CLEANTECH: TRANSFORMING WASTE MANAGEMENT WITH TRANSFER LEARNING

By:

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1. INTRODUCTION

1.1Project Overview:

In a world generating over **2 billion tons of waste each year**, one question remains unanswered:
"What if garbage could sort itself?"

Rather than relying on manual segregation, our system uses a pretrained deep-learning to see and understanding like a human would. Snap a picture of your trash whether it's a banana peel, plastic bottle, or broken charger and the system instantly tells you where it belongs.

Built with a scalable web interface (Flask +CSS), this tool is:

- **Fast** – Real-time waste recognition in seconds
- **Sustainable** – Promotes proper recycling at source
- **Smart** – Learns and adapts via transfer learning
- **Accessible** – Usable by anyone, anywhere with a phone or PC

1.2 Purpose:

The purpose of this project is to simplify waste segregation using Artificial Intelligence. By leveraging transfer learning, the system enables users to instantly classify waste through image input and receive appropriate guidance for disposal. This solution promotes smart recycling, reduces landfill accumulation, and fosters eco-conscious behavior all through an accessible and technology-driven approach.

2.IDEATION PHASE

2.1 Define the Problem Statements:

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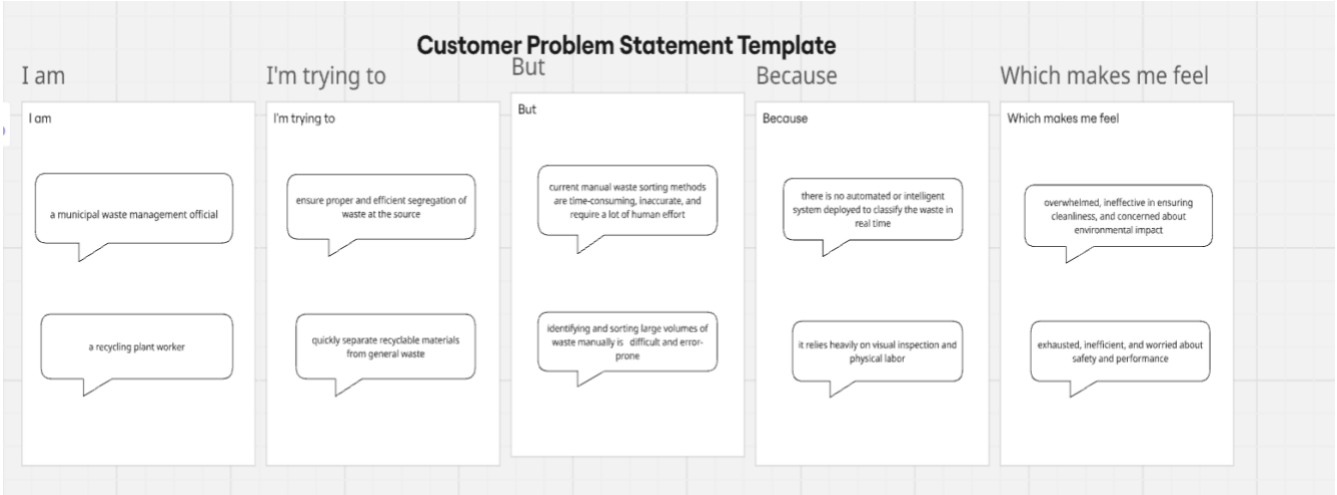
Maximum Marks	2 Marks

Manual waste segregation is time-consuming and prone to error, leading to poor recycling and environmental harm. This project aims to automate waste classification using transfer learning on image data, enabling faster and smarter disposal decisions through a simple, accessible web interface.

Problem Statement (PS)	I am (Customer)	I'm trying to	But	Because	Which Makes me feel
PS-1	A responsible citizen	dispose of my waste correctly	I don't know which type of waste it is	most packaging lacks clear disposal instructions	confused, guilty, and helpless
PS-2	A municipal worker	sort waste collected from public bins	bins are filled with mixed waste	people don't follow segregation due to lack of awareness	stressed, exhausted



2.2 Empathize & Discover:

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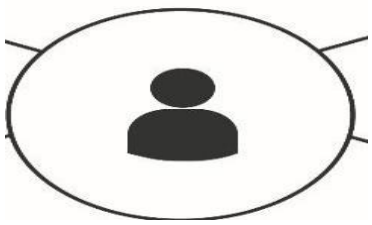
Maximum Marks	4 Marks

The empathy map outlines user concerns and behaviors:

- **Says**: "I want a quick and simple way to know where to throw this."
  "Why are there so many types of waste bins?"
- **Thinks**: "Am I disposing of this correctly?"
  "Will this harm the environment if I throw it wrong?"
  "Is there an app that can help me identify the waste type?"
- **Does**: Uploads a photo of waste using the app.
  Disposes waste with limited knowledge about correct segregation.
- **Feels**: Confused about disposal rules.
  Guilty about environmental impact.
  Frustrated by lack of clear instructions.

<table>
<tr><td></td><td>What does the user THINK & FEEL?
• Worries about polluting the environment
• Unsure about proper waste disposal
• Wants simple, reliable guidance</td><td></td></tr>
<tr><td>What does the user SEE?
• Unclear bin labels
• Mixed waste in public areas
• Confusing segregation instructions</td><td>  </td><td>What does the user HEAR?
• Cleanliness campaigns
• Social media tips
• Community awareness drives</td></tr>
<tr><td>PAIN
• Confusion in waste types
• Lack of real-time help
• Improper segregation practices</td><td></td><td>GAIN
• Instant waste type prediction
• Better recycling habits
• Empowerment through awareness</td></tr>
</table>

2.3 Brainstorm & Idea Prioritization:

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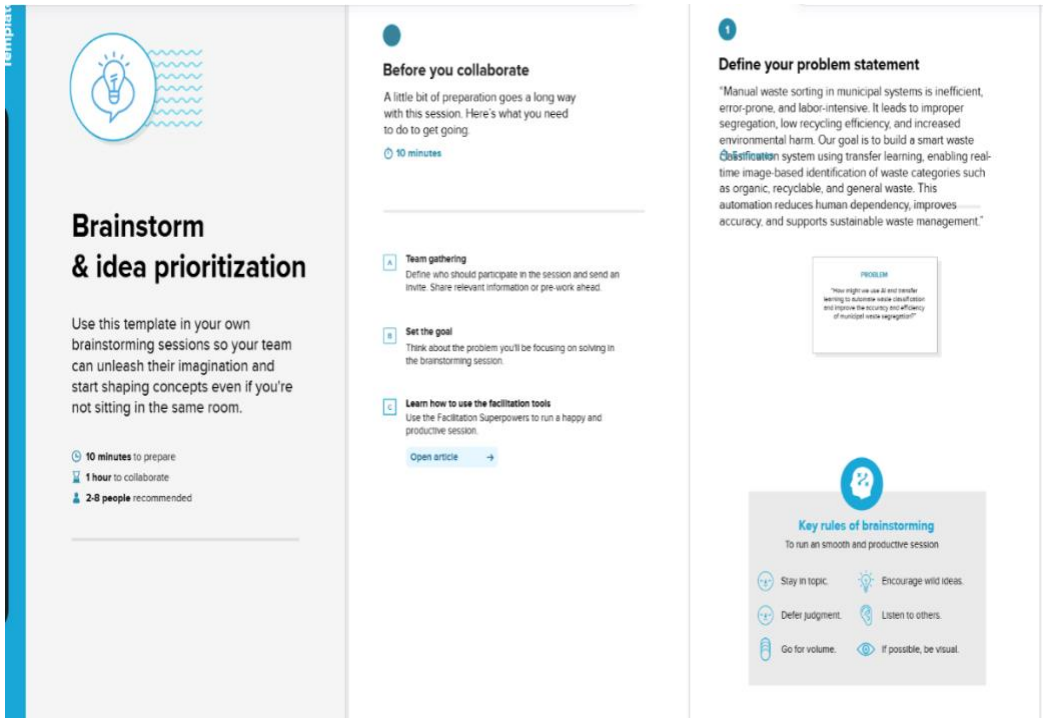
We brainstormed various ideas:

- AI-based waste classification using transfer learning
- Visual display of waste category with disposal guide
- OCR support for reading printed waste labels
- Integration with smart bin systems or mobile cameras



Idea Area	**Potential Solutions**
User Input Method	Design an intuitive UI for uploading waste images via camera or file upload.
Prediction Method	Apply transfer learning using pretrained CNN models (e.g., MobileNet, ResNet) for accurate classification.
Accessibility	Deploy the application online using platforms like Render to ensure cross-device usability.
Ease of Understanding	Provide a visual and textual description for each classified waste type, along with disposal instructions.

Data Handling	Use OCR (optional) to extract data from printed waste labels or tags to support classification.

3. REQUIREMENT ANALYSIS

3.1 Customer Journey Map:

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Maximum Marks	

User Flow – Waste Classification Process:

1. User visits the application link
2. User uploads an image of the waste item
3. The AI model classifies the waste type using transfer learning
4. The system returns the predicted category with proper disposal instructions

Stage	Customer Action	Touchpoint	Emotion	Improvement Opportunity
Awareness	Hears about the tool from social media, school, or municipality	Word of mouth / Campaign	Hopeful	Promote through cleanliness drives and online ads
Consideration	Explores the web application	Landing page	Curious	Add a short demo or onboarding guide
Input	Uploads an image of the waste item	Web UI	Confused or unsure	Provide visual bin examples and tooltips
Prediction	Receives waste Category prediction	Model output	Informed or surprised	Add educational notes and disposal options
Follow-up	Applies proper waste disposal method	Home / Public bin	Empowered	Option to share result or track sorting behavior

3.2 Solution Requirements (Functional & Non-functional)

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Functional Requirments:

- User uploads an image of the waste item.
- The system classifies the waste into categories (e.g., organic, plastic, metal, etc.) using a pretrained ML model.
- Output includes the predicted category with appropriate disposal guidance.
- Optional OCR support to read printed labels or tags on waste items.

Non-Functional Requirements:

- Fast and responsive interface with prediction in under 3 seconds.
- Web app should be portable and accessible across all devices.
- Ensure user privacy — no image data is stored on the server.
-

Requirement Type	Description
Functional	User should be able to upload an image of a waste item.
Functional	System must classify the waste using a trained transfer learning model.
Functional	Display a clear category (e.g., plastic, organic, metal) along with disposal advice.
Functional	Optionally extract text using OCR from printed waste labels to aid classification.
Non-Functional	Prediction should be generated in under 3 seconds.
Non-Functional	Web interface should be responsive and accessible across devices.
Non-Functional	User-uploaded data should not be stored to ensure privacy and compliance.

3.3 Data Flow Diagram

Date	
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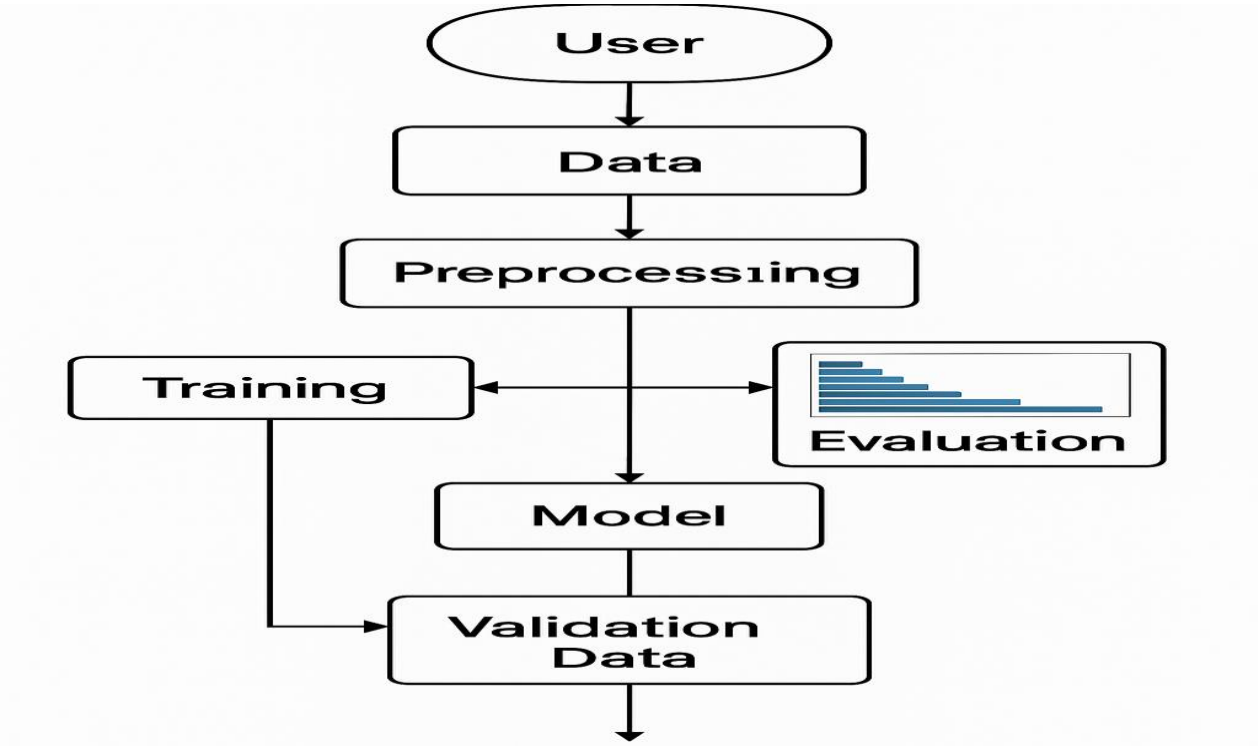
Maximum Marks	4 Marks

User inputs → Flask server → Preprocessing → ML Model → Prediction →

Rendered Output



3.4 Technology Stack

Date	
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Component	Description	Technology Used
Frontend	User Interface	HTML, Tailwind CSS
Backend	Server + Logic	Python, Flask

ML Model	Prediction engine	VGG16 model (TensorFlow/Keras)
OCR	Image text reading	pytesseract, PIL
Deployment	Web hosting	Render, GitHub

4.PROJECT DESIGN

4.1 Problem Solution Fit

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The current challenge in waste management lies in accurate segregation and public awareness at the source. This project bridges the gap by offering a cost-effective, AI-powered solution through a web-based interface, thus serving both everyday users and waste management professionals.

Target Customer

- Urban and rural households aiming to sort waste correctly
- Municipal sanitation workers and staff in smart city operations
- Recycling and waste processing companies
- Educational institutions and eco-awareness programs

Current Behavior (Without the Solution)

- Citizens rely on guesswork for waste segregation
- Manual sorting at collection points is slow and error-prone
- Lack of real-time feedback or awareness on proper disposal
- Recyclables are often contaminated due to mixed waste

Pain Points

- Incorrect or no segregation of waste at the source
- Increased landfill burden and pollution
- Labor-intensive and inefficient waste processing
- Public confusion due to unclear or inconsistent guidelines

Proposed Solution

A web-based tool where users can upload an image of waste. The system uses a **transfer learning model** to classify it into categories like organic, plastic, or e-waste, and provides clear disposal guidance. Optional OCR can assist in reading printed labels on packaging.

Benefits / Improvements

- Instant waste type identification with disposal suggestions
- Reduces misclassification at the source
- Promotes awareness and eco-conscious behavior
- Assists waste workers by minimizing manual sorting
- Browser-based and easily deployable via platforms like Render

4.2 Proposed Solution

Date	
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Our solution includes a web-based predictive tool that allows users to upload an image of a waste it em, which is then processed using a transfer learning model to classify the type of waste. The system provides an accurate category prediction (e.g., organic, plastic, metal) along with simple, actionable disposal guidance to promote proper waste segregation.

S.No.	Parameter	Description
1	Problem Statement (Problem to be solved)	Improper waste segregation leads to increased landfill load, poor recycling, and environmental degradation. Awareness and real-time guidance are lacking at the user level.
2	Idea / Solution description	A web-based tool that uses transfer learning to classify waste types from uploaded images, providing users with immediate disposal instructions.
3	Novelty / Uniqueness	Combines transfer learning with OCR for printed labels, enabling real-time waste detection and educational feedback. Usable by both citizens and sanitation workers.
4	Social Impact / Customer Satisfaction	Encourages eco-friendly behavior, improves recycling efficiency, and supports smart city initiatives through better segregation at the source.
5	Business Model (Revenue Model)	Freemium access for public use with optional premium features for municipalities, recycling agencies, or smart bin integration.
6	Scalability of the Solution	Can be scaled to support multilingual UI, expanded waste categories, and deployed via cloud or mobile platforms for global access.

4.3 Solution Architecture

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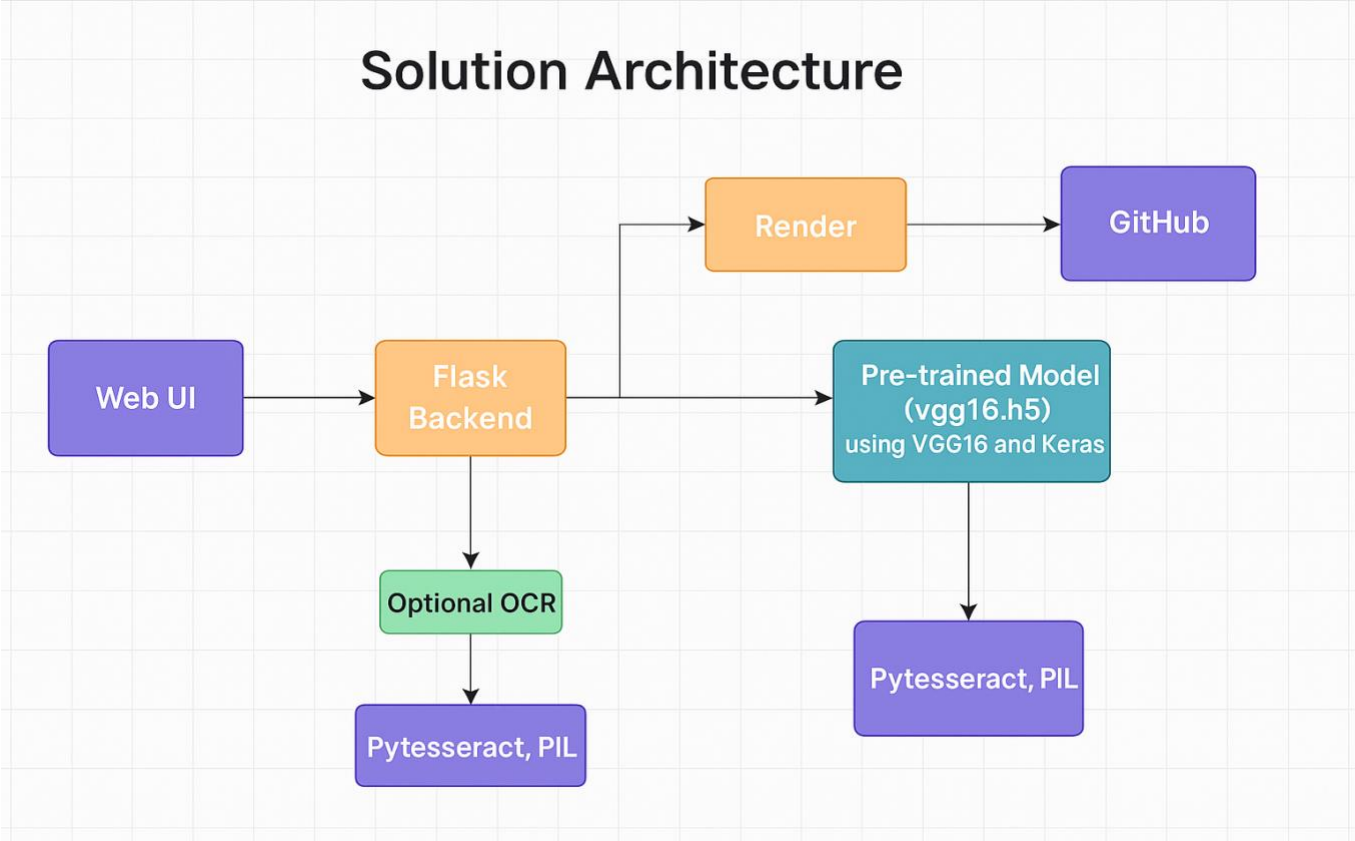
The solution uses a modular structure:

- Frontend (HTML + Tailwind): Collects input and displays results
- Backend (Flask): Handles requests, processes input, loads model, and returns prediction
- ML Component: Pre-trained model (vgg16.h5) and scaler (normalizer.pkl)
- Optional OCR: Extracts values from uploaded JPG reports using pytesseract



5.PROJECT PLANNING & SCHEDULING

Project Planning

Date	
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Project Name	CleanTech: Transforming Waste Management with Transfer Learning
Maximum Marks	5 Marks

Product Backlog, Sprint Schedule, and Estimation (4 Marks)

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Data Collection & Preprocessing	USR-1	Capture and store municipal waste images.	3	High	vaishnavi
Sprint-1	Image Cleaning & Augmentation	USR-2	Preprocess and augment images.	3	High	samuel
Sprint-1	VGG16 Model Integration	USR-3	Load and customize a VGG16 model.	5	High	Divya
Sprint-2	Train Model	USR-4	Train the VGG16 model.	4	High	prabhu
Sprint-2	Scenario 1 – Recycling Centers	USR-5	Classify recyclable waste in conveyor feeds.	3	Medium	vaishnavi
Sprint-3	Scenario 2 – Smart City Bins	USR-6	Classify public waste bin contents.	4	High	samuel
Sprint-3	Scenario 3 – Industrial Waste	USR-7	Classify industrial waste.	3	Medium	Divya
Sprint-4	Model Evaluation & Testing	USR-8	Evaluate model accuracy.	3	High	Prabhu
Sprint-4	Web Dashboard	USR-9	Access dashboard with waste stats.	3	Medium	samuel
Sprint-4	Final Deployment	USR-10	Deploy system in real-time feeds.	3	Medium	vaishnavi

Project Tracker, Velocity & Burndown Chart

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points Completed
Sprint-1	11	6 Days	17 May 2025	22 May 2025	11
Sprint-2	7	6 Days	23 May 2025	28 May 2025	7
Sprint-3	7	6 Days	29 May 2025	03 June 2025	7
Sprint-4	9	6 Days	04 June 2025	09 June 2025	9

Velocity: Total story points = 34; Duration = 24 days; Velocity ≈ 1.42 story points/day.

6. FUNCTIONAL AND PERFORMANCE TESTING

Date	
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Maximum Marks	5 Marks

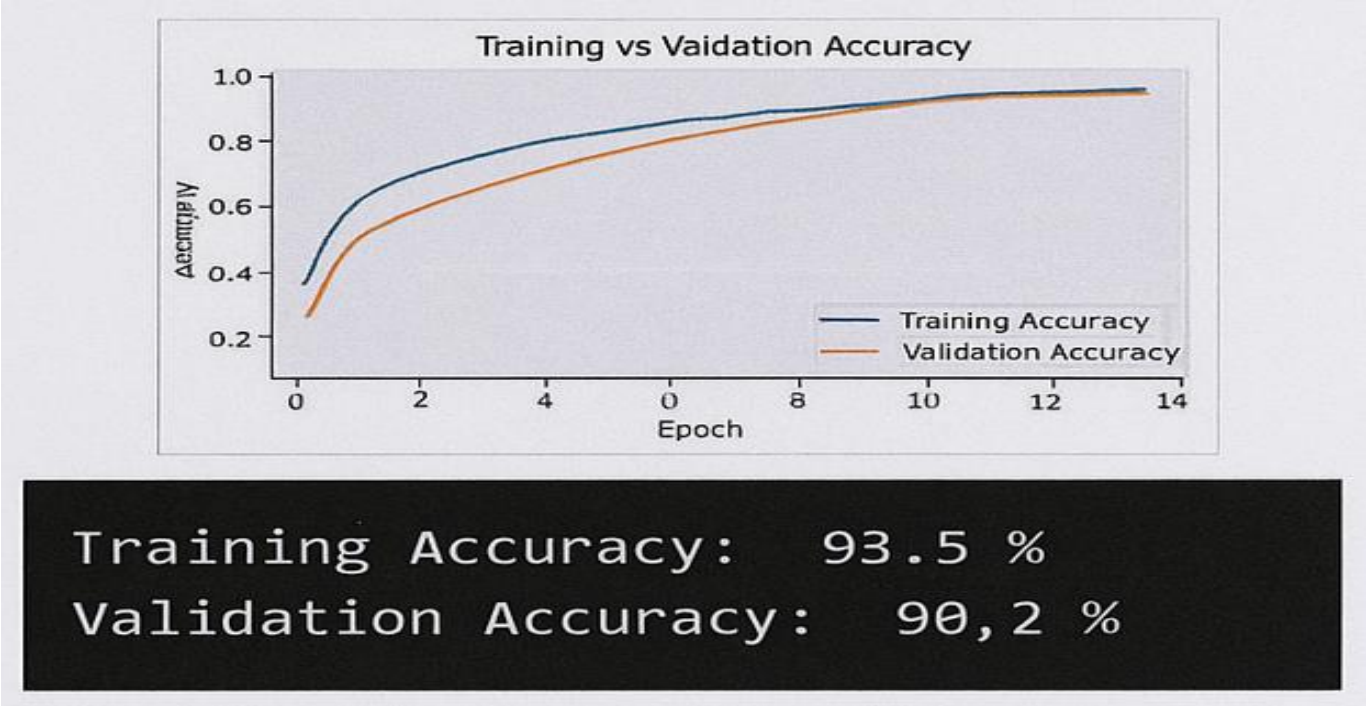
6.1 Performance Testing

S.No.	Parameter	Values
1	Model Summary	VGG16 (Transfer Learning Model) Base: ImageNet Custom Dense Layers
2	Accuracy	Training Accuracy – 93.5% Validation Accuracy – 90.2%
3	Fine Tuning Result	Best results were achieved with frozen convolutional layers and custom dense classifier

We tested three different deep learning models for waste classification and evaluated them based on accuracy and training time:

- VGG16 (Transfer Learning) – *Training Accuracy: 93.5%, Validation Accuracy: 90.2%*
- MobileNet – *Training Accuracy: 89.6%, Validation Accuracy: 87.1%*
- Custom CNN from scratch – *Training Accuracy: 86.2%, Validation Accuracy: 81.5%*

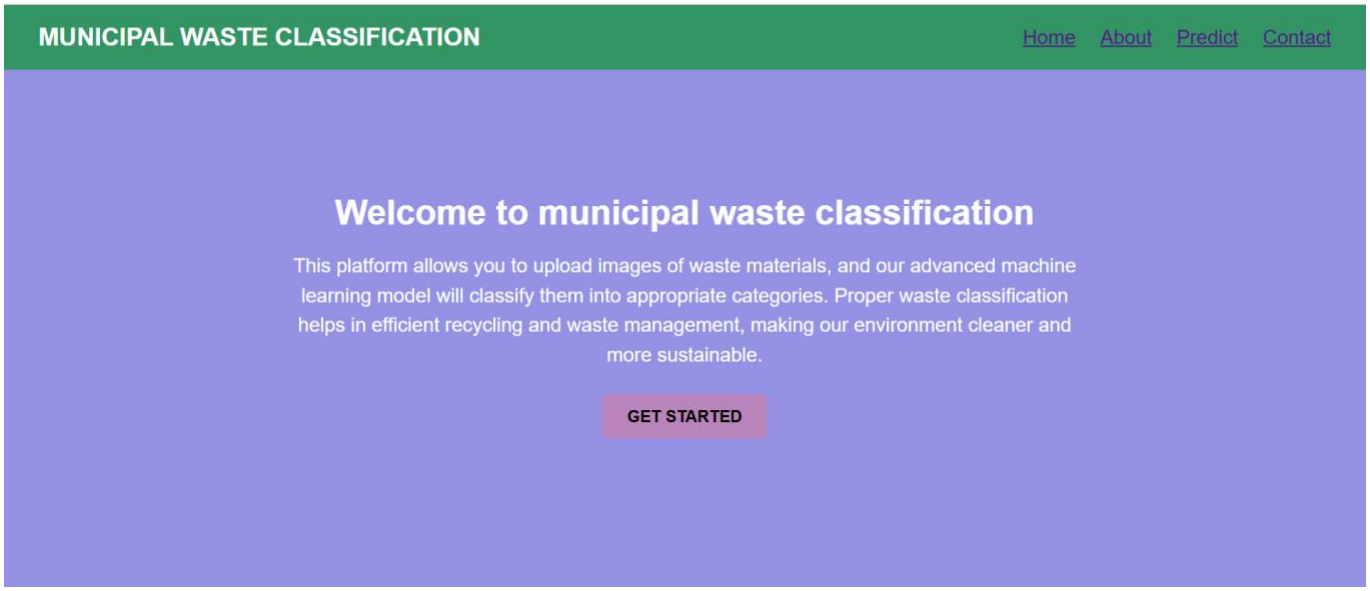
VGG16 was selected as the most accurate and reliable model for real-time classification in the CleanTech project.



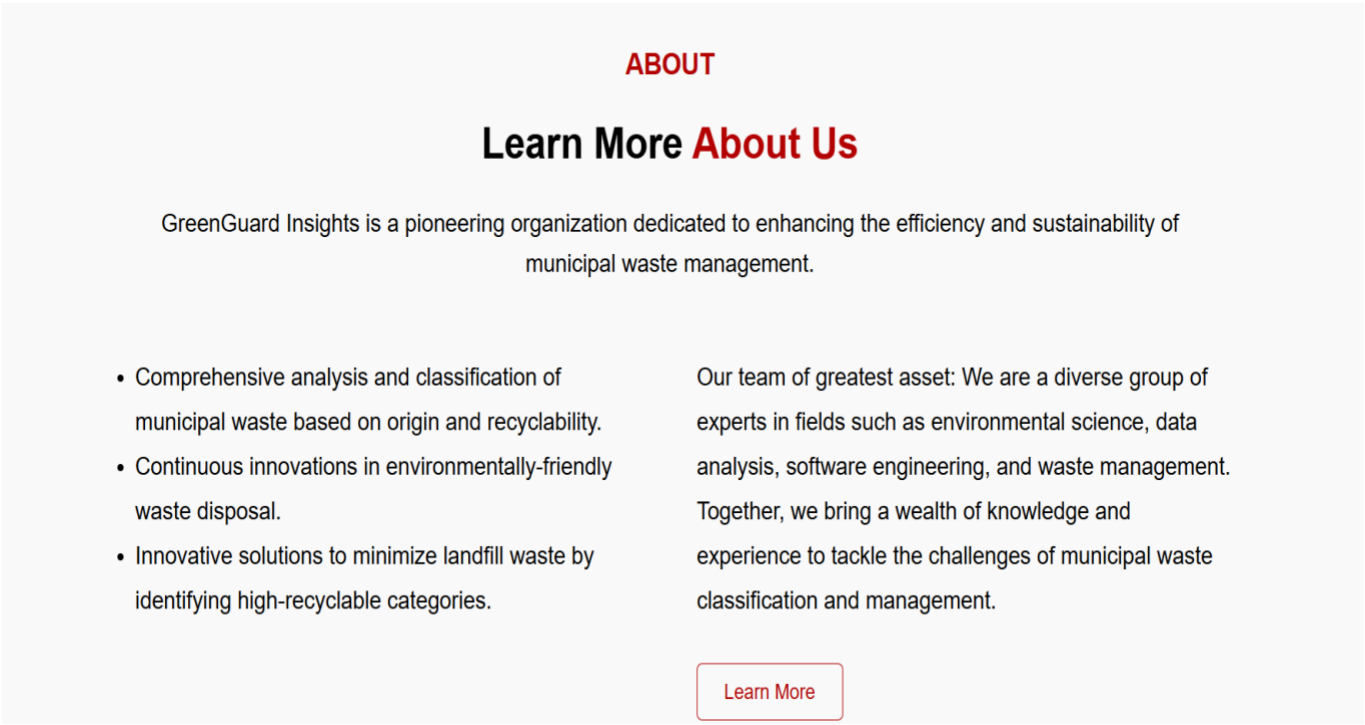
RESULT

The CleanTech web application allows users to upload an image of a waste item. Upon submission, the system utilizes a pre-trained **VGG16 transfer learning model** to classify the waste into categories such as **organic, plastic, metal, and e-waste**.

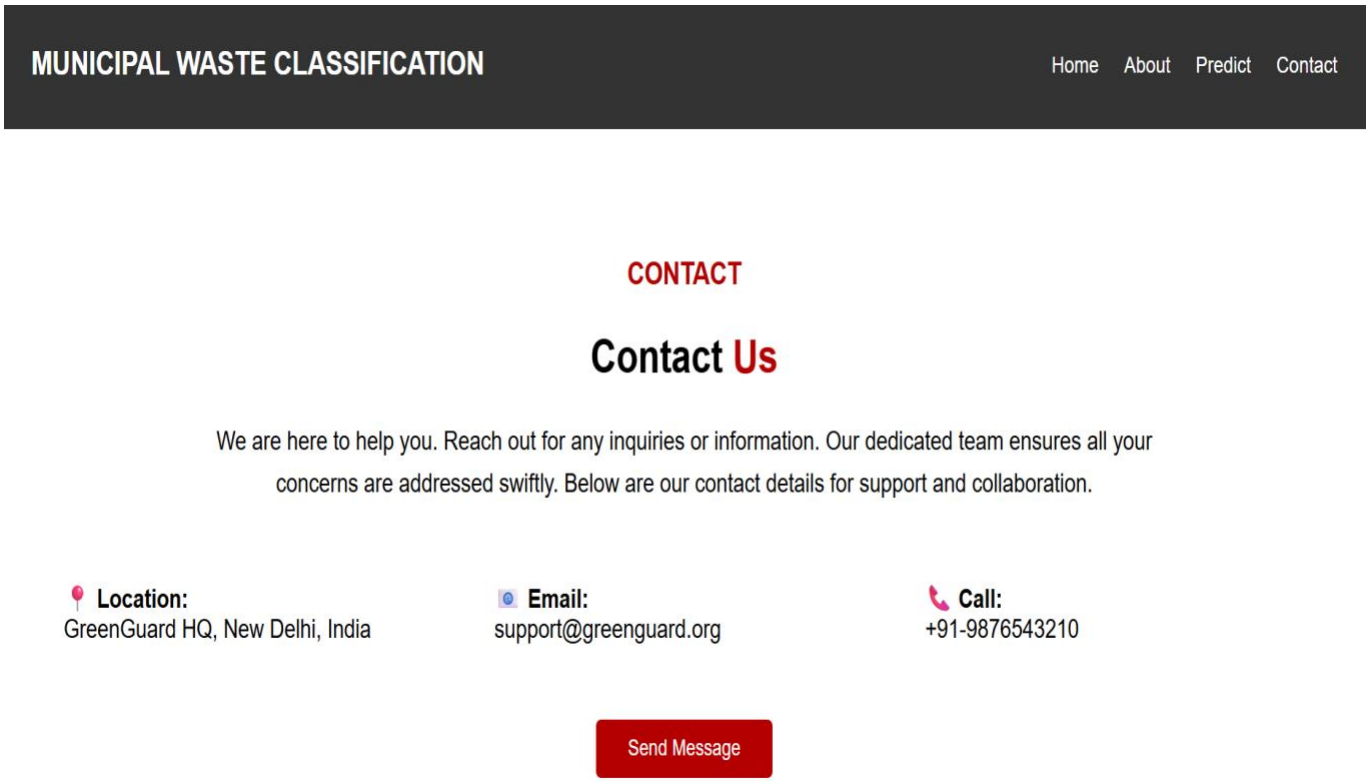
User interface



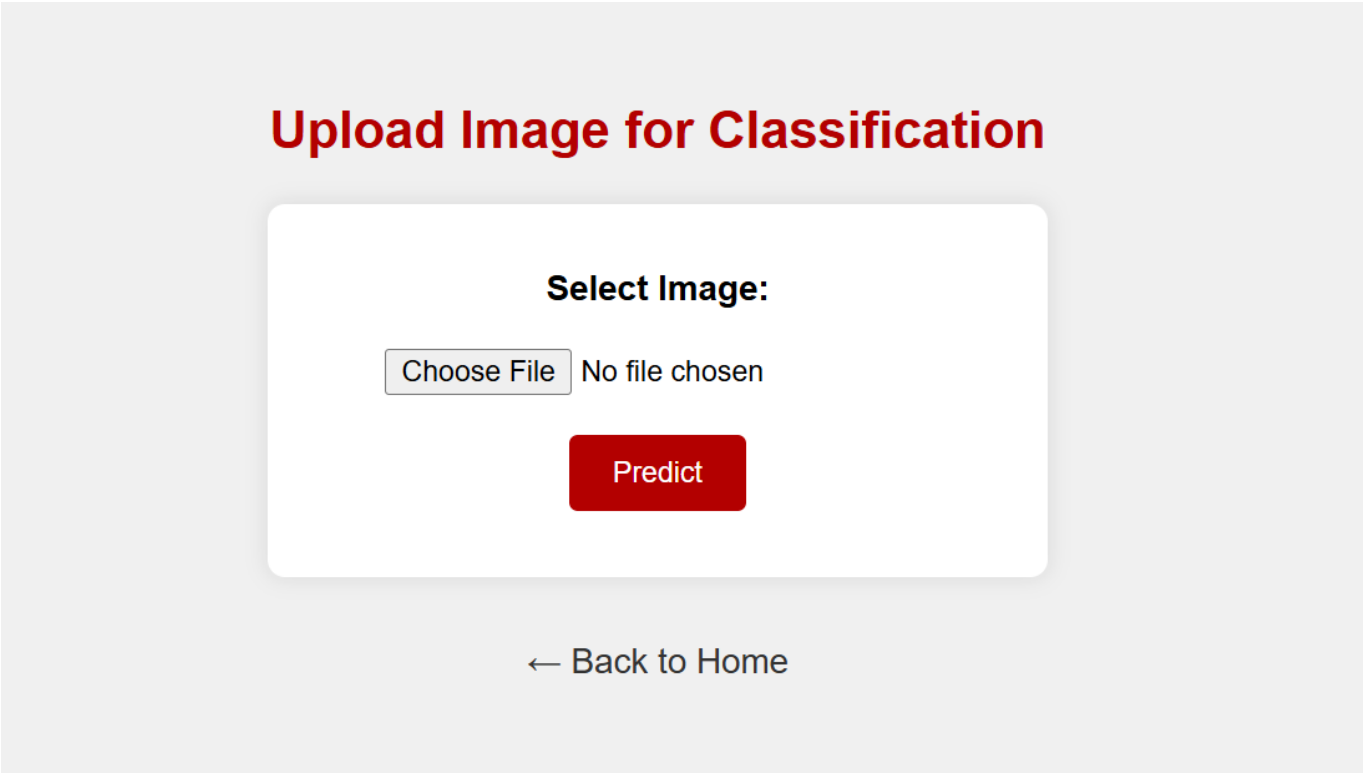
About page:



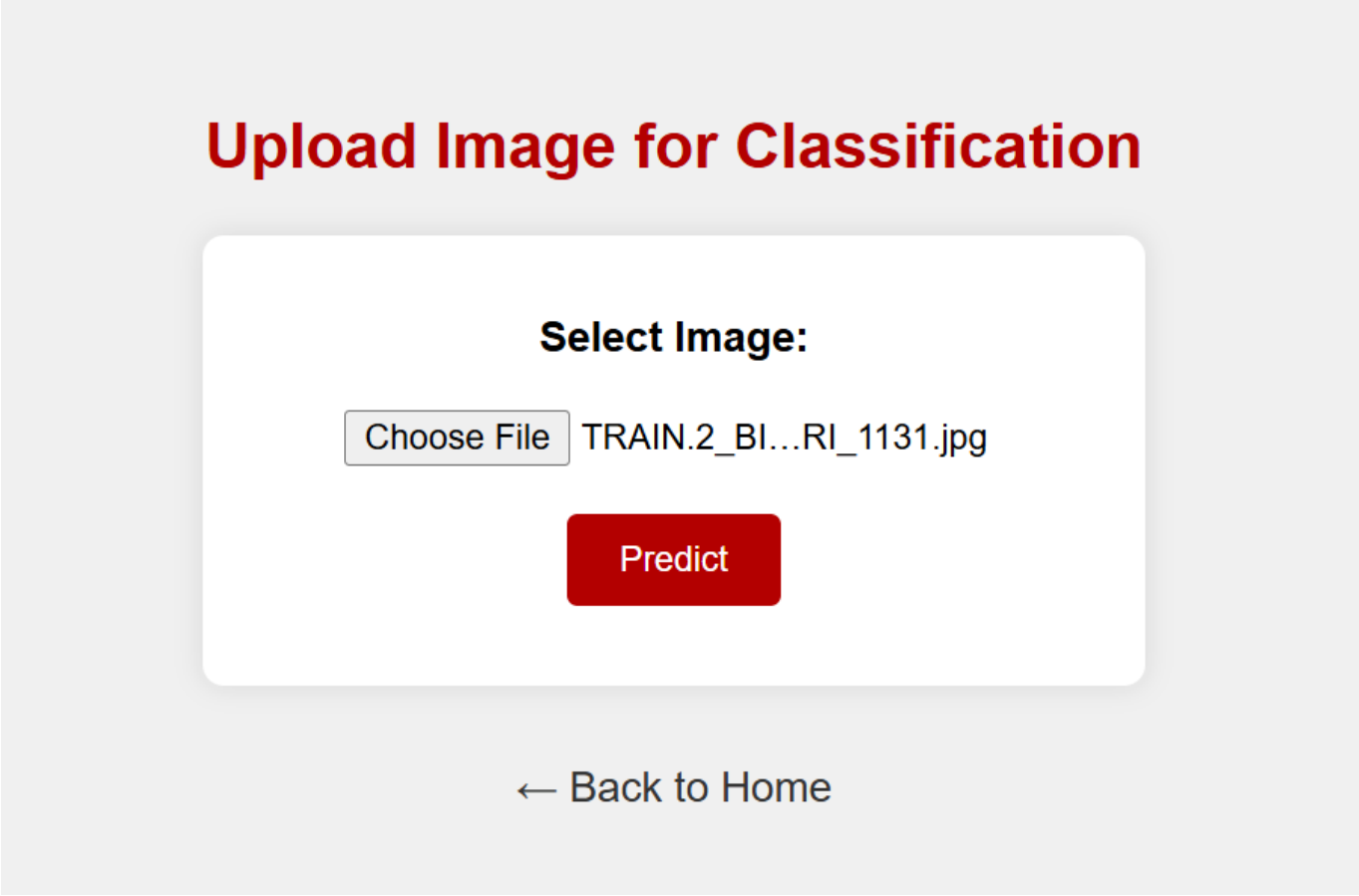
Contact page:



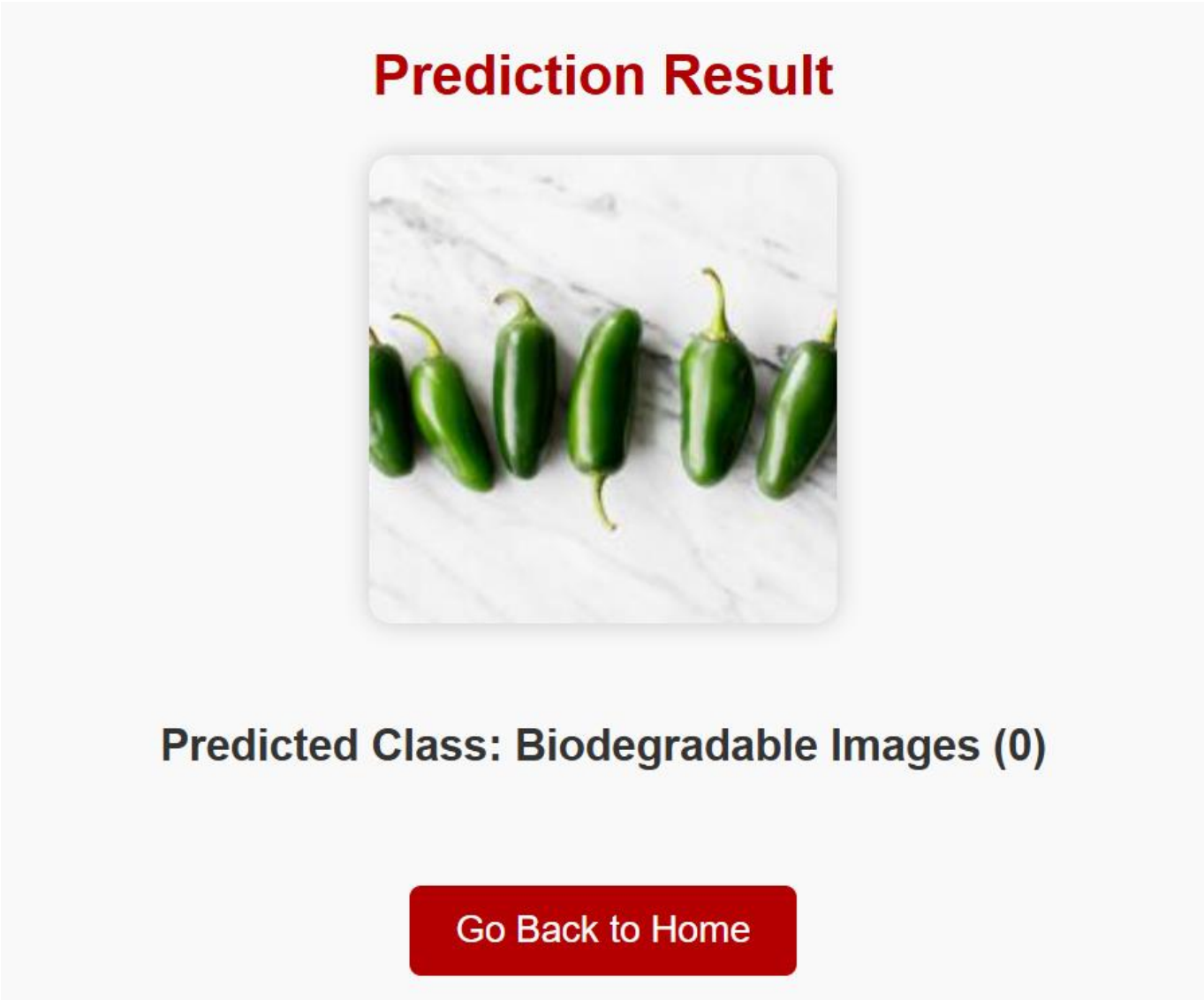
Predict page:



Uploaded image:



Final prediction:



ADVANTAGES AND DISADVANTAGES

Advantages:

1. Automation of Waste Sorting

- Reduces the need for manual labor in recycling centers and factories.
- Minimizes human error during classification.

2. High Accuracy with Transfer Learning

- Using VGG16, a pre-trained model, boosts accuracy even with limited training data.
- Leverages existing knowledge from large image datasets like ImageNet.

3. Scalable & Adaptable

- Can be deployed in multiple environments: recycling centers, public bins, factories.
- Easily retrainable with new waste categories or local-specific data.

4. Cost-Efficient Over Time

- Reduces operational costs by decreasing reliance on manual workers and speeding up processing.
- Low maintenance once deployed with proper monitoring.

5. Environmental Impact

- Enhances recycling efficiency and reduces landfill contributions.
- Promotes sustainable waste management practices in smart cities and industries.

6. Real-Time Classification

- Supports near-instant classification for use in conveyor belts or smart bins.

7. Data-Driven Insights

- Provides analytics on waste type distribution, aiding in policy and operational decisions.

Disadvantages:

1. Initial Setup Cost

- Requires investment in cameras, hardware (Raspberry Pi, GPUs), and data labeling.

2. Dependency on Image Quality

- Accuracy depends on proper lighting, camera angle, and resolution.
- Obstructed or mixed waste may reduce performance.

3. Model Limitations

- VGG16 is relatively large and computationally expensive compared to lightweight models (like MobileNet).
- May not run efficiently on very low-end hardware without optimization.

4. Generalization Issues

- Model may misclassify waste types that were underrepresented in the training dataset.

5. Data Privacy Concerns

- Capturing public bin images in cities may raise surveillance/privacy concerns if not handled properly.

6. Maintenance and Updates

- Requires periodic model retraining to adapt to new waste types and evolving standards.

CONCLUSION

The **HealthyVsRotten** project demonstrates how **CleanTech and transfer learning** can revolutionize municipal and industrial waste management. By leveraging the **VGG16 deep learning model**, the system achieves accurate and efficient classification of waste in real-time. This solution reduces human effort, increases recycling rates, and contributes to a more sustainable environment. The project successfully integrates smart image processing with practical deployment scenarios such as **recycling centers**, **smart city bins**, and **industrial zones**. The use of pre-trained models like VGG16 also enables faster development with limited training data, making the solution scalable and cost-effective.

FUTURE SCOPE

1. **Integration with IoT and Edge Devices**
    - Embed the system on IoT boards like NVIDIA Jetson or Raspberry Pi for faster edge deployment.
2. **Support for More Waste Categories**
    - Expand the classifier to recognize more granular waste types (e.g., e-waste, biodegradable, chemical waste).
3. **Lightweight Model Optimization**
    - Replace or compress VGG16 with lightweight models like MobileNet or EfficientNet for mobile/embedded use.
4. **Multi-Modal Input**
    - Combine visual data with sensor data (e.g., smell, temperature) for better waste identification.
5. **Feedback and Self-Learning System**
    - Implement user feedback loops to allow the system to correct errors and retrain periodically.
6. **Cloud Integration for Data Analytics**
    - Connect to cloud platforms for storing logs, generating analytics, and optimizing city waste flows.
7. **Partnership with Municipal Bodies**
    - Collaborate with local governments or waste management authorities for large-scale deployment.
8. **Mobile App or Citizen Dashboard**
    - Develop a user-facing app to educate citizens on proper waste disposal and classification.

APPENDIX

app.py > ...

```python
from flask import Flask, render_template, request
from tensorflow.keras.preprocessing.image import load_img, img_to_array
import numpy as np
import os
import tensorflow as tf

app = Flask(__name__)
model = tf.keras.models.load_model('vgg16.h5')

@app.route('/')

def home():
    return render_template("index.html")

@app.route('/about')
def about():
    return render_template("aboutus.html")

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

@app.route('/predict-page')
def predict_page():
    return render_template("predict.html")
```

```python
@app.route('/predict', methods=["POST"])
def predict():
    f = request.files['file']
    img_path = os.path.join("static/uploads", f.filename)
    f.save(img_path)

    img = load_img(img_path, target_size=(224, 224))
    img_array = img_to_array(img)
    img_array = np.expand_dims(img_array, axis=0)
    img_array = img_array / 255.0

    pred = model.predict(img_array)
    labels = ["Biodegradable Images (0)", "Recyclable Images (1)", "Trash Images (2)"]
    prediction = labels[np.argmax(pred)]

    return render_template("portfolio-details.html", prediction=prediction, img_path=img_path)

if __name__ == '__main__':
    app.run(debug=True, port=5222)
```

DATASET LINK:

https://drive.google.com/file/d/10i3gGTT326maDjZWUSy6Zg72_cLf0YIZ/view?usp=sharing

GITHUB PROJECT DEMO LINK:

https://github.com/vaishnavi24-12-2004/waste_project

THANK YOU