AI-POWERED WASTE REUSE RECOMMENDATION SYSTEM

A DESIGN PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this design project report titled **"AI-POWERED WASTE REUSE RECOMMENDATION SYSTEM"** is the bonafide work of **KARTHICK DHARSHAN S (811722001021), MELVIN JEFFERSON M (811722001030) AND MUKESH KANNAN A (811722001035)** who carried out the design project under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other design project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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DECLARATION

We jointly declare that the design project report on **"AI-POWERED WASTE REUSE RECOMMENDATION SYSTEM"** is the result of original work done by us and best of our knowledge, similar work has not been submitted to **"ANNA UNIVERSITY CHENNAI"** for the requirement of Degree of **BACHELOR OF TECHNOLOGY**. This design project report is submitted on the partial fulfilment of the requirement of the award of Degree of **BACHELOR OF TECHNOLOGY**.

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ABSTRACT

AI-Powered Waste Reuse Recommendation System is designed to promote sustainable waste management by leveraging artificial intelligence to generate creative and practical reuse ideas for household and industrial waste items. The system utilizes a lightweight image classification model to identify objects in user-uploaded images and a powerful language generation model to provide step-by-step reuse instructions tailored to the identified item. This real-time system encourages users to engage in upcycling and responsible disposal by delivering actionable, eco-friendly suggestions directly through a user-friendly web interface. It aims to minimize landfill contribution and support environmental conservation efforts. Future improvements propose integrating more advanced image analysis, such as object dimension estimation and material recognition, and expanding reuse suggestions through region-specific databases. The low-cost, cloud-integrated architecture ensures scalability and applicability across households, educational platforms, and waste management sectors. Ultimately, the project bridges AI and sustainability to encourage smarter, greener reuse decisions in everyday life.

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LIST OF ABBREVIATIONS

API	-	Application Programming Interface
CNNS	-	Convolutional Neural Networks
DIY	-	Do-It-Yourself
HDPE	-	High-Density PolyEthylene
IOT	-	Internet Of Things
LDPE	-	Low-Density PolyEthylene Collision
MRF	-	Material Recovery Facilities
PET	-	PolyEthylene Terephthalate

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The AI-Powered Waste Reuse Recommendation System is developed to promote environmental sustainability by providing intelligent reuse suggestions for common waste items using artificial intelligence. This project integrates image classification and natural language generation to identify waste materials and generate practical, eco-friendly reuse ideas in real time. The system is built around a lightweight convolutional neural network (MobileNetV2) for image recognition and uses the Together AI Mixtral-8x7B language model to generate creative step-by-step reuse instructions. It offers users an accessible web interface to upload images of waste items, receive identification results, and get recycling or upcycling recommendations instantly.

In this project, the image classification model processes the uploaded image to determine the waste item category—such as plastic bottles, containers, paper, or metal. Once identified, this label is used to formulate a dynamic prompt for the language model, which then generates a set of reuse or recycling instructions tailored to the specific object. These instructions are designed to be practical, eco-conscious, and easy to follow, encouraging responsible disposal and reuse at both individual and community levels.

Implementation involves integrating a pretrained image classification model using PyTorch, setting up the Together AI API for text generation, and deploying the application with Gradio for web access. Image preprocessing ensures accuracy in classification, while the language model is configured to generate relevant content based on the item type.

Although this system simplifies waste management guidance, limitations include occasional misclassification due to visual ambiguity and the dependency on external API latency for instruction generation. Nevertheless, it presents a low-cost, scalable, and AI-driven approach to foster sustainable habits and reduce environmental impact. With further development, it holds potential for broader deployment in educational platforms, waste sorting stations, and household sustainability tools.

1.2 OBJECTIVE

The objective of the AI-Powered Waste Reuse Recommendation System is to create an intelligent and accessible platform that helps users reduce waste by providing practical, creative, and eco-friendly reuse ideas for common household waste items. In a world facing growing environmental challenges, improper waste disposal and lack of awareness about reusability contribute significantly to pollution and resource depletion. This system leverages artificial intelligence to address this problem by identifying waste materials through image recognition and generating step-by-step reuse instructions using a large language model.

The key goal of this project is to develop a low-cost, user-friendly, and efficient tool that encourages sustainable practices by transforming waste into usable or decorative items. The system uses a convolutional neural network to classify the uploaded waste image—such as plastic bottles, paper cups, or tin cans—and then generates reuse suggestions tailored to the identified object. These ideas are generated in real time using a powerful natural language processing model, ensuring that the recommendations are relevant, easy to understand, and environmentally conscious.

By automating the process of waste identification and reuse idea generation, the project seeks to make sustainability approachable for users with minimal technical knowledge. It serves educational, practical, and ecological purposes by increasing awareness about recycling and reuse possibilities. Through extensive testing and model fine-tuning, the system aims to achieve high accuracy in waste classification and generate meaningful, creative suggestions that promote responsible waste management.

Ultimately, the objective is to support the global shift toward sustainability by using artificial intelligence to inspire reuse, reduce waste, and promote greener .

CHAPTER 2

LITERATURE SURVEY

2.1 AI-POWERED WASTE CLASSIFICATION USING CONVOLUTIONAL NEURAL NETWORKS

S. Patel, R. Mehta, and A. Kumar

This paper presents a deep learning-based approach to automated waste classification using CNNs. The authors developed and tested a web-enabled classification system capable of recognizing and categorizing waste items into distinct groups, including plastic, metal, glass, organic, and paper waste. The main goal of the study was to support smart city waste management initiatives by improving the accuracy and efficiency of waste.

Merits

- Demonstrates high accuracy in waste classification using CNNs.
- Provides a practical web-based application for real-time waste classification.
- Contributes to efficient waste segregation, facilitating recycling processes.
- The CNN model consistently achieved over 90% accuracy across common waste types, demonstrating strong performance on well-labeled image data.

Demerits

- Limited to predefined waste categories; may not generalize well to novel or mixed waste items.
- Relies on the quality and diversity of the training dataset for optimal performance.
- The model is trained only on five specific categories and struggles with mixed waste or uncommon items not represented in the dataset.

2.2 MULTI-CATEGORY SORTING OF PLASTIC WASTE USING SWIN TRANSFORMER: A DEEP LEARNING APPROACH

L. Joshi, P. Das, and N. Bhatia

This study introduces an advanced deep learning method for sorting plastic waste into multiple categories using the **Swin Transformer** model. Transformers, traditionally used in natural language processing, are now gaining traction in computer vision. This paper explores how the Swin Transformer's hierarchical and window-based attention mechanism can outperform CNNs in the specific task of identifying different types of plastic waste, such as PET, HDPE, LDPE, and polypropylene. The study demonstrates that precise plastic classification can lead to better sorting at recycling centers, thereby increasing the efficiency.

Merits

- Utilizes advanced transformer-based architecture for improved classification performance.
- Achieves high accuracy in distinguishing between different plastic waste categories.
- Demonstrates the potential of transformer models in waste classification tasks.
- The model excels at fine-grained classification of similar-looking plastic materials, which is a key challenge in plastic recycling.

Demerits

- Requires substantial computational resources for training and inference.
- May be complex to implement in resource-constrained environments.
- Swin Transformers are significantly more resource-intensive than CNNs, requiring GPUs with large memory for training and inference.

2.3 DO-IT-YOURSELF RECOMMENDER SYSTEM: REUSING AND RECYCLING WITH BLOCKCHAIN AND DEEP LEARNING

S. Pandey, M. Sharma, and V. Pillai

This study introduces a Do-It-Yourself recommender system that utilizes deep learning in conjunction with blockchain technology to provide personalized reuse and recycling recommendations for household waste. Unlike traditional static suggestion systems, this model dynamically analyzes user-uploaded content and historical interactions to generate intelligent, context-aware reuse ideas. Additionally, blockchain is incorporated to ensure data transparency, traceability, and community-driven validation, making the system trustworthy and user-inclusive. The aim is to not only automate eco-friendly suggestions but also to encourage user participation and long-term behavioral change.

Merits

- Combines deep learning and blockchain for personalized and transparent recommendations.
- Encourages user participation in sustainable waste management practices.
- Offers a novel approach to promoting reuse and recycling behaviors.

Demerits

- The integration of blockchain may introduce complexity and scalability challenges.
- The effectiveness of recommendations depends on user engagement and data quality.
- New users with no activity history may receive generic suggestions until enough interactions are recorded.

2.4 INTELLIGENT WASTE MANAGEMENT SYSTEM USING DEEP LEARNING WITH IOT

H. Singh, R. Krishnan, and Y. Feng

This paper presents an intelligent waste management system that combines deep learning for waste classification with IoT infrastructure for real-time waste bin monitoring and automated collection scheduling. The goal is to streamline urban waste handling by integrating data-driven automation into the existing waste collection and recycling framework. The system uses sensors embedded in smart bins to monitor fill levels, temperature, and the type of waste, while a deep learning model classifies the waste to assist in segregation at source.

Merits

- Integrates deep learning and IoT for real-time waste monitoring and classification.
- Enhances efficiency in waste collection and recycling processes.
- Provides a scalable solution for smart city waste management.
- Encourages waste segregation and improves recycling by classifying waste at the source using AI.

Demerits

- Implementation may require significant infrastructure investment.
- System performance is dependent on the reliability of IoT devices and network connectivity.
- Expanding the system to a city-wide deployment may require significant backend and cloud resources.
- The system relies on continuous internet or network access; disruptions may delay data collection or classification.

2.5 AI IN SMART WASTE MANAGEMENT AND THE CIRCULAR ECONOMY: TOWARDS A ZERO WASTE FUTURE

H. Singh, R. Krishnan, and Y. Feng

This article explores the transformative potential of Artificial Intelligence (in advancing smart waste management systems and supporting the broader goals of a circular economy. It focuses on how AI technologies, such as machine learning, computer vision, and robotics, can be integrated into the waste lifecycle to reduce reliance on landfills and maximize the reuse, recycling, and recovery of resources. The article provides a conceptual framework that maps AI applications—from smart bin monitoring to AI-powered sorting robots—in achieving the goal of zero waste cities.

Merits

- Showcases the application of AI in promoting sustainable waste management practices.
- Emphasizes the potential of AI in achieving circular economy objectives.
- Provides insights into the integration of AI technologies in waste sorting processes.
- Provides a visionary look at how AI can revolutionize waste management from a systems-level perspective.

Demerits

- The article is more conceptual and lacks detailed empirical data.
- Implementation challenges and cost considerations are not extensively discussed.
- Lacks technical depth regarding how each AI model is trained or evaluated in waste management contexts.
- could be scaled globally or in low-resource settings.

CHAPTER 3

SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

Current waste management and recycling systems primarily rely on manual sorting, user awareness, and traditional disposal methods, which often lead to inefficient recycling and increased environmental burden. Public recycling efforts typically involve separating waste into pre-defined categories like plastic, paper, metal, and organic waste, using labeled bins. However, many individuals lack the necessary knowledge or motivation to properly sort items, resulting in cross-contamination of recyclable materials and reduced overall effectiveness.

In many urban areas, MRFs use mechanical and human-operated sorting methods that, while effective to a degree, are resource-intensive and not scalable to meet growing waste volumes. Moreover, conventional awareness campaigns about recycling are generic and do not provide item-specific guidance, limiting their impact on daily behavior.

Several mobile apps and digital tools exist to assist users in identifying recyclable items through barcode scanning or manual input, but these systems often fall short due to limited databases or lack of real-time visual recognition. Some advanced recycling solutions have adopted computer vision for object classification, mainly in industrial applications, but they are rarely accessible to the general public due to high cost, complexity, and lack of integration with user-friendly platforms.

In terms of reuse and upcycling ideas, existing platforms like blogs, DIY websites, and community forums offer suggestions, but they are not tailored to the specific object at hand and require users to manually search for applicable projects. There is also a gap in combining automated waste recognition with intelligent suggestion systems for reuse, leaving many potentially recyclable or reusable items discarded.

Recent innovations in AI and machine learning present promising solutions to these challenges by enabling automated waste identification and intelligent guidance. However, most existing AI-based solutions are either limited to classification alone or focus primarily on sorting rather than education or reuse inspiration. Additionally, such systems often lack real-time interactivity and accessibility through intuitive web or mobile interfaces, reducing their adoption among everyday users.

Therefore, while there has been progress in applying technology to waste management, there remains a clear need for a low-cost, accessible, and AI-powered system that not only identifies waste types but also provides intelligent, practical reuse instructions tailored to each item.

3.1.1 Demerits

Misclassification of Waste Items

• Image classification models may misidentify waste items due to visual similarities or poor image quality.

• Misclassification can lead to irrelevant or unhelpful reuse suggestions, reducing system reliability.

Dependency on External APIs

• The system relies on third-party language models (e.g., Together AI),

• API usage may incur additional operational costs and limits based on usage quotas.

Limited Training Dataset

• The image classifier's performance is highly dependent on the diversity and quality of its training dataset.

• A limited dataset can restrict the system's ability to recognize uncommon or complex waste items.

Internet Connectivity Requirement

• Real-time functionality requires a stable internet connection for both image classification and reuse idea generation.

• This can limit usage in rural or low-connectivity areas.

Generic Suggestions in Edge Cases

• In cases of uncertain classification or ambiguous items, the system might generate overly generic reuse instructions.

• Lack of context-aware refinement may reduce the practical usefulness of suggestions.

User Trust and Adoption

• Users may be skeptical of automated suggestions, especially if prior results were inaccurate or not useful.

• Building trust in AI-generated reuse advice takes time and consistent reliability.

Lack of Physical Integration

• The system operates as a web interface and is not integrated into smart bins, mobile apps, or physical waste-sorting infrastructure.

• This limits its impact to users who manually upload waste images rather than streamlining everyday waste disposal.

3.2 PROPOSED SYSTEM

The proposed AI-powered system offers an intelligent solution for promoting sustainable waste management by providing real-time reuse or recycling suggestions based on uploaded images of common waste items. The system integrates a lightweight image classification model (MobileNetV2) with the Together AI Mixtral-8x7B language model to identify waste materials and generate eco-friendly reuse ideas. Upon image upload, the system preprocesses and classifies the waste item into categories such as plastic bottles, containers, paper, or metal. Based on this classification, it dynamically prompts the language model to generate detailed, creative, and actionable reuse or upcycling instructions. These instructions are displayed to the user via a simple and intuitive web interface built using Gradio, ensuring accessibility to a wide audience. The system is developed using PyTorch for model integration and is connected to the Together AI API for generating contextual suggestions. Although dependent on external APIs and internet connectivity, the system presents a scalable and low-cost approach to encourage responsible waste reuse practices in homes, schools, and communities. Through its real-time, intelligent suggestions, the project aims to reduce environmental impact and raise awareness of practical recycling methods.

3.2.1 Merits

Promotes Environmental Sustainability

The system encourages eco-conscious behavior by offering creative and practical reuse suggestions, reducing waste and promoting circular economy principles.

Real-Time and Intelligent Feedback

Provides instant reuse ideas based on AI analysis of the uploaded image, helping users make sustainable decisions quickly and effectively.

User-Friendly Web Interface

With its intuitive Gradio interface, users of all ages and technical skill levels can easily upload images and receive helpful suggestions without complex navigation.

Cost-Effective and Scalable

Uses lightweight models and open-source tools (e.g., PyTorch, Gradio), minimizing infrastructure requirements while allowing for scalable deployment in various environments.

Accessible Across Devices

Being web-based, the system can be accessed via smartphones, tablets, or computers, increasing its reach and usability in diverse settings.

Educational Potential

The system can be used as an educational tool in schools and communities to teach sustainable waste management and creative reuse practices.

Encourages Responsible Habits

By making recycling and upcycling guidance easily available, the system fosters long-term sustainable habits among users, contributing to broader environmental goals.

CHAPTER 4

SYSTEM SPECIFICATIONS

4.1 HARDWARE SPECIFICATIONS

Computer/Server (Local or Cloud-Based): Used to run the image classification model and connect to the Together AI API. A basic system with 8GB RAM and GPU support is recommended for faster processing.

Camera or Image Capture Device: Optional hardware for users who want to capture waste images directly instead of uploading.

Internet Connectivity: Required for API calls to Together AI for generating reuse suggestions.

Power Supply: Standard AC power for running the host system (laptop/PC/server).

4.2 SOFTWARE SPECIFICATIONS

Operating System: Windows, macOS, or Linux (for development and deployment).

Frameworks/Libraries:

- Python (main programming language)
- PyTorch (for image classification model integration)
- Gradio (for web interface)
- Together AI API (for generating reuse suggestions)

Image Classification Model: MobileNetV2 trained or fine-tuned for waste item categories (e.g., plastic, glass, paper).

Natural Language Processing: Together AI Mixtral-8x7B model for step-by-step reuse idea generation.

Preprocessing Algorithm: Resizes and normalizes uploaded images before classification.

Integration Logic: Binds classification output with the language model input

CHAPTER 5

SYSTEM DESIGN

5.1 SYSTEM ARCHITECHTURE

The system architecture of the AI-powered Waste Reuse Recommendation System is designed to promote sustainability by intelligently analyzing images of waste items and generating creative reuse ideas. The core components of the system include an image classifier, a natural language generation model, and a user-friendly web interface. The process begins when a user uploads a photo of a waste item—such as a plastic bottle or cardboard box—through the Gradio-based web interface. This image is first passed through a preprocessing module, where it is resized, normalized, and prepared for analysis. The processed image is then input to a lightweight convolutional neural network (MobileNetV2), which identifies the type of waste material by classifying it into categories such as plastic, metal, glass, or paper.

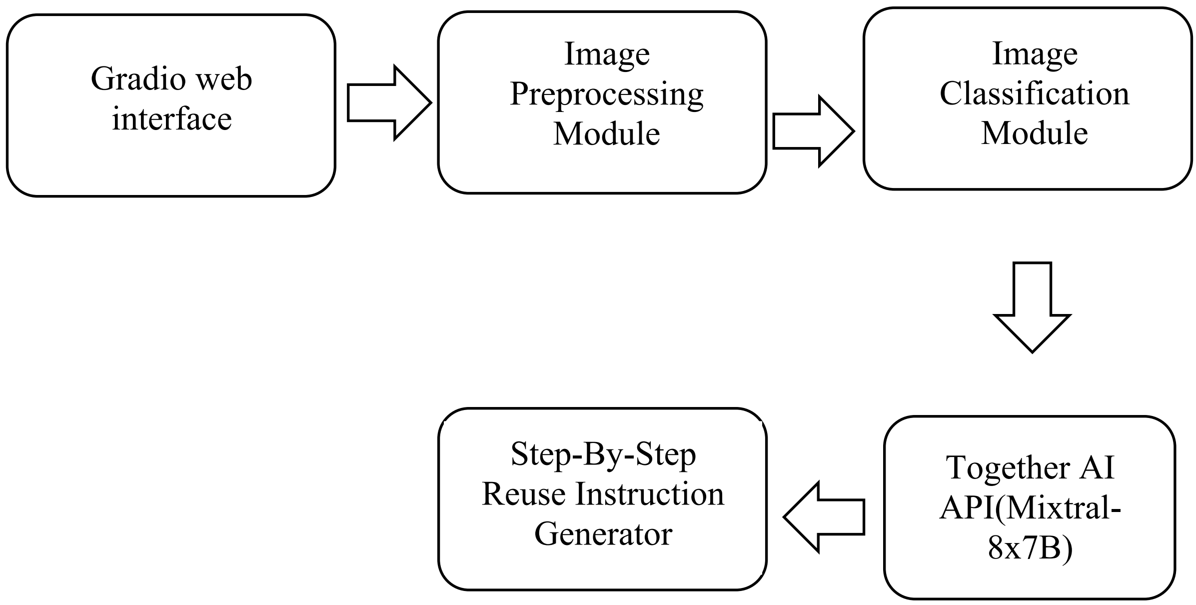

Fig. 5.1 System Architecture

Once classification is complete, the identified waste category is used to generate a dynamic prompt. This prompt is structured to ask for practical, eco-friendly reuse suggestions for the detected item. The prompt is then sent via API to the Together AI Mixtral-8x7B language model, which serves as the system's intelligent suggestion engine. The model generates detailed, step-by-step reuse or upcycling ideas specific to the identified waste type. These suggestions are returned to the application and displayed on the same Gradio interface, offering users instant, actionable reuse ideas.

The entire system is powered by a computer or cloud-based server and requires an active internet connection to communicate with the Together AI API. It is optimized for low-latency response, enabling near real-time feedback. The architecture ensures seamless integration of image classification and natural language generation, offering a powerful yet accessible tool for promoting sustainable behavior. By automating the process of waste identification and recommendation, the system not only simplifies recycling but also encourages creative and environmentally responsible reuse of everyday waste materials.

CHAPTER 6

MODULES DESCRIPTION

6.1 IMAGE UPLOAD AND PREPROCESSING MODULE

The Image Upload & Preprocessing Module is the first stage in the system workflow. It enables the user to provide input to the AI system by uploading an image of a waste item (e.g., plastic bottle, cardboard, or glass). This module ensures that the image is valid, readable, and formatted correctly before it is passed to the classification model. Built using Gradio, a Python-based interface library, this component makes the process accessible and interactive even for non-technical users.

Components

Gradio Image Input Interface (gr.Image)

- Provides a graphical interface for uploading waste item images in JPG or PNG format.
- Includes features like drag-and-drop and image preview.
- Offers a simple interface where users can upload images via file selection or drag-and-drop.
- Ensures compatibility with common image formats (JPG, JPEG, PNG).
- Shows a live preview to the user to confirm the correct image has been uploaded

Pillow (PIL) Image Loader

- Loads and converts the uploaded image into an RGB format for uniformity.
- Rescales and adjusts image properties to maintain clarity and consistency.
- Acts as a gateway to perform additional operations such as cropping or quality filtering (future scope).
- Converts the uploaded image to RGB format regardless of its original color mode.
- Rescales and adjusts image properties to maintain clarity and consistency.

Torchvision Transform Pipeline

- Applies transformations such as:

    Resizing (to 224×224 pixels)

    Tensor conversion (PIL → PyTorch tensor)

    Normalization (mean and standard deviation matching ImageNet.

Validation Logic

- Verifies that the uploaded image is not empty, corrupted, or of unsupported format.
- Detects if the file size is too large or the aspect ratio is incompatible.
- Ensures the system does not proceed with unusable inputs.

Error Handling

- Returns friendly messages if the user uploads an invalid file or skips image upload.
- If validation fails, user receives a helpful error message (e.g., "Unsupported format. Please upload a JPG or PNG image.").
- Helps users understand what went wrong and how to correct it.

Working Principle

Image Upload

When a user accesses the application, they are prompted to upload a photo of a waste item through the Gradio interface.

Image Loading

The system reads the image using Pillow and ensures it's in RGB mode to avoid issues with grayscale.

Preprocessing

A composed series of transformations from Torchvision resizes the image to 224×224 pixels, converts it to a tensor, and normalizes pixel intensity. These steps standardize the input, removing variability due to lighting, size, and camera type.

Tensor Output

The processed image is returned as a 4D tensor (batch size, channel, height, width) that is ready to be used as input to the classification model.

Function

The Image Upload & Preprocessing Module ensures a clean and consistent input pipeline for the AI system. Its core functions include:

Reliable Input Capture

- It handles the user's image selection and performs validation to ensure the system does not proceed with faulty or incompatible data.

Data Cleaning

- Preprocessing eliminates common variations in images, which helps the classifier perform more accurately and reduces the chance of misclassification.

Compatibility with AI Models

- By applying the correct input shape and normalization, it ensures that the output matches the input format expected by MobileNetV2, preventing crashes and improving prediction stability.

Enhancing Model Confidence

- By removing noise and standardizing the image, this module contributes to a more confident and correct classification.

6.2 IMAGE CLASSIFICATION MODULE

The Image Classification Module is the visual intelligence component of the AI-powered Waste Reuse Recommendation System. It plays a pivotal role in determining the type of waste material uploaded by the user, such as "plastic bottle," "paper," "metal can," or "glass jar." This module leverages the MobileNetV2 model, a lightweight Convolutional Neural Network architecture known for its high accuracy and computational efficiency. Developed with mobile and embedded systems in mind, MobileNetV2 ensures fast and reliable classification, making it ideal for real-time applications in sustainability and waste management.

Components

MobileNetV2 Model (Pretrained on ImageNet)

- The CNN backbone that extracts visual features and classifies the image into one of the 1000 ImageNet categories.
- A lightweight CNN architecture optimized for speed and low-resource environments.
- Uses depthwise separable convolutions to reduce computational complexity.
- Although pretrained on ImageNet, it still performs well in classifying common waste items due to the generality of features learned.

Image Preprocessing Pipeline (Torchvision Transforms)

- Includes image resizing, tensor conversion, and normalization to match the model's expected input format.
- Ensures that the input fed into MobileNetV2 is properly formatted.
- Maintains input consistency by transforming images to a normalized tensor of shape [1, 3, 224, 224].

PyTorch Inference Engine

- Handles loading the model, feeding input tensors, and producing classification predictions.
- Loads the pretrained model and executes a forward pass on the input tensor.
- Outputs a 1x1000 tensor where each value corresponds to a class confidence score.

Class Label File (imagenet_classes.txt)

- A plain-text file mapping numeric model outputs to human-readable labels like "plastic bottle" or "cardboard."
- Maps output indices (0–999) to human-readable names.
- Can be customized later with a new set of waste-specific labels using transfer learning.

Prediction Logic

- Compares model outputs and selects the highest probability class to determine the detected waste item.
- Sorts the output probabilities using torch.max() or torch.topk().

- Extracts the label with the highest confidence score as the final classification.

Operation Principle

- Image Input: The image uploaded by the user is passed into the preprocessing pipeline where it is resized to 224×224 pixels and normalized using predefined ImageNet statistics.
- Feature Extraction: The preprocessed image is then input into the MobileNetV2 model, which applies convolutional layers to detect features like shape, edges, and textures.
- Classification: The model computes probabilities for 1000 predefined classes and returns the class index with the highest score.
- Label Mapping: The output index is then matched to the label file to generate a readable name (e.g., "plastic bottle"), which will be used in the next module for instruction generation.

Function

The Waste Classification Module performs several critical functions that are central to the reuse recommendation pipeline:

Image Understanding

The module analyzes visual content using a deep neural network trained on millions of images. This allows it to generalize and recognize everyday waste items with high accuracy.

Data Flow to Next Module

The classification label generated here is passed as a textual input to the Reuse Idea Generation Module. This makes the classifier an essential link in the decision-making pipeline.

Efficient Processing

MobileNetV2 is chosen for its fast inference time and minimal memory footprint. It runs efficiently on standard CPU-based systems and cloud platforms, ensuring that users receive fast results even without GPUs

Flexibility and Expandability

The system can be adapted to accept custom-trained MobileNet models for better waste-specific classification in the future. This modular design ensures long-term scalability.

6.3 REUSE INSTRUCTION GENERATION MODULE

The Reuse Instruction Generation Module is the brain of the system, designed to transform the classified waste item into meaningful, creative, and eco-friendly reuse ideas. It utilizes Together AI’s Mixtral-8x7B language model, a state-of-the-art large language model (LLM), to generate step-by-step instructions based on the waste type identified by the classifier. This module ensures that every user receives personalized and practical suggestions on how to repurpose their waste, shifting the focus from disposal to sustainable reuse.

Components

Together AI API Integration

- Connects the system to the Mixtral-8x7B model hosted on Together AI’s cloud infrastructure.
- Uses secure API calls with authentication tokens.
- Establishes a secure HTTPS connection to Together AI’s Mixtral-8x7B model.
- Utilizes bearer tokens for authenticated access.
- Allows easy scaling as no model hosting is needed locally.

Prompt Construction System

- Dynamically builds a text prompt using the label predicted by the classifier.
- Example: “Give step-by-step reuse ideas for a cardboard box.”
- Automatically generates context-aware prompts such as:
  “Suggest 3 creative ways to reuse a plastic bottle at home.”
  “What DIY projects can be made from a cardboard box?”
- Ensures prompts are concise yet rich enough for creative AI output.

Language Model (Mixtral-8x7B)

- A powerful LLM trained on a wide range of internet data and instructional formats.
- Capable of generating coherent, instructional, and practical text.
- A multi-expert transformer with billions of parameters.
- Trained on diverse datasets including DIY instructions, sustainability blogs, and instructional texts.
- Excels at generating long-form, coherent, and actionable content.

API Response Handler

- Processes the response, extracts the generated text, and formats it for display in the UI.
- Parses the JSON response to extract the text output.
- Adds bullet points or step numbers for clarity and readability.

Error Handling

- Detects API errors such as invalid keys, quota limits, or timeouts and returns user-friendly error messages.

Working Principle of the Indicator Light Module

Prompt Formation

Once the classification module outputs a label (e.g., "plastic bag"), it is inserted into a pre-written sentence to form a complete prompt requesting reuse ideas.

API Call to Together AI

The system sends this prompt via HTTPS POST to Together AI's API endpoint for the Mixtral-8x7B model, including authentication headers.

Model Processing

The Mixtral-8x7B model interprets the prompt, draws from its training knowledge, and composes a creative and useful response.

Receiving and Formatting the Output

The system receives the generated instructions in JSON format. The relevant text is extracted, cleaned, and formatted into readable steps.

Delivery to Frontend

The final reuse instructions are displayed to the user through the Gradio interface in the next module.

Function

The Reuse Instruction Generation Module enhances the utility and value of the system by providing real, actionable steps to repurpose waste. Its primary functions include:

Promoting Sustainability

By suggesting creative reuse ideas, this module encourages a shift from "throw-away" habits to responsible reuse behavior.

Instructional Output

Unlike generic content, the generated ideas are usually multi-step, personalized, and context-aware, making them ideal for users seeking detailed guidance.

AI-Powered Creativity

The Mixtral-8x7B model brings advanced generative intelligence to the system, enabling it to produce ideas that may not be commonly found through manual search.

Modular Integration

The API design allows this module to be upgraded independently — future versions can support other models (e.g., Gemini, GPT-4) with minimal code changes.

Error Awareness

The module is capable of handling network failures, rate limits, and API errors gracefully, ensuring that the user always gets informative feedback.

6.4 WEB INTERFACE AND OUTPUT MODULE

The Web Interface & Output Display Module serves as the communication layer between the user and the backend AI system. Built using Gradio, this module is responsible for capturing user input (image uploads), displaying system outputs (waste item classification and reuse suggestions), and handling the interaction flow. It turns a complex multi-stage AI pipeline into a simple and accessible web-based experience for the user.

Components

Gradio Blocks Interface (gr.Interface)

- Handles layout creation using Gradio’s high-level API.
- Defines input and output components, connects them to backend Python functions.
- Organizes layout using gr.Blocks and gr.Row() or gr.Column() to align UI components neatly.
- Each Gradio component is linked to a Python function handling backend logic.

Image Upload Box (gr.Image)

- Allows users to upload a waste image from their device.
- Provides drag-and-drop functionality and image previews.
- Can include input filters to restrict uploads to image files only.
- Preview window confirms the correct image has been selected.

Text Output Box (gr.Textbox)

- Displays classification results and AI-generated reuse instructions.
- Automatically formats long text into readable paragraphs or bullet points.
- Separates classification output from reuse suggestions.
- Uses markdown or HTML for rich formatting (e.g., bold headers, bullet lists).

Submit & Clear Buttons

- Enables the user to trigger the model pipeline or reset the interface.
- "Submit" initiates the pipeline and "Clear" resets session state.
- Gradio’s interactive=True setting enables dynamic UI updates.

Loading Indicators & Error Feedback

- Communicates system status (e.g., “Processing...”) and error messages (e.g., “Invalid image uploaded”).
- Provides visual feedback like spinners during model processing.
- Uses popups or label messages to guide the user.

Hosting Integration

- Provides web deployment environment for making the application publicly accessible.
- Gradio apps can be deployed via Hugging Face Spaces, localhost, or custom servers.
- Allows private or public access for user testing or live demos.

Working Principle

User Input

The user accesses the web application via a browser and uploads an image using the Gradio interface.

Input Routing

Gradio passes the uploaded image to the preprocessing and classification modules in the backend via a linked Python function.

Real-Time Interaction

As the backend modules complete their tasks, Gradio receives the classification label and the AI-generated reuse instructions.

Output Display

These results are formatted and displayed instantly within the UI using text boxes and status prompts.

Session Control

The user may clear the session using a "Clear" button, or upload a new image to start again — enabling continuous usage.

Function

The Web Interface & Output Display Module ensures that complex AI capabilities are delivered in a friendly, usable format. It handles:

User Interaction

Provides an intuitive, no-code platform where users can engage with the AI system using simple controls like buttons and image inputs.

Device Accessibility

The interface is mobile and desktop-friendly, allowing use from a wide range of devices — without the need for app installation.

Seamless Integration

Gradio's design ensures smooth communication with other modules, from image upload to API response handling.

Result Presentation

Results are formatted for clarity and user comprehension, increasing the value of the AI-generated suggestions.

Debugging and Testing

The UI also supports debugging features during development by showing real-time outputs and logs.

CHAPTER 7

CONCLUSION AND FUTURE ENHANCEMENT

7.1 CONCLUSION

The AI-powered Waste Reuse Recommendation System represents a significant step forward in integrating artificial intelligence with environmental sustainability. Traditional waste management systems focus primarily on recycling and disposal, often lacking personalized reuse guidance and accessibility. This project addresses those gaps by offering a user-friendly, image-based platform that not only identifies waste items through AI but also provides meaningful and actionable reuse instructions. It empowers individuals to become proactive in waste reduction and sustainability practices, starting from their own homes.

By combining MobileNetV2—a lightweight but powerful convolutional neural network—with the Mixtral-8x7B large language model from Together AI, the system delivers a dual-layered solution. The first layer accurately classifies waste items such as plastic bottles, cans, and cartons, while the second layer generates tailored reuse suggestions, such as turning plastic into household tools or crafts.

Furthermore, the project's use of Gradio for the web interface ensures that the system is not only functional but also accessible to a broad audience. Users with little to no technical knowledge can interact with the tool, upload waste images, and instantly receive ideas for upcycling and repurposing.

In conclusion, the project not only fulfills its objective of making waste reuse intelligent and interactive, but also contributes to global sustainability goals by encouraging behavior change through technology. It highlights the role of AI as a tool for social good and lays a strong foundation for further innovation in smart waste management. With continued development and adoption, systems like this could lead to a more circular economy, reduce landfill dependency, and foster a culture of conscious consumption and creative reuse.

7.2 FUTURE ENHANCEMENT

While the current system successfully classifies common waste items and generates reuse suggestions, there is significant scope for enhancement and expansion to make the solution more robust, scalable, and practical for real-world deployment.

One of the primary future enhancements is to expand the waste item classification model by training it on a custom dataset that includes a wider range of real-world waste categories, such as e-waste, bio-degradable materials, and mixed recyclables. This will improve classification accuracy, especially for complex or less common items. Integration with object detection models like YOLOv7 or Vision Transformers can also enable multi-item recognition in a single image, making the system even more useful for users uploading images of multiple waste items.

Another key enhancement is multilingual support. By enabling the reuse suggestions to be generated in regional languages, the system can reach a wider audience, including users in rural or non-English-speaking areas. Additionally, incorporating geolocation features can allow the platform to suggest local recycling centers or community-based reuse programs.

Future versions could also support mobile application deployment for offline use. A lightweight version of the model can be embedded in Android or iOS devices, allowing users to scan and receive reuse suggestions even without internet access. Furthermore, user feedback mechanisms can be introduced to allow users to rate, comment, or submit their own reuse ideas, enabling the system to learn and evolve over time through reinforcement learning and community input.

Lastly, integrating AR features or step-by-step DIY visuals could make the reuse instructions more engaging and easier to follow. These enhancements would elevate the platform from a basic recommendation tool to a full-fledged, smart, and interactive sustainability assistant.

APPENDIX A

SOURCE CODE

```
import os
import ssl
import torch
import logging
import together
import gradio as gr
from PIL import Image
from torchvision import models, transforms
from torchvision.models import MobileNet_V2_Weights
# Disable SSL verification (only for dev environments)
ssl._create_default_https_context = ssl._create_unverified_context

# Configure logging
logging.basicConfig(level=logging.INFO,format="%(asctime)s
[%(levelname)s] %(message)s")

# Set Together AI API key securely (you can also use dotenv in production)
os.environ["TOGETHER_API_KEY"]="tgp_v1_wpMDTCEa-
9VJLlcMt_H0fZfhisxI_ebnLqVmBFhaMXs"
together.api_key = os.environ["TOGETHER_API_KEY"]

# Load pretrained MobileNetV2 model and weights
logging.info("Loading MobileNetV2 model...")
weights = MobileNet_V2_Weights.DEFAULT
model = models.mobilenet_v2(weights=weights)
model.eval()
```

```
logging.info("Model loaded successfully.")

# Image preprocessing pipeline
preprocess = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.485, 0.456, 0.406],
                         std=[0.229, 0.224, 0.225]),
])

def identify_waste_item(image: Image.Image) -> str:
    """
    Identifies the class label of the waste item in the image using MobileNetV2
    Args:
        image (PIL.Image.Image): Input waste item image.
    Returns:
        str: Predicted label/category of the waste item.
    """
    try:
        tensor = preprocess(image).unsqueeze(0)  # Add batch dimension
        with torch.no_grad():
            output = model(tensor)
        idx = torch.argmax(output, dim=1).item()
        label = weights.meta["categories"][idx]
        logging.info(f"Predicted label: {label}")
        return label
    except Exception as e:
        logging.error(f"Error in identifying image: {e}")
        return "Unknown Item"
```

```python
def generate_reuse_ideas(label: str) -> str:
    """
    Generates 5 creative and eco-friendly reuse/recycling ideas using Together AI.
    Args:
        label (str): Waste item label predicted by the image model.
    Returns:
        str: Step-by-step reuse/recycling instructions.
    """
    prompt = (
        f"Suggest 5 creative and practical reuse or recycling ideas for a '{label}'. "
        "Provide step-by-step instructions for each idea."
    )
    try:
        logging.info("Sending request to Together AI for reuse ideas...")
        response = together.Completion.create(
            model="mistralai/Mixtral-8x7B-Instruct-v0.1",
            prompt=prompt,
            max_tokens=300,
            temperature=0.7,
            top_p=0.9,
            stream=False,
        )
        ideas = response.choices[0].text.strip()
        logging.info("Reuse ideas generated successfully.")
        return ideas
    except Exception as e:
        logging.error(f"Failed to generate reuse ideas: {e}")
        return "Error generating reuse ideas. Please try again later."
```

```python
def classify_and_generate(img: Image.Image) -> str:
    """
    Full pipeline function: Classify waste item and generate reuse suggestions.

    Args:
        img (PIL.Image.Image): Uploaded image.

    Returns:
        str: Markdown output with label and instructions.
    """
    label = identify_waste_item(img)
    instructions = generate_reuse_ideas(label)
    return f"**Identified Item:** {label}\n\n**Reuse
Instructions:**\n{instructions}"


interface = gr.Interface(
    fn=classify_and_generate,
    inputs=gr.Image(type="pil", label="Upload Waste Item Image"),
    outputs=gr.Markdown(label="AI-Generated Reuse Instructions"),
    title="♻️ AI-Powered Waste Reuse Generator",
    description=(
        "Upload an image of a waste item (e.g., plastic bottle, cardboard, bag,
etc.).\n\n"
        "The system will identify the item and suggest 5 creative reuse/recycling
ideas, "
        "with clear step-by-step instructions using AI.\n\n"
```

```
        "Powered by MobileNetV2 and Together AI Mixtral-8x7B."
    ),
    examples=[
        ["example_plastic_bottle.jpg"],
        ["example_cardboard_box.jpg"],
    ],
    allow_flagging="never",
    theme="default"
)
if __name__ == "__main__":
    logging.info("Launching Gradio interface...")
    interface.launch(share=True)    # share=True to allow public URL (for
demo/presentation)
```

APPENDIX B

SCREENSHOTS

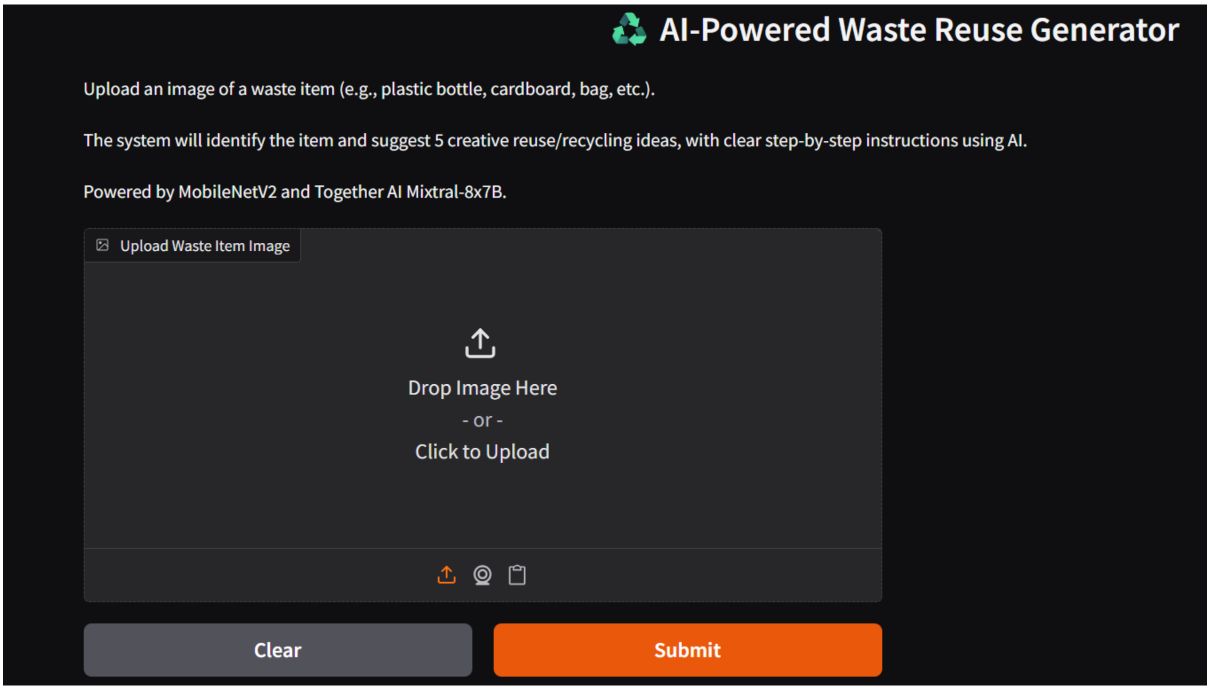

Fig. B.1 Upload Interface

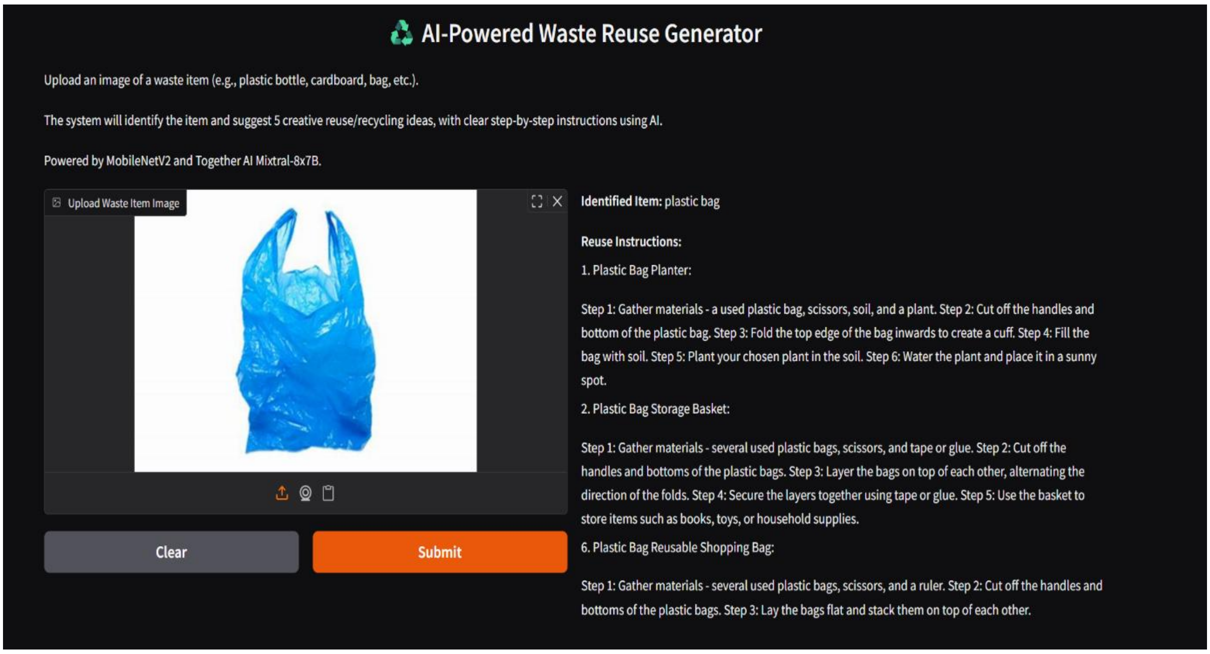

Fig. B.2 Reuse Ideas

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