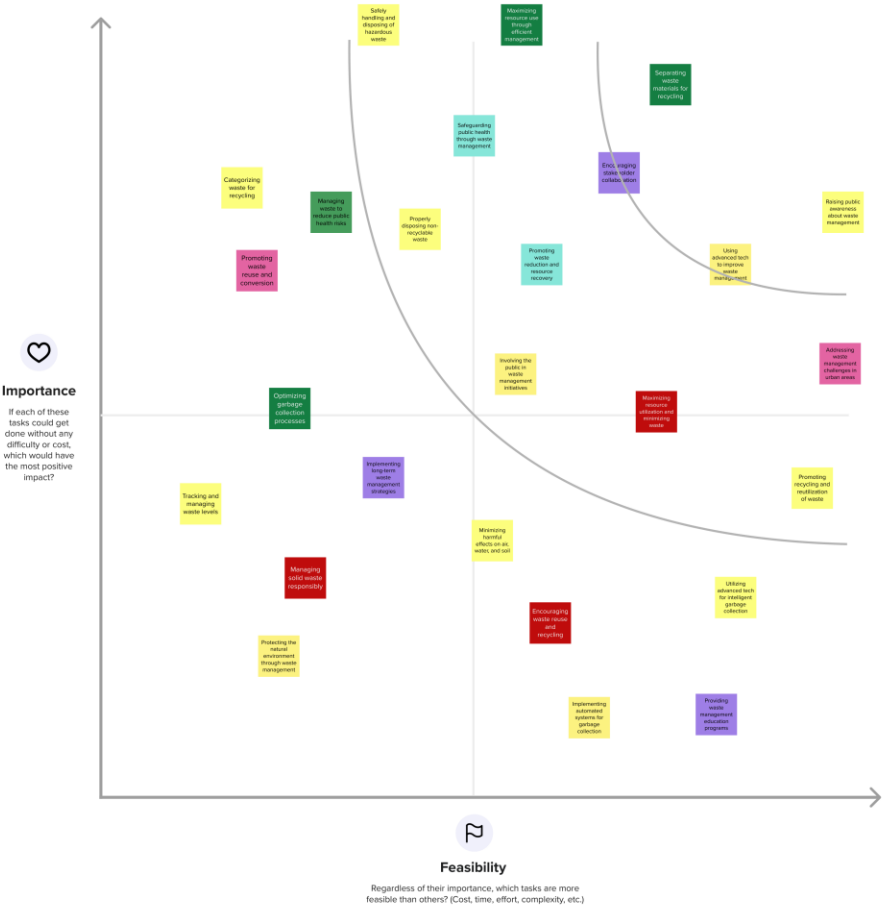
Prioritize

Your team should all be on the same page about what's important moving forward. Place your ideas on this grid to determine which ideas are important and which are feasible.

20 minutes

TIP

Participants can use their cursors to point at where sticky notes should go on the grid. The facilitator can confirm the spot by using the laser pointer holding the **H key** on the keyboard.



After you collaborate

You can export the mural as an image or pdf to share with members of your company who might find it helpful.

Quick add-ons

A **Share the mural**
Share a view link to the mural with stakeholders to keep them in the loop about the outcomes of the session.

B **Export the mural**
Export a copy of the mural as a PNG or PDF to attach to emails, include in slides, or save in your drive.

Keep moving forward

Strategy blueprint
Define the components of a new idea or strategy.
Open the template →

Customer experience journey map
Understand customer needs, motivations, and obstacles for an experience.
Open the template →

Strengths, weaknesses, opportunities & threats
Identify strengths, weaknesses, opportunities, and threats (SWOT) to develop a plan.
Open the template →

Share template feedback

2.4 Proposed Solution

The proposed solution is to develop a deep learning model that can classify garbage items based on their images. By training the model on a dataset of labeled images, it can learn to differentiate between different types of garbage and provide accurate classifications.

S.No.	Parameter	Description
1.	Problem Statement (Problem to be solved)	The project aims to address the problem of accurate garbage classification, which is currently a time-consuming and error-prone process. Manual sorting of garbage items can lead to improper waste management practices. The project seeks to automate the classification using deep learning techniques and image recognition to improve waste management and recycling processes.
2.	Idea / Solution description	The proposed solution involves developing a deep learning model that can classify garbage items based on their images. By training the model on a labeled dataset, it can learn to differentiate between different types of garbage, such as cardboard, glass, metal, paper, plastic, and trash. Users can upload images of garbage items through a user interface, and the system processes the images to provide accurate classification results.
3.	Novelty / Uniqueness	The novelty of this project lies in the application of deep learning and image recognition techniques to automate garbage classification. By using a deep learning model, the system can learn from a dataset and make accurate predictions based on new input images. This automation improves efficiency and reduces human error in waste management processes.
4.	Social Impact / Customer Satisfaction	The project has a significant social impact by promoting proper waste management and recycling practices. By automating garbage classification, the system assists in creating a more sustainable and eco-friendly environment. It simplifies the process for users, reduces the burden of manual sorting, and encourages individuals to participate in recycling initiatives.
5.	Business Model (Revenue Model)	The project report does not mention a specific revenue model. However, potential revenue streams could include offering the system as a service to waste management companies or municipalities, charging a fee for access to the system or its API, or partnering with recycling organizations for collaborative initiatives.

6.	Scalability of the Solution	The proposed solution demonstrates scalability by being able to handle a large number of image uploads and classification requests simultaneously. The system's architecture and design allow for efficient processing and quick response times. As the system relies on deep learning techniques, it can be continuously improved and scaled up to handle a growing volume of data and new garbage classification categories.

REQUIREMENT ANALYSIS

3.REQUIREMENT ANALYSIS

3.1 Functional Requirements

- Image upload: Users should be able to upload images of garbage items for classification.
- Image processing: The system should preprocess the uploaded images to a standardized format suitable for the deep learning model.
- Garbage classification: The deep learning model should classify the garbage items into predefined categories.
- Result display: The system should display the classification result to the user.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	Image Upload	User interface for image upload
FR-2	Image Processing	Preprocessing of uploaded images
FR-3	Garbage Classification	Deep learning model for garbage classification
FR-4	Result Display	Display of classification result to the user

3.2 Non-Functional Requirements

- Accuracy: The classification model should achieve a high level of accuracy in identifying the correct garbage category.
- Speed: The system should process the uploaded images and provide the classification result within a reasonable time frame.
- User-friendly interface: The user interface should be intuitive and easy to use for users of varying technical backgrounds.
- Scalability: The system should be able to handle a large number of image uploads and classification requests simultaneously.

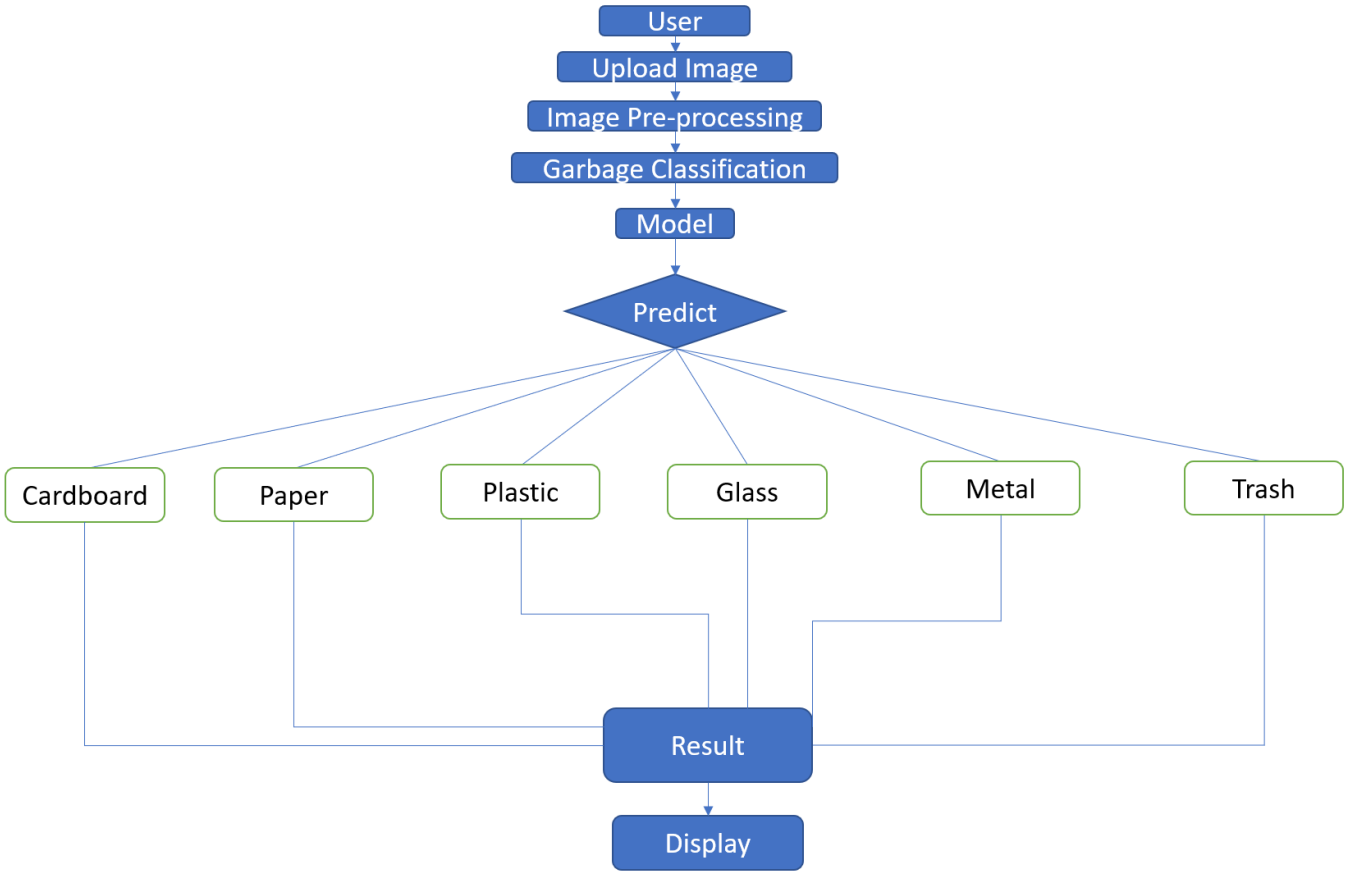
FR No.	Non-Functional Requirement	Description
NFR-1	Usability	The user interface should be intuitive and easy to use for users of varying technical backgrounds.
NFR-2	Security	The system should ensure the security of user registration information and uploaded images.
NFR-3	Reliability	The system should be reliable and perform consistently without errors.
NFR-4	Performance	The system should process the uploaded images and provide the classification result within a reasonable time frame.
NFR-5	Availability	The system should be available for users to access and use at any time.
NFR-6	Scalability	The system should be able to handle a large number of image uploads and classification requests simultaneously.

PROJECT DESIGN

4.PROJECT DESIGN

4.1 Data Flow Diagrams

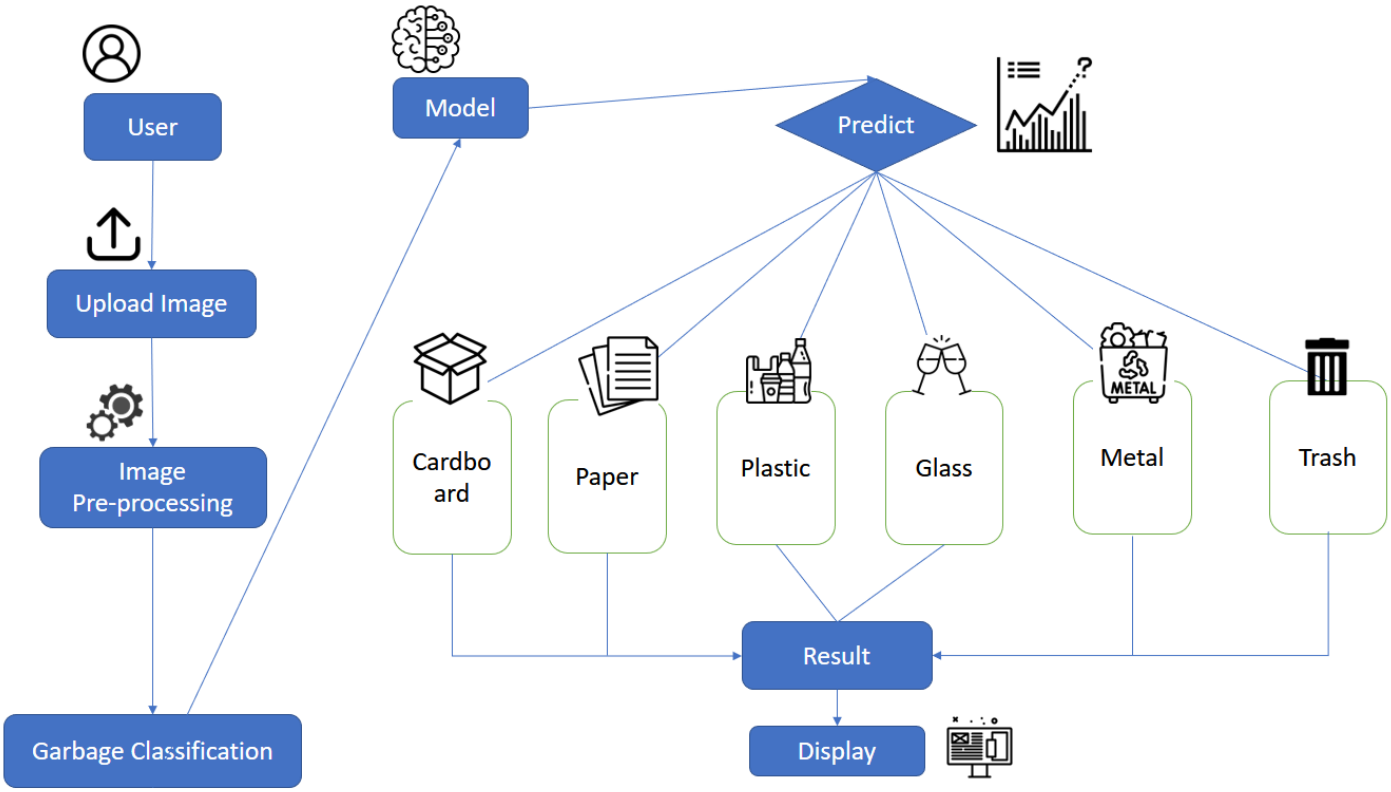
Data flow diagrams can provide a visual representation of how data flows within the system. They illustrate the interactions between different components and entities involved in the garbage classification process.



4.2 Solution & Technical Architecture

The solution architecture involves the following components:

- User interface: Allows users to upload images and view the classification results.
- Image processing module: Preprocesses the uploaded images to a suitable format for the deep learning model.
- Deep learning model: Performs the garbage classification based on the preprocessed images.
- Result display module: Shows the classification result to the user.



4.3 User Stories

User stories describe the functionality from the user's perspective. They help in defining the specific features and interactions expected by the users.

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance Criteria	Priority	Team Member
Customer (Mobile user)	Garbage Classification	USN-1	Upload image for classification	Select image from mobile device and successfully upload it	High	Hema Hariharan S
Customer (Mobile user)	Garbage Classification	USN-2	Image preprocessing for garbage classification	Uploaded image is preprocessed to a suitable format for classification	High	Hema Hariharan S
Customer (Mobile user)	Garbage Classification	USN-3	Accurate garbage classification	Classification result correctly identifies the category of the garbage item	High	Hema Hariharan S
Customer (Mobile user)	Garbage Classification	USN-4	Display classification result	Classification result is clearly and prominently displayed on the mobile interface	Medium	Jeevanadham S
Customer (Web user)	-	USN-5	Same functionality as mobile user to upload and classify garbage	Web interface allows uploading images, processing them, and displaying classification	High	Madhan Raj R
Administrator	-	USN-6	Access to dashboard with system statistics and performance metrics	Dashboard displays metrics such as accuracy, speed, and usage statistics of the system	Medium	Guruprasath J

CODING & SOLUTIONING

5. CODING & SOLUTIONING

5.1 Feature 1: Image Upload and Processing

In this feature, users can upload images of garbage items through the user interface. The system then preprocesses the uploaded images to a standardized format suitable for the deep learning model.

Code snippet for image upload and processing:

```
@app.route('/result',methods=["GET","POST"])
def res():
    if request.method=="POST":
        f=request.files['image']
        basepath=os.path.dirname(__file__) #getting the current path i.e where
app.py is present
        #print("current path",basepath)
        filepath=os.path.join(basepath,'uploads',f.filename) #from anywhere in
the system we can give image but we want that image later  to process so we are
saving it to uploads folder for reusing
        #print("upload folder is",filepath)
        f.save(filepath)

        img=image.load_img(filepath,target_size=(128,128))
        x=image.img_to_array(img)#img to array
        x=np.expand_dims(x,axis=0)#used for adding one more dimension
        #print(x)
```

5.2 Feature 2: Garbage Classification

In this feature, the deep learning model, trained on a dataset of labeled images, performs the classification of the garbage items. The model predicts the category of the garbage item based on the preprocessed image.

Code snippet for garbage classification:

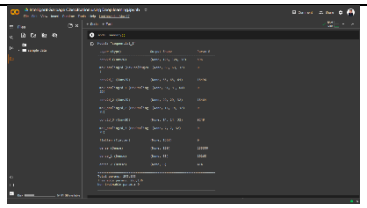
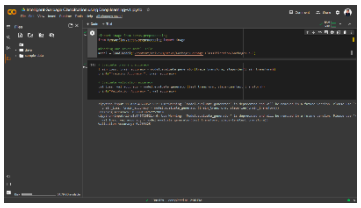
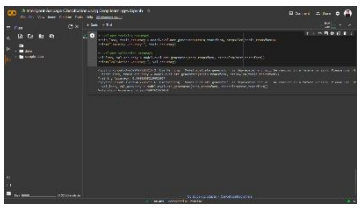
```
@app.route('/result',methods=["GET","POST"])
def res():
    if request.method=="POST":
        # Image upload and preprocessing code here

        prediction=np.argmax(model.predict(x), axis =1) #instead of
predict_classes(x) we can use predict(X) ---->predict_classes(x) gave error
        #print("prediction is ",prediction)
        index=["cardboard","glass","metal","paper","plastic","trash"]
        result = index[prediction[0].item()]
        result
        return render_template('prediction.html',prediction=result)
```

RESULTS

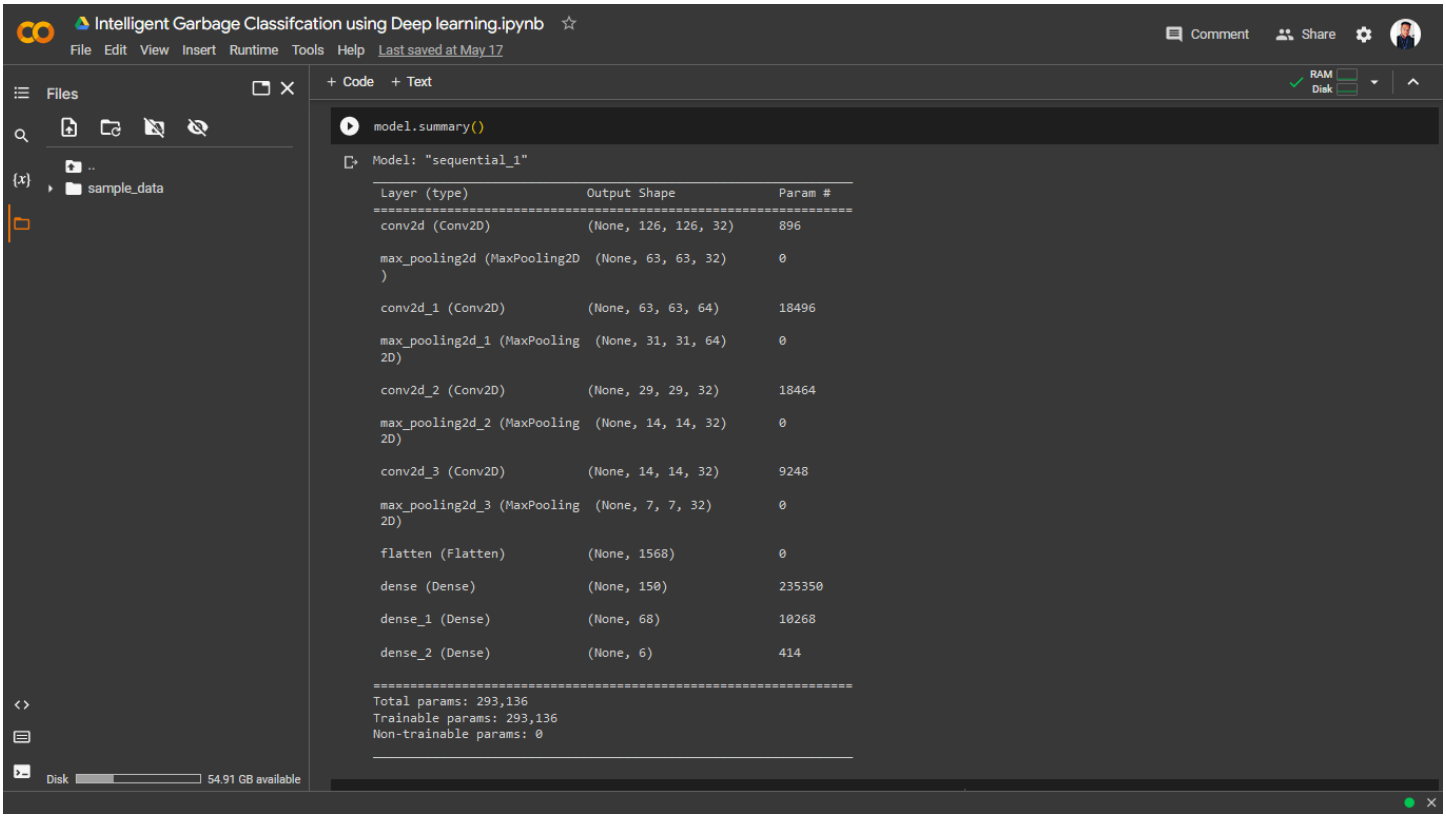
6.RESULTS

6.1 Performance Metrics

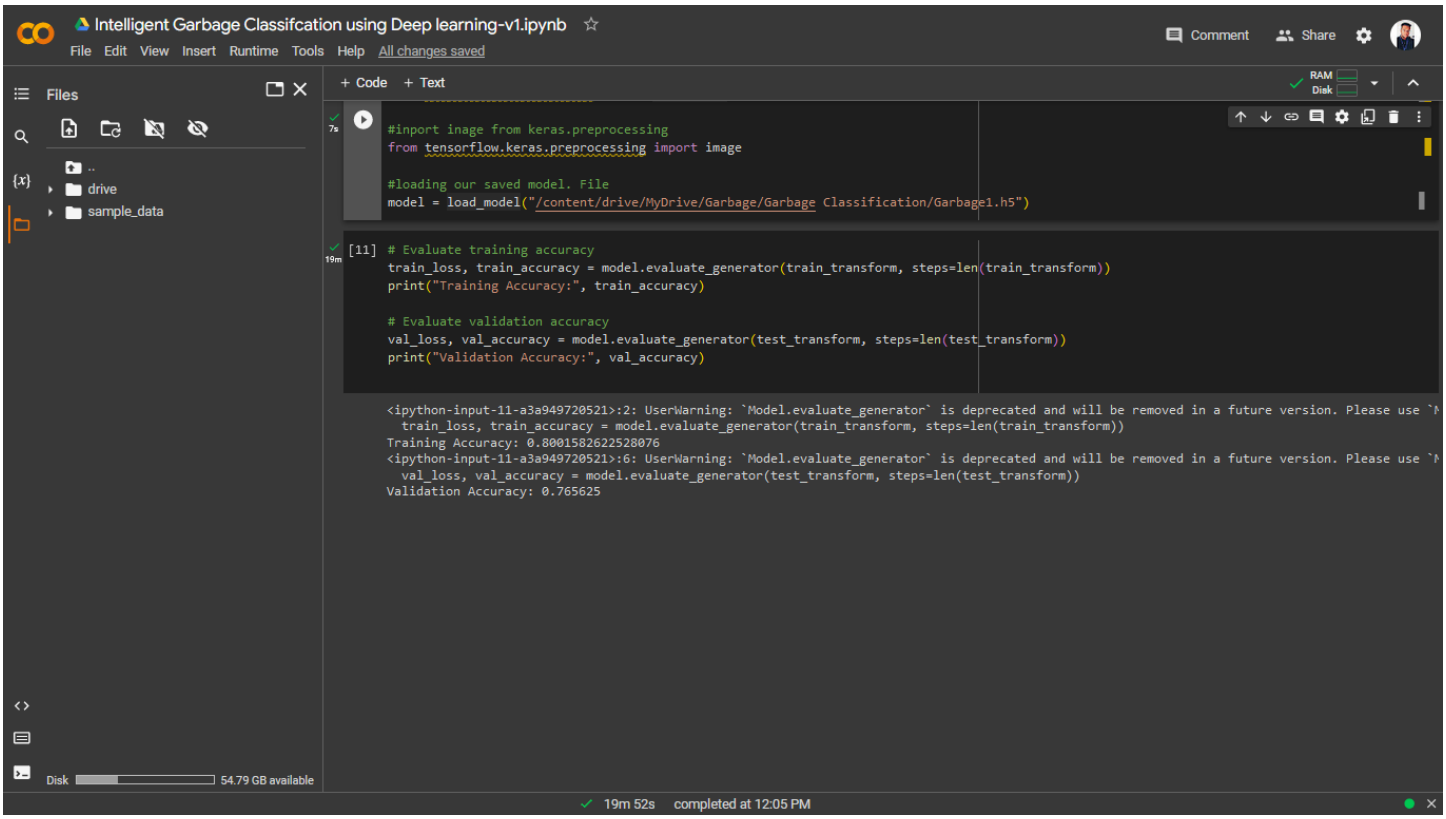
The performance of the deep learning model can be evaluated using various metrics such as accuracy, precision, recall, and F1 score. These metrics indicate the model's ability to correctly classify the garbage items.

S.No.	Parameter	Values	Screenshot
1.	Model Summary	-	
2.	Accuracy	Version 1 (V1) Training Accuracy - Training Accuracy: 79.5% Validation Accuracy - Validation Accuracy: 76.5% Version 2 (V2) Training Accuracy - Training Accuracy: 99.0% Validation Accuracy - Validation Accuracy: 99.3%	V1  V2 
3.	Confidence Score (Only Yolo Projects)	Class Detected - Confidence Score -	Remarks: Our project don't need yolo we use CNN alone

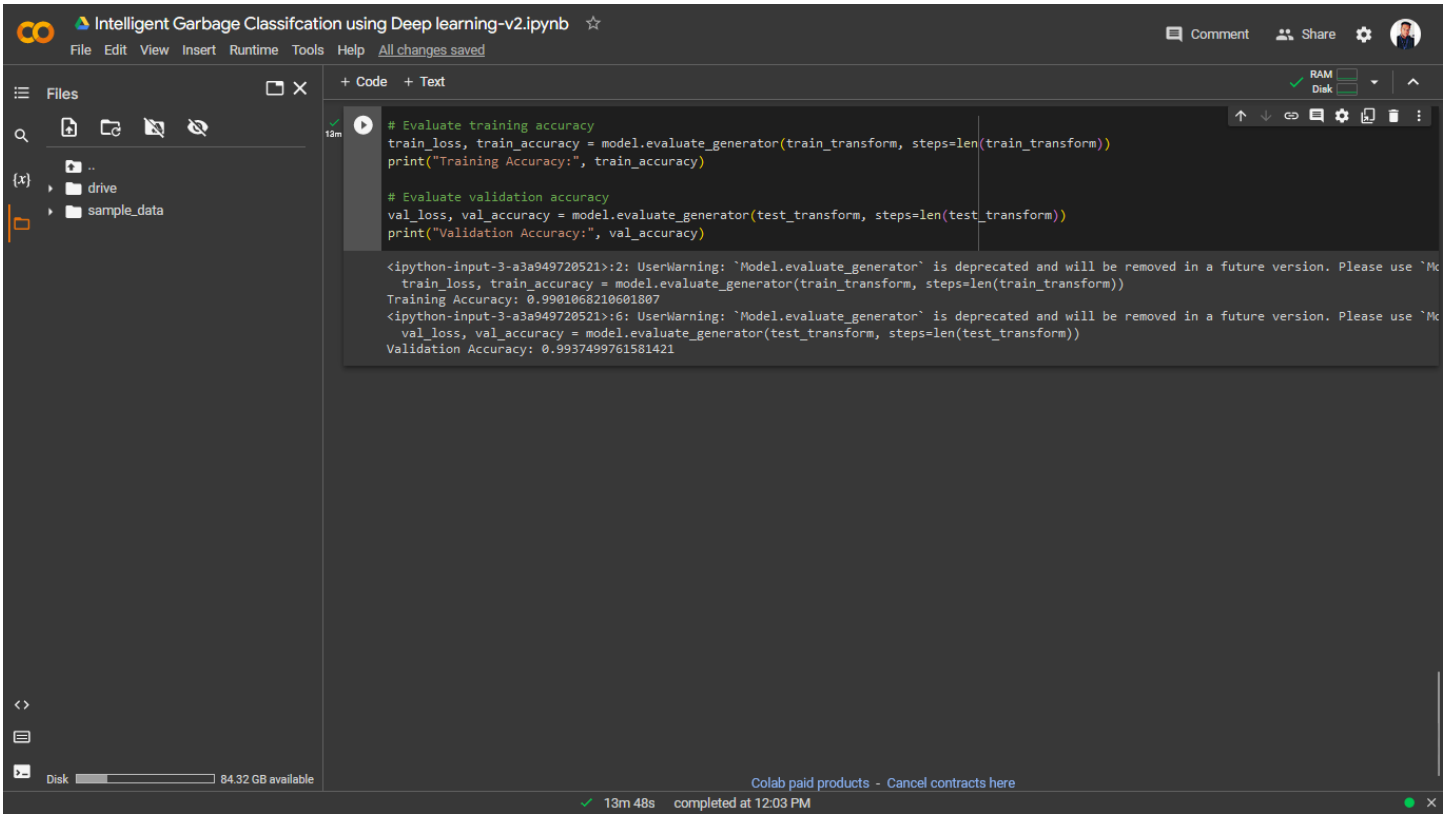
Model Summary



Accuracy V1



Accuracy V2


Intelligent Garbage Classifcation using Deep learning-v2.ipynb
File Edit View Insert Runtime Tools Help All changes saved
Comment
Share
Files
drive
sample_data
+ Code + Text
RAM
Disk
13m
Evaluate training accuracy
train_loss, train_accuracy = model.evaluate_generator(train_transform, steps=len(train_transform))
print("Training Accuracy:", train_accuracy)
# Evaluate validation accuracy
val_loss, val_accuracy = model.evaluate_generator(test_transform, steps=len(test_transform))
print("Validation Accuracy:", val_accuracy)
<ipython-input-3-a3a949720521>:2: UserWarning: `Model.evaluate_generator` is deprecated and will be removed in a future version. Please use `Mo
train_loss, train_accuracy = model.evaluate_generator(train_transform, steps=len(train_transform))
Training Accuracy: 0.9901068210601807
<ipython-input-3-a3a949720521>:6: UserWarning: `Model.evaluate_generator` is deprecated and will be removed in a future version. Please use `Mo
val_loss, val_accuracy = model.evaluate_generator(test_transform, steps=len(test_transform))
Validation Accuracy: 0.9937499761581421
Disk 84.32 GB available
Colab paid products - Cancel contracts here
13m 48s completed at 12:03 PM

ADVANTAGES & DISADVANTAGES

7. ADVANTAGES & DISADVANTAGES

Advantages:

- Automation: The system automates the garbage classification process, saving time and reducing human error.
- Sustainable Waste Management: Proper garbage classification contributes to effective waste management and recycling practices.
- Scalability: The system can handle a large number of image uploads and classification requests simultaneously.

Disadvantages:

- Dependency on Image Quality: The accuracy of the classification depends on the quality of the uploaded images.
- Limited Categories: The system is limited to the predefined categories of cardboard, glass, metal, paper, plastic, and trash.

CONCLUSION

8.CONCLUSION

The project "Intelligent Garbage Classification using Deep Learning" aims to automate the classification of garbage items based on their images. By implementing a deep learning model and providing a user-friendly interface, the system assists in proper waste management and recycling. The system demonstrates the potential to improve efficiency and contribute to a more sustainable environment.

FUTURE SCOPE

9.FUTURE SCOPE

- Expansion of Categories: The system can be enhanced to classify garbage items into more specific categories, allowing for more precise waste management.
- Mobile Application: Developing a mobile application version of the system would increase accessibility and usability for users.
- Continuous Improvement: Regular updates and improvements to the deep learning model can enhance the accuracy and performance of garbage classification.

APPENDIX

10. APPENDIX

Source Code:

```
import re
import numpy as np
import os
from flask import Flask, app,request,render_template
from tensorflow.keras import models
from tensorflow.keras.models import load_model
from tensorflow.keras.preprocessing import image
from tensorflow.python.ops.gen_array_ops import concat

#Loading the model
model=load_model("Garbage1k.h5")
app=Flask(__name__)


#default home page or route
@app.route('/')
def index():
    return render_template('index.html')

@app.route('/prediction.html')
def prediction():
    return render_template('prediction.html')

@app.route('/index.html')
def home():
    return render_template("index.html")

@app.route('/result',methods=["GET","POST"])
def res():
    if request.method=="POST":
        f=request.files['image']
        basepath=os.path.dirname(__file__) #getting the current path i.e where
app.py is present
        #print("current path",basepath)
        filepath=os.path.join(basepath,'uploads',f.filename) #from anywhere in
the system we can give image but we want that image later  to process so we are
saving it to uploads folder for reusing
        #print("upload folder is",filepath)
        f.save(filepath)

        img=image.load_img(filepath,target_size=(128,128))
        x=image.img_to_array(img)#img to array
        x=np.expand_dims(x,axis=0)#used for adding one more dimension
        #print(x)
```

```
        prediction=np.argmax(model.predict(x), axis =1) #instead of
predict_classes(x) we can use predict(X) ---->predict_classes(x) gave error
        #print("prediction is ",prediction)
        index=["cardboard","glass","metal","paper","plastic","trash"]
        result = index[prediction[0].item()]
        result
        return render_template('prediction.html',prediction=result)


""" Running our application """
if __name__ == "__main__":
    app.run(debug=True,port=8000)
```

Github Repo Link:

https://github.com/naanmudhalvan-SI/PBL-NT-GP--22314-1684156546

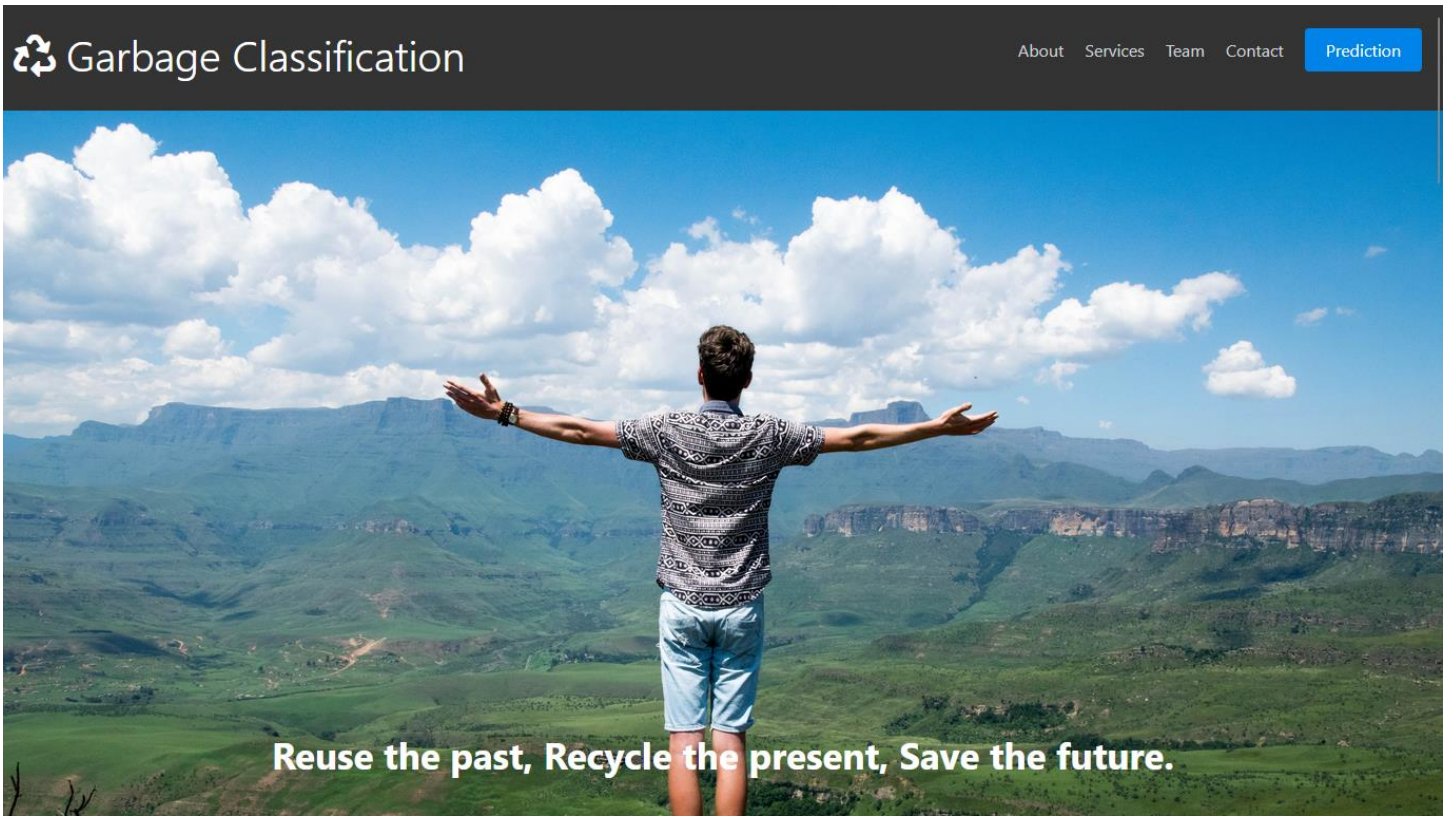
Demo Link:

https://youtu.be/FB_BSpv_Yjs

SCREENSHOTS

SAMPLE SCREENSHOTS

Home Page:



ABOUT PROJECT

Problem:

According to projections for the next 25 years, waste accumulation in less developed countries is expected to increase significantly. With the rise in industrialization in urban areas, the management of solid waste, including paper, wood, plastic, metal, and glass, has become a major challenge. The conventional method of waste disposal, such as burning waste, contributes to air pollution and the release of hazardous materials that can have detrimental effects on human health, including the risk of cancer. Therefore, there is a need to recycle waste and separate it into different components for efficient recycling processes.

Solution:

The current approach to waste separation involves manual sorting by individuals, which exposes them to health risks due to the harmful substances present in the garbage. To address this issue, our project aims to develop an automated waste sorting system. This system will significantly reduce the time required for waste sorting and enhance the accuracy of the process compared to manual methods. By implementing this automated system, the recyclable waste can be efficiently separated, allowing for its proper recycling and conversion into energy and fuel, thereby contributing to the growth of the economy. The proposed system is based on the utilization of a combination of Convolutional Neural Network (CNN) algorithms, which enables effective waste separation and classification.

WE CLASSIFY

CARDBOARD

Cardboard, also referred to as corrugated cardboard, is a recyclable material that is recycled by small and large scale businesses to save money on waste disposal costs.

GLASS

Glass is found in municipal solid waste (MSW), primarily in the form of containers such as beer and soft drink bottles; wine and liquor bottles; and bottles and jars for food, cosmetics and other products.

METAL

Metal waste/scrap waste can be subjected to the recycling process over and over again without changing its properties. Steel, for example, is one of the most recycled metals on the planet. Lorem ipsum dolor sit amet.

PAPER

Paper Waste is a severe problem in many industries and offices. Because of printing mistakes, junk mails, billings, and packaging.

PLASTIC

Plastic waste, or plastic pollution, is the accumulation of plastic objects in the Earth's environment that adversely affects wildlife, wildlife

TRASH

Trash, rubbish, or refuse is waste material that is discarded by humans, usually due to a perceived lack of utility. Lorem ipsum dolor sit amet.

WE ARE

HEMA HARIHARAN S

Team Lead

Deep Learning Developer

MADHAN RAJ R

Team Member

Documentation Specalist

JEEVANANDHAM S

Team Member

Graphics Designer

GURUPRASATH

Team Member

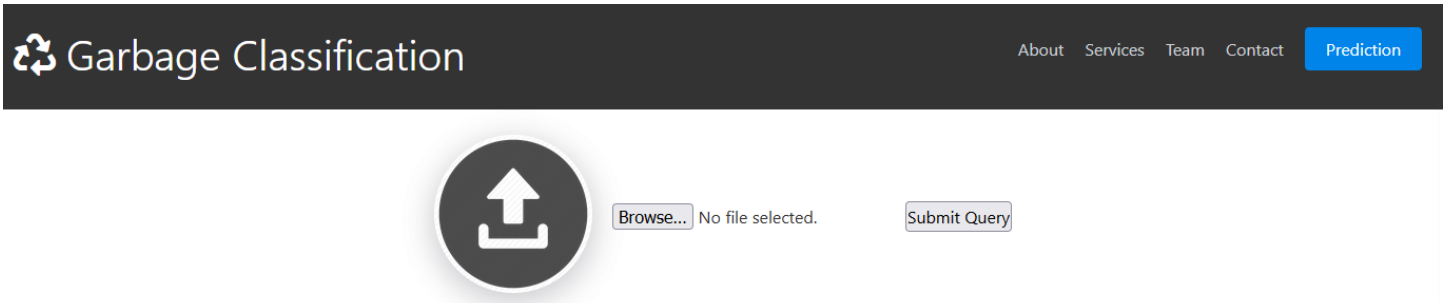
Assistive Technology Coordinator

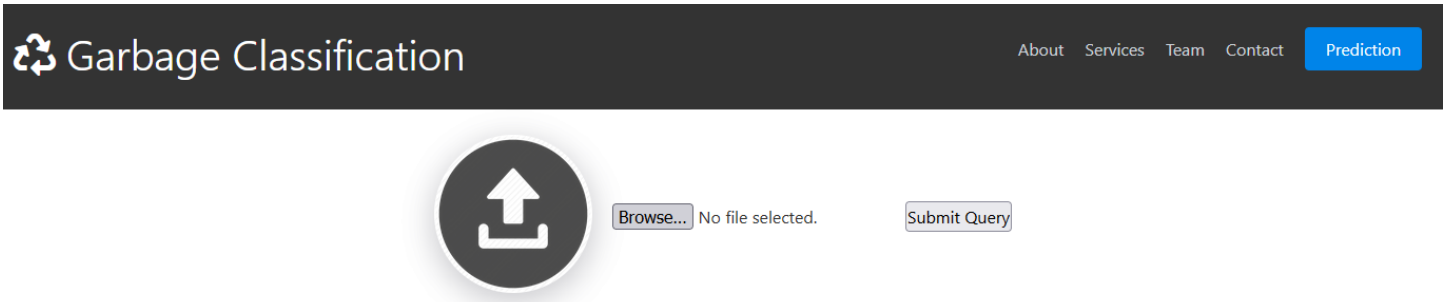
CONTACT US

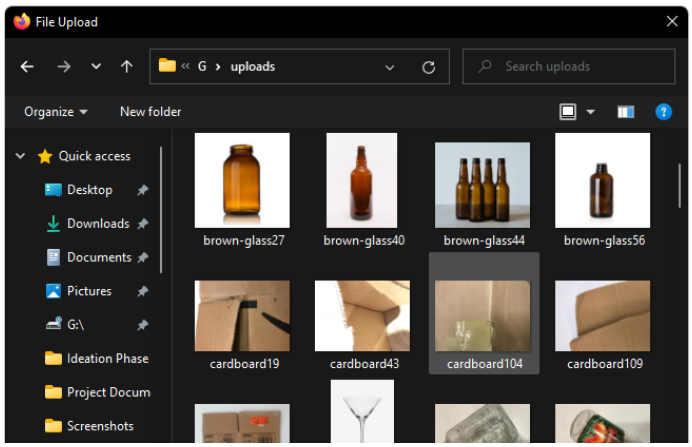
Enquiries: hemahariharansamson@gmail.com

Call Us: +919080602796

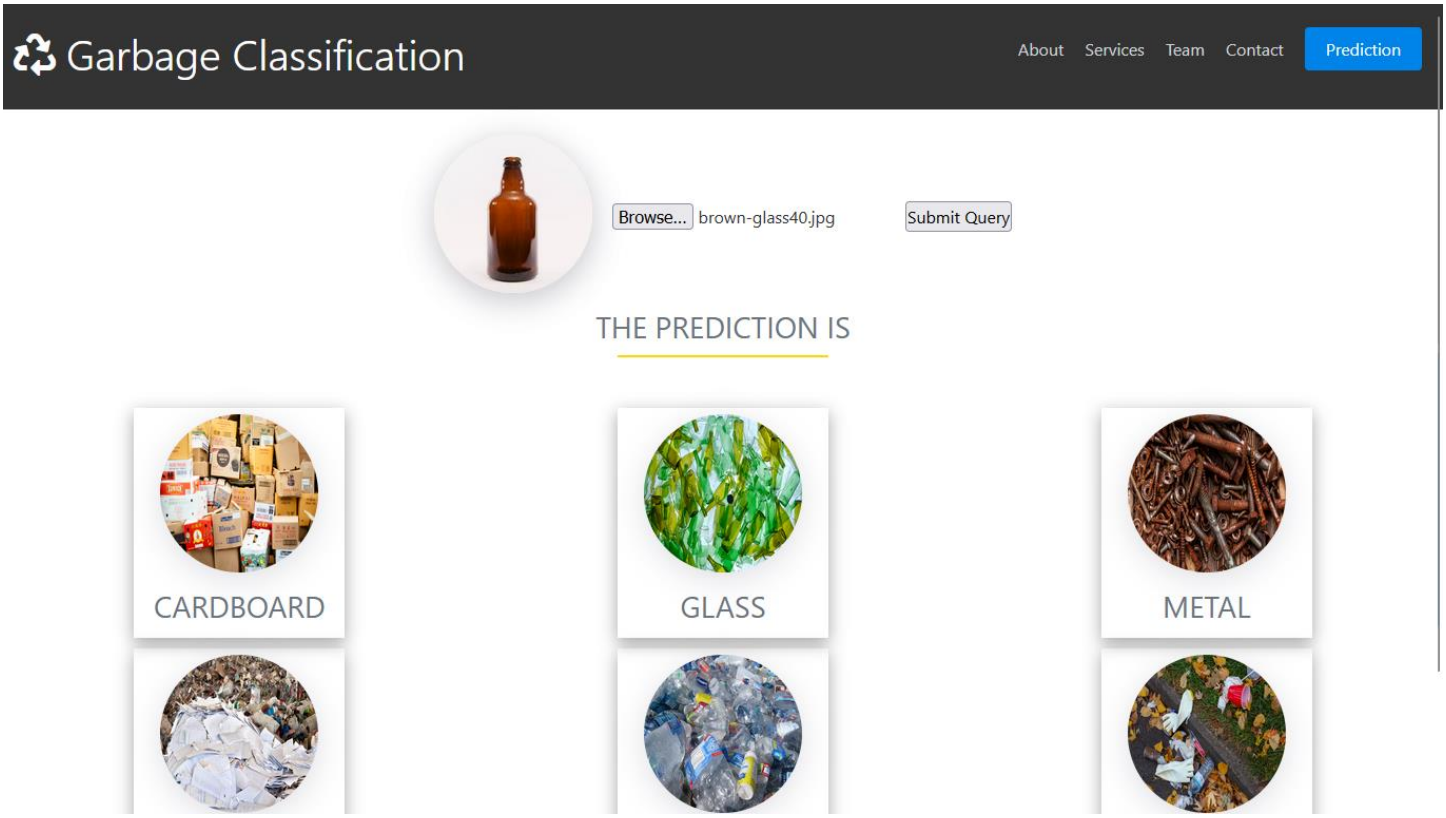
Prediction Page:



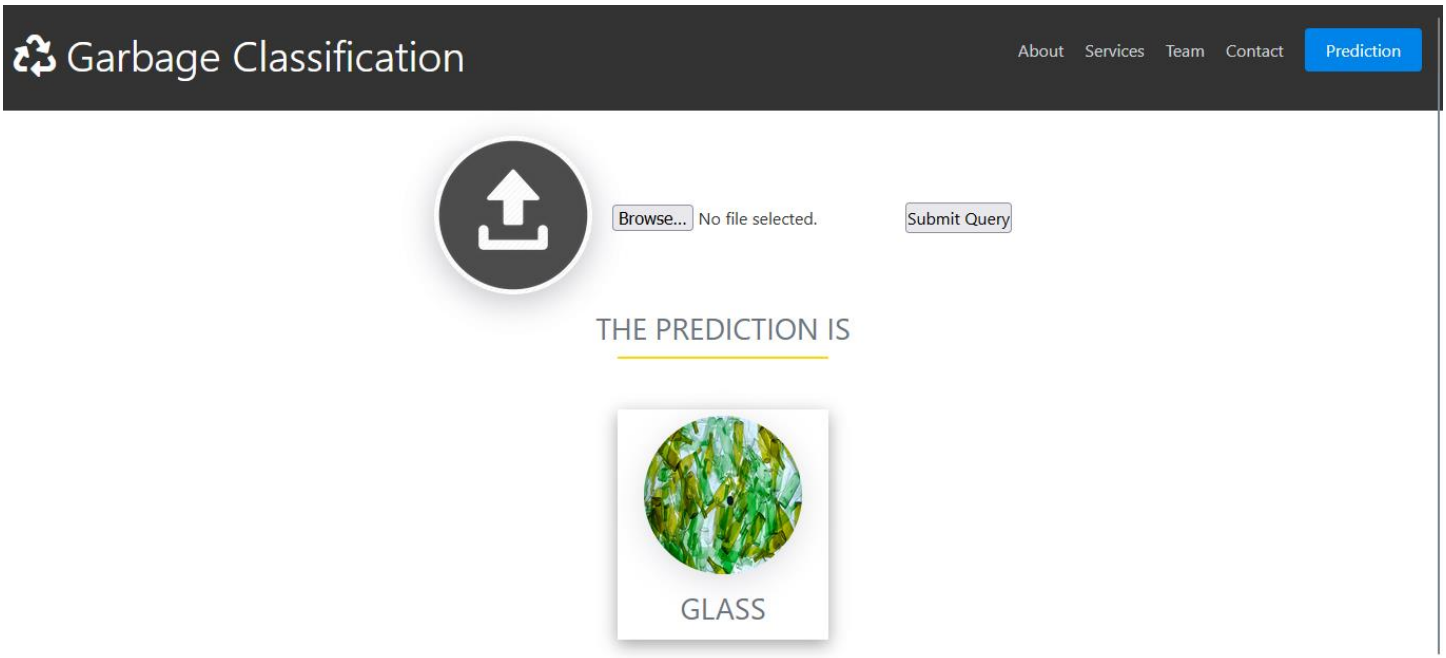




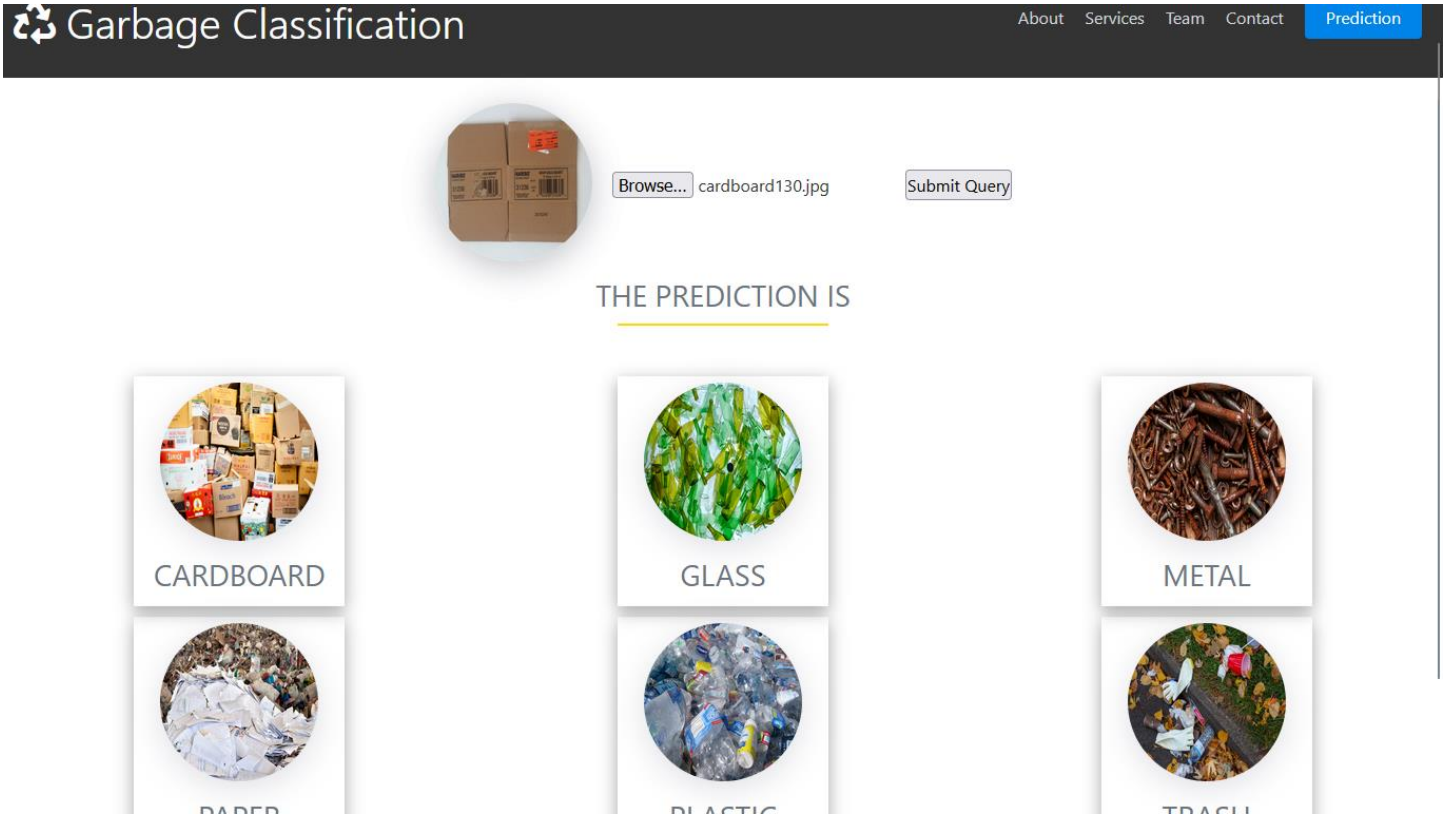
Input:



Output:



Input:



Output: