Department of Computer and Information Systems Engineering

CS-406 Computer Engineering Project

Proposal for the Final Year Design Project

Title	**AI-Powered Smart Waste Segregation System Using Computer Vision**

Domain	**Domain 1** Artificial Intelligence/ Machine learning	**Domain 2** Computer Vision	**Domain 3** Embedded Systems	**Domain 4** Sustainable Technology	**Domain 5**	**Domain 6**

1. Nature of Project [Tick all that applicable]

☒ New Project OR ☐ Extension of Existing Project	☐ Industrial Collaboration	☒ Funded
☐ Other Department Collaboration (If yes) Department Name_________________	☐ Other Academic Institution Collaboration (If yes) Institution Name________________	

2. Brief Outline (*Problem Identification and Significance*)

Improper waste disposal has become a global challenge, leading to recycling inefficiencies and environmental damage. One of the key problems is that people often fail to sort recyclables and organic waste due to inconvenience or lack of awareness. This project proposes the development of an AI-powered smart bin that can automatically detect, classify, and sort waste into respective compartments using computer vision and artificial intelligence. The system will be further enhanced with a chatbot interface displayed on a screen, offering interactive and educational feedback to users, thereby promoting awareness and encouraging responsible waste disposal. This smart bin can be implemented in smart cities, universities, offices, and public spaces to support sustainable waste management and align with UN Sustainable Development Goals.

3. Objectives

The main objectives of this project are to design and implement a real-time waste classification and sorting system. Specifically, the project aims to develop a deep learning model capable of classifying waste such as plastic, paper, metal, glass, and organic matter, and to deploy this model on embedded edge devices like **Raspberry Pi** for real-time recognition using a camera. The system will integrate a **mechanical sorting mechanism with servo motors** to automatically direct waste into separate compartments. An **interactive chatbot interface** will also be designed to provide both visual and voice-based feedback to educate and engage users in sustainable practices. Additionally, a **data analytics module** will be developed to track and analyze the type and frequency of waste collected. To enhance practicality, the system will incorporate a **compartment monitoring feature using sensors and LED indicators**, which will signal when a bin compartment is full, ensuring timely collection and efficient maintenance.

4. Scope

1. Automated Sorting Mechanism

- Hardware: Integrate a Raspberry Pi, camera, and servo motors to physically direct waste.
- Software: Develop image capture and servo control software.
- AI: Train a CNN model (using TensorFlow Lite) on a curated waste dataset to classify items in real-time.

2. AI:

Train a CNN model on a curated waste dataset to classify items into the following categories in real-time:

- Plastic
- Paper
- Metal
- Glass
- Organic (Biodegradable/Compost)
- Non-Recyclable (Landfill)

2. Interactive User Interface

- Hardware: Mount a touchscreen display for user communication.
- Interaction: Implement a rule-based interface to:
- Provide instructions and educational facts.
- Request user feedback on classification accuracy ("Was this correct?").
- Allow manual item identification for unknown objects.

3. Capacity Monitoring & Alerts

- Sensors: Install ultrasonic sensors in each compartment to monitor fill-level.
- Alerts: Program RGB LEDs to glow red when a bin is full.
- Notifications: Display full-compartment warnings on the touchscreen.

5. Proposed Methodology

Proposed Methodology

The development of the Smart AI Trashcan will follow a structured six-stage methodology:

1. **Dataset Preparation:** Publicly available datasets (TrashNet, TACO, WasteNet) will be utilized. Data augmentation (rotation, zooming, flipping) will enhance diversity and model robustness.
2. **Model Training & Optimization: Transfer** learning will be employed using lightweight CNNs (e.g., MobileNet, EfficientNet). The final architecture will be selected based on a trade-off between accuracy, inference speed, and model size. A hybrid fine-tuning approach (freezing initial layers, retraining later layers) will be used. The model will be optimized for edge deployment using TensorFlow Lite or ONNX.
3. **Hardware Integration:** A Raspberry Pi/Jetson Nano will serve as the controller. A camera module will capture waste images for real-time processing without storage to ensure privacy. Servo motors will control the sorting flap mechanism. Ultrasonic sensors will detect object placement, and LEDs will signal full compartments. A touchscreen display will be integrated for user interaction.
4. **User Interface Development:** A rule-based interactive system will be implemented on the touchscreen (using a Python GUI framework). It will provide instructions, educational facts, and prompt users for feedback on classification accuracy. Text-to-speech may be added for accessibility.
5. **Data Logging & Analytics**: Classification results and user feedback will be stored in a local database (e.g., SQLite) for offline analysis, generating usage statistics (waste types, volumes) for performance monitoring.

6. **Testing & Validation:** The model will be evaluated on accuracy and inference speed. The physical sorting mechanism will be tested for reliability with various materials. User feedback will be collected to assess interface usability and system effectiveness**.**

The overall workflow of the proposed system is illustrated in Figure 1, which highlights the sequence of waste detection, image capture, classification, and sorting through servo-motor control.

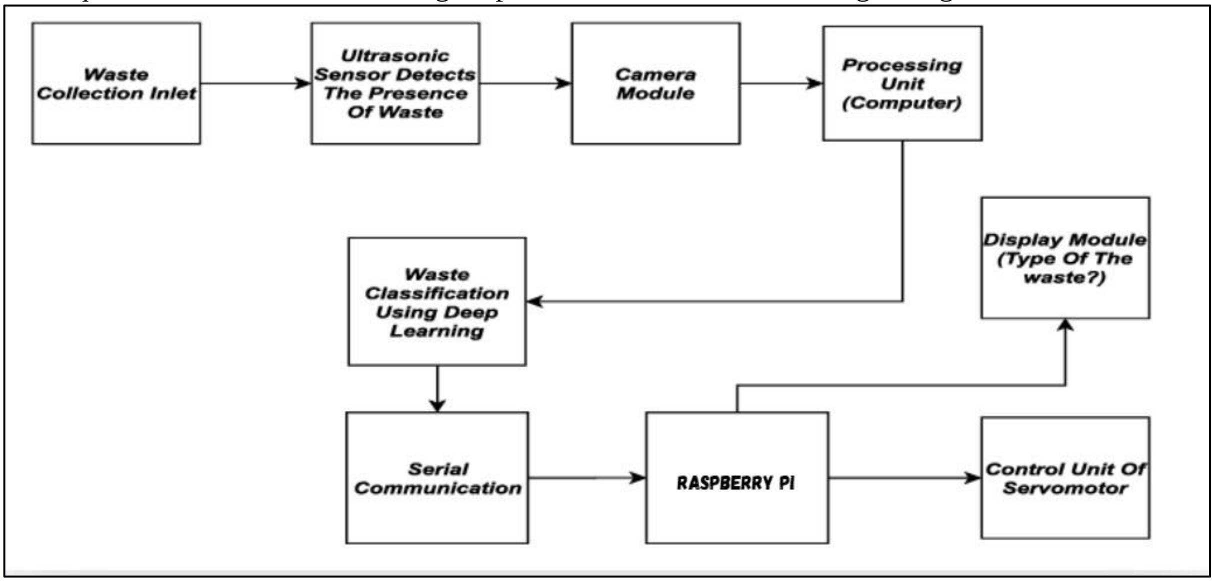


Figure 1 : Overall Workflow of the system

Deliverables

- **An Optimized AI Model:** A trained and optimized deep learning model (using transfer learning on waste datasets such as TrashNet, TACO, or WasteNet) capable of classifying waste into predefined categories (e.g., plastic, paper, metal, glass, organic)
- **Hardware Prototype** – A functional smart trashcan prototype integrating Raspberry Pi/Jetson Nano, camera module, servo motors, sensors (ultrasonic/IR), LED indicators, and LCD/touchscreen interface
- **Integration Software** – The complete software system connecting model inference, hardware control, user interaction screen
- **Testing & Validation Report** – A detailed evaluation report on model performance, real-time inference efficiency, sorting accuracy, and user feedback analysis.
- **Final Documentation & Presentation** – Literature Review and Problem Statement, Comprehensive project documentation, user manual, and final year project presentation and demonstration.

6. Resources Involved

The hardware resources required include Raspberry Pi or Jetson Nano, Pi Camera or USB Camera, Servo Motors, IR/Ultrasonic Sensors, LED Indicators, Touchscreen LCD, and a power supply**.**

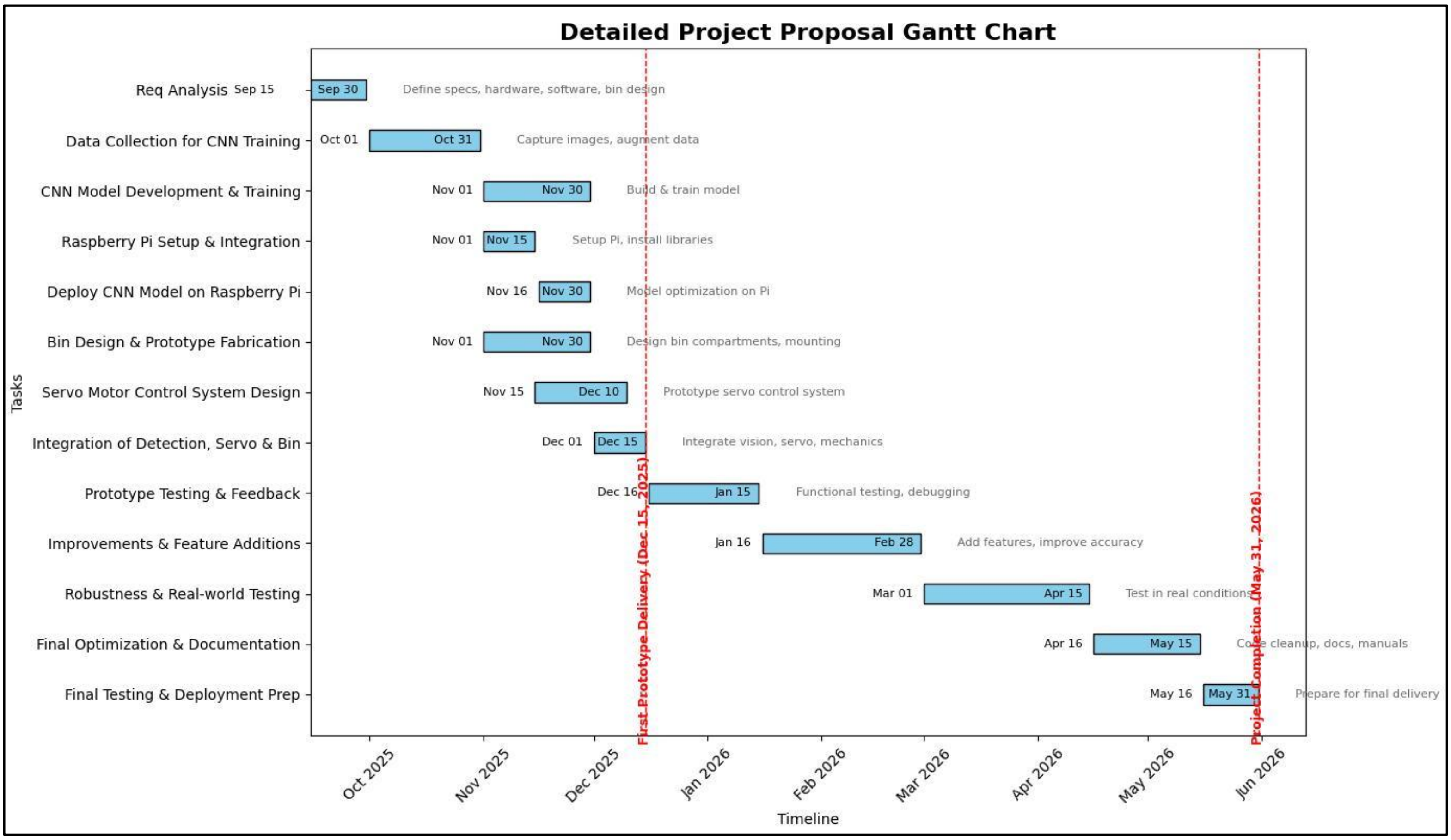
The software resources include PyTorch for AI model training, OpenCV for computer vision, TorchScript/ONNX for model deployment, Python for GUI, pyttsx3 or gTTS for voice feedback, and Firebase or SQLite for backend analytics**.**

7. Description of Industrial Support (If any)

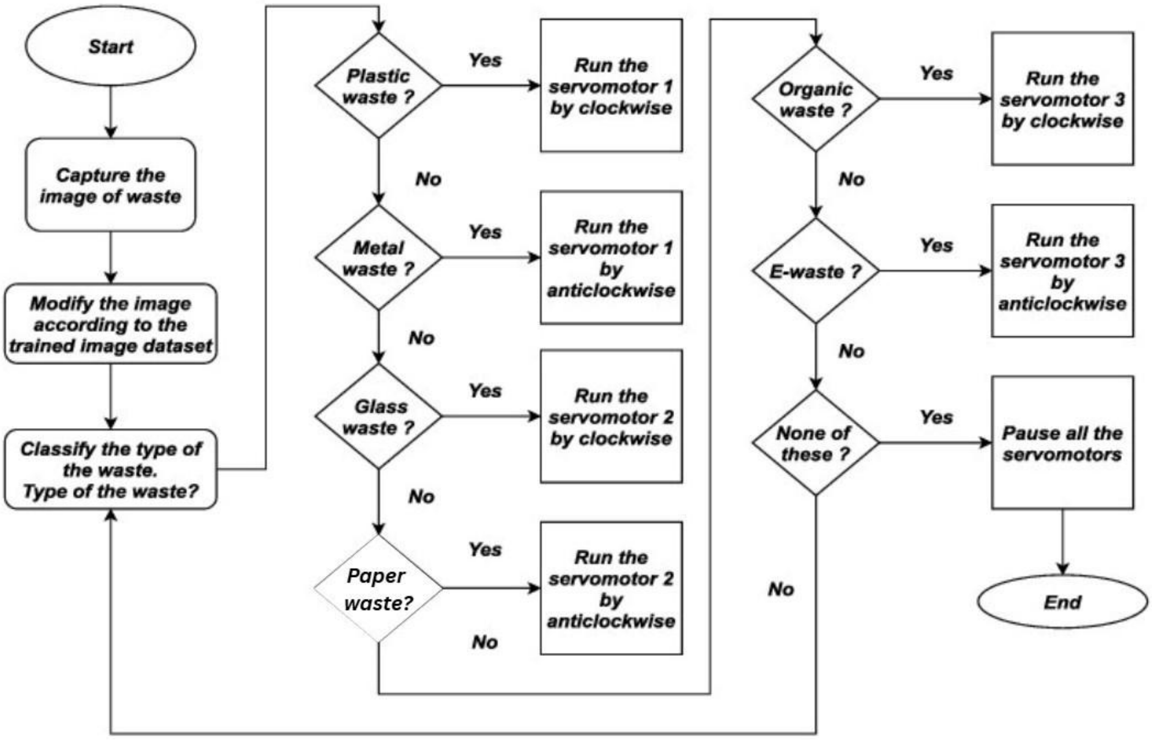
8. SDGs (If Applicable)

☐ No Poverty	☐ Zero Hunger
☐ Good Health and Well-Being	☐ Quality Education
☐ Gender Equality	☒ Clean water and Sanitation
☒ Affordable and Clean Energy	☐ Decent Work and Economic growth
☐ Industry, Innovations and Infrastructure	☐ Reduced Inequalities
☒ Sustainable Cities and Communities	☒ Responsible Consumption and Production
☒ Climate action	☐ Life Below Water
☐ Life on Land	☐ Peace, Justice and Strong Institutions
☐ Partnerships	

9. Gantt Chart



10. Flowchart of the project



11. Details of Project Team

i. Students

No.	Name	Seat No.	Signature (s)
1	Ayesha Ahmed	CS-22013	
2	Amina Shahzad	CS-22019	
3	Noor-ul-Huda	CS-22023	
4	Syeda Maida Jilani	CS-22037	

ii. Supervisors / Advisors

	Name	Designation & Department	Address & Contact	Signature(s)
Supervisor	Dr.Khurram	Associate Professor		
Co-Supervisor (If any)				

Industrial Advisor (If any)				

For Office Use Only		
Project Serial No.: ____________ Dated: ______________________	Signature Convener Steering Committee	Signature FYP Coordinator

☐ Proposal Approved	☐ Not Approved	☐ Returned for Clarification / Modification
Comments: (if any)		

____

(Signature of Chairperson)

Date: ______________________________