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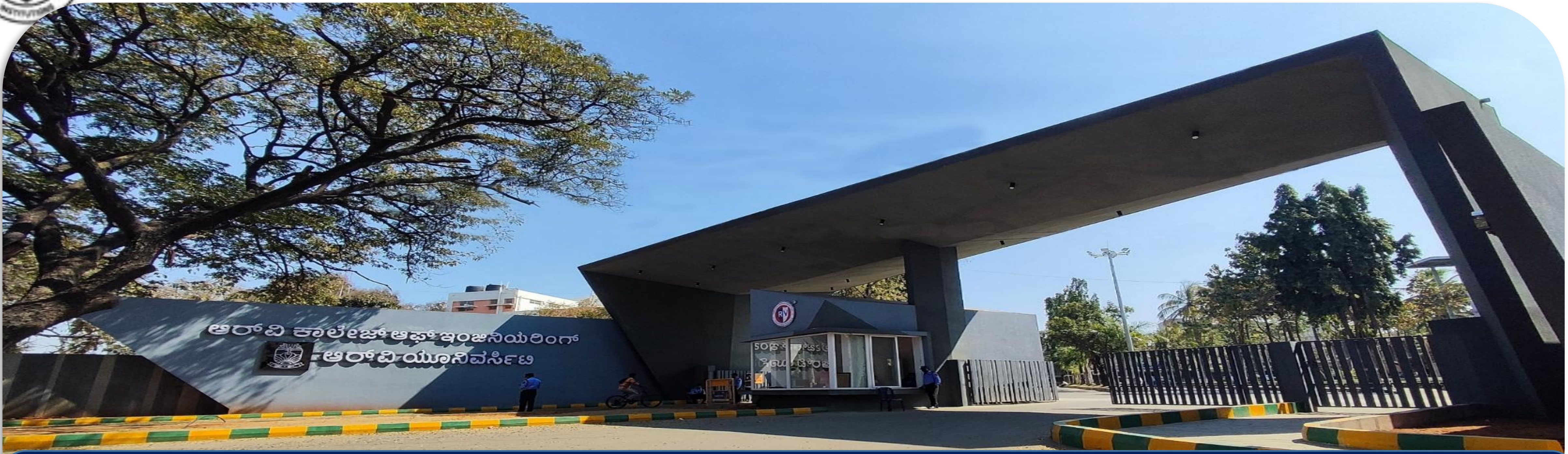

Machine Learning-Based Classification of Biomedical Waste Segregation in Healthcare Facilities

CSE-Cluster

Go, change the world

EL Phase-I
Presentation Outline

- Introduction
- Literature Review
- Problem Definition
- Objectives
- Methodology
- Proposed Outcomes
- Timeline of the project
- Conclusion
- References

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Introduction

Overview of the Topic

Biomedical waste (BMW) generated in hospitals contains infectious, hazardous, and sharp materials that require strict segregation into four categories—Yellow, Red, Blue, and White—as mandated by BMW Management Rules (2016 & 2023). However, manual segregation is prone to human error, leading to contamination, injuries, and biosafety violations.

Importance of the Topic

- India generates ~775 tons/day of biomedical waste (CPCB, 2023).
- 35–40% of hospitals show segregation errors due to human fatigue, lack of training, or improper disposal.
- Misclassification directly increases infection risk, needle-stick injuries, and cross-contamination.

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Literature Review

Author(s), Year	Title	Summary
Sharma & Gupta (2021)	Enhanced Segmentation Network with Deep Learning for Biomedical Waste Classification	Introduces EnSegNet with deep neural networks for biomedical waste classification. Uses segmentation + classification to improve accuracy. Demonstrates feasibility of image-based BMW recognition for automation.
Akkajit & Sukkuea, 2024	Medical Waste Classification Using Convolutional Neural Network	Proposes a CNN-based system to classify common medical waste items (syringes, vials, gloves). Achieved high accuracy using transfer learning. Study proves CNNs can reliably identify healthcare waste categories.
Haritha et al., 2025	Leveraging IoT and Deep Learning for Sustainable Biomedical Waste Management	Proposes a real-time IoT + DL framework for monitoring and classifying biomedical waste. Integrates sensors and ML for automated waste handling. Highly relevant for hardware-based smart bin systems.
Chhabra et al., 2024	Intelligent Waste Classification Approach Based on Improved Multi-Layered CNN	Presents an improved CNN for multi-class waste classification. Though focused on general waste, the methodology is applicable to biomedical waste segmentation and ML-based sorting systems.

Literature Review

Trends in Literature

- Growing use of deep learning models (CNNs, MobileNet, EfficientNet) for image-based biomedical waste classification.
- Increasing integration of IoT for real-time waste monitoring and smart bins.
- Movement toward hardware–software hybrid systems that automate both classification and physical sorting.
- Strong focus on reducing human error in biomedical waste segregation to improve biosafety.

Relevance to Current Research

- Existing studies show ML can accurately classify medical waste → supports feasibility of your system.
- Research highlights the need for automation to reduce segregation errors → your hardware solution addresses this gap.
- Few works combine ML classification with mechanical sorting → your project provides a novel, end-to-end solution aligned with current trends.

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Problem Definition

Clear Statement of the Problem

To prevent biosafety hazards and regulatory violations, hospitals must overcome the challenges associated with human errors in biomedical waste segregation.

Context of the Problem

- Manual waste segregation is unreliable.
- Workers often lack training or protective equipment.
- Misclassifications increase risk of infection and improper treatment of hazardous waste.

Significance of Addressing the Problem

If not solved, hospitals will continue to face:

- Increased needle-stick injuries
- Improper disposal leading to environmental contamination
- Spread of infectious diseases
- Legal penalties for non-compliance with BMW rules

Identified Gaps

- Lack of automated BMW classification systems
- No integration of ML with real mechanical bin-sorting hardware
- Limited research on error reduction in real hospital settings

Objectives

Main Objective:

To design and develop a hardware-integrated ML system that automatically classifies biomedical waste into its four prescribed categories and physically segregates it.

Specific Objectives:

- To build a 4-class ML classification model (Yellow, Red, Blue, White).
- To integrate the model with a Raspberry Pi + camera module.
- To develop a servo-based mechanical segregation system.
- To evaluate classification accuracy, system reliability, and biosafety compliance.

Expected Contributions to the Field:

- A functional prototype demonstrating real-world hospital application.
- A dataset and model that can be used for advanced research.
- Potential for IEEE publication and patent filing.

Methodology

Design:

A mixed-methods approach is used because both quantitative performance measurements and qualitative observations are important.

QUALITATIVE	QUANTITATIVE
Observing how different biomedical waste types visually differ Identifying mis-segregation patterns	Collecting image datasets for four waste categories. Measuring ML model performance using numerical metrics

Data Collection Methods:

1. Image data set collection (Primary)
   - Capture realistic images of biomedical waste for four categories
   - Capture images from different angles, lighting conditions, and distances
2. Sample waste collection
   - Plastic tubing (red), glass vials (blue), sharp needles (white), gloves, cotton (yellow)
3. Observational data
   - Record how often the ML model misclassifies items

the world

Methodology

Data Analysis Techniques:

Image Preprocessing
- Resize images
- Normalize pixel values

Machine Learning Model Training
- Use CNN-based architectures
- Split dataset into training, validation, and test sets

Performance Evaluation
- Use quantitative measures like accuracy, precision and recall, F1-score, confusion matrix

Hardware System Accuracy
- Measure sorting accuracy
- Measure mechanical response time of servo mechanism

Qualitative Analysis
- Identify types of waste that frequently confuse the ML model.
- Analyze environmental factors

Tools and Techniques:

Software
1. TensorFlow / Keras
2. TensorFlow Lite
3. OpenCV
4. LabelImg / Roboflow
5. Jupyter Notebook, Python
6. Matplotlib / Seaborn

Hardware
1. Raspberry Pi 4
2. Pi Camera Module
3. Servo motors
4. IR Sensors

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Methodology

METHODOLOGY

WASTE DETECTED

IR sensor detects the presence of biomedical waste in the input chamber.

IMAGE CAPTURED

Camera captures the image of the waste item.

IMAGE PROCESSED

Captured image is preprocessed and sent to the ML model.

ML MODEL CLASSIFIES WASTE

Model predicts one of the four categories: Yellow, Red, Blue, or White.

SERVO MECHANISM ACTIVATED

Based on prediction, the servo rotates the chute toward the correct bin.

Proposed Outcomes

Expected Results:

- Achieve >90% classification accuracy for four BMW categories.
- Fully functional hardware prototype demonstrating automated segregation.
- Reduction in human error rate in waste management workflows.

Potential Impact on the Field:

Enhanced biosafety & infection control in hospitals.
Contribution toward AI-driven smart hospital systems.
Reduction in workforce exposure to hazardous waste.
Data-driven approach to monitoring segregation compliance.

Future Research Directions:

Add hyperspectral imaging for better classification.
Expand system to 12-category BMW segregation.
Integrate with hospital HMIS for real-time compliance monitoring.
Use robotic arms for advanced waste handling.

Timeline of the project

Project Timeline Overview

- **Initiation Phase (Weeks 1-2)**
  Understand BMW rules and ML requirements
  Form team and allocate responsibilities
  Conduct feasibility analysis
- **Planning Phase (Weeks 3-4)**
  Finalize model architecture and hardware
  Dataset planning & collection strategy
  Budget allocations
- **Execution Phase (Weeks 5-10)**
  Collect dataset & train ML model
  Build hardware chute + servo mechanism
  Integrate ML with Raspberry Pi
  Test and refine system via repeated trials
- **Closure Phase (Weeks 11-13)**
  Compile final results and documentation
  Prepare IEEE-format paper
  Present prototype and final report
  Conclude EL Phase-I with evaluation

Conclusion

Summary of Key Points:

- Biomedical waste segregation is critical for biosafety in healthcare.
- ML and hardware can automate classification and reduce human error.
- Our system integrates camera + ML model + servo-based mechanism to segregate waste in real-time.

Final Thoughts:

- This project demonstrates how AI + IoT + Mechatronics can solve serious biosafety challenges and improve hospital waste management.

Call to Action or Next Steps:

- The system can be expanded into a full-scale hospital solution and is suitable for IEEE publication and further research.

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References

List of References:

1. Enhanced segmentation network with deep learning for Biomedical waste classification — 2021, Indian Journal of Science and Technology

2. Medical Waste Classification Using Convolutional Neural Network — 2024, E3S Web of Conferences / ICFEE 2024: 10.1051/e3sconf/202453004001

3. Health Care Waste Classification Using Deep Learning — 2025

4. Leveraging Internet of Things (IoT) and Deep Learning for Sustainable Biomedical Waste Management: An Advanced Framework for Real-Time Monitoring and Waste Classification — 2025, IJIAR

5. Intelligent waste classification approach based on improved multi-layered convolutional neural network — 2024, Multimedia Tools and Applications: 10.1 007/s11042-024-18939-w

Expected Outcome by the end of First Year

EL should aim for tangible results in one of the following forms:

- **Patent Filing:** If your prototype shows novel functionality or an innovative process, file for a patent. Steps include drafting a patent description, claims, and conducting a prior art search.
- **Journal Publication:** Write a comprehensive paper detailing the methodology, prototype design, testing, and results. Submit to journals related to manufacturing technology, engineering design, or industrial innovation.
- **Conference Publication:** Prepare an abstract or full paper for submission to conferences. Present your prototype development, key findings, and future research possibilities (Paper to be drafted as per IEEE format. Format will be shared later on)
- **Research Proposal:** Propose extending the research into a larger project, securing funding for mass production, or applying the process to different industries. Include objectives, proposed methodology, expected impacts, and a budget estimate.

Thank You!