INTELLIGENT WASTE SORTING SYSTEM USING DEEP LEARNING

Project Report submitted by

SONY	**SRAJANA S N**
(4NM20CS184)	(4NM20CS185)
ZULAIKHA ASHIQ	**SUSHMITHA S**
(4NM20CS218)	(4NM21CS416)

Under the Guidance of

Mr. ASHWIN SHENOY M
Asst. Professor
Dept. of CSE, NMAMIT, NITTE

In partial fulfillment of the requirements for the award of

the Degree of

Bachelor of Engineering in Computer Science and Engineering

from

Visvesvaraya Technological University, Belagavi

Department of Computer Science and Engineering
NMAM Institute of Technology, Nitte - 574110
(An Autonomous Institution affiliated to VTU, Belagavi)

APRIL 2024

NITTE
EDUCATION TRUST
N.M.A.M. INSTITUTE OF TECHNOLOGY
(An Autonomous Institution affiliated to Visvesvaraya Technological University, Belagavi)
Nitte – 574 110, Karnataka, India

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

Certified that the project work entitled

"Intelligent Wate Sorting System Using Deep Learning"

is a bonafide work carried out by

SONY *(4NM20CS184)* ***SRAJANA S N*** *(4NM20CS185)*
ZULAIKHA ASHIQ *(4NM20CS218)* ***SUSHMITHA S*** *(4NM21CS416)*

in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in Computer Science and Engineering

prescribed by ***Visvesvaraya Technological University, Belagavi***

during the year ***2023-2024****.*

It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library.

The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the Bachelor of Engineering Degree.

Signature of the Guide	***Signature of the HOD***	***Signature of the Principal***

Semester End Viva Voce Examination

Name of the Examiners	**Signature with Date**
1. ____________________	____________________
2. ____________________	____________________

ACKNOWLEDGEMENT

The satisfaction that accompanies the completion of any task would be incomplete without the mention of all the people, without whom this endeavor would have been a difficult one to achieve. Their constant blessings, encouragement, guidance, and suggestions have been a constant source of inspiration.

First and foremost, our gratitude to our project guide **Mr. Ashwin Shenoy M** for his constant guidance throughout this project and the valuable suggestions.

We also take this opportunity to express deep gratitude to the project coordinators for their valuable guidance and support.

We acknowledge the support and valuable inputs given by, **Dr. Jyothi Shetty** the Head of the Department, of Computer Science and Engineering, NMAMIT, Nitte.

Our sincere thanks to our beloved principal, **Dr. Niranjan N Chiplunkar** for permitting us to carry out this project at our college and providing us with all the needed facilities.

Finally, thanks to the staff members of the Department of Computer Science and Engineering and our friends for their honest opinions and suggestions throughout our project.

SONY(4NM20CS184)
SRAJANA S N(4NM20CS185)
ZULAIKHA ASHIQ(4NM20CS218)
SUSHMITHA S(4NM21CS416)

ABSTRACT

The escalating global waste management crisis necessitates efficient solutions to handle the increasing volume of municipal solid waste while minimizing environmental impact. In response, we introduce an innovative Intelligent Waste Sorting System (IWSS) that leverages deep learning techniques to automate and optimize waste sorting processes. Our system utilizes the state-of-the-art YOLOv7 object detection model, achieving an impressive accuracy of 92% in classifying waste into five distinct categories: paper, plastic, glass, metal, and other. By training our software on a diverse dataset of waste images, we eliminate the need for additional hardware components, making our solution accessible and cost-effective.

Furthermore, our IWSS demonstrates adaptability through real-time learning, continually refining its performance without requiring hardware modifications. This software-only solution not only improves waste management efficiency by reducing reliance on manual sorting processes but also promotes recycling and minimizes environmental impact. Through extensive experimentation and validation, we showcase the effectiveness, reliability, and potential of our approach in addressing the challenges of municipal solid waste management. Our project contributes to paving the way for sustainable waste management practices in both urban and rural environments, marking a significant step towards a cleaner and greener future.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

Waste management is managing waste by disposing and recycling it. Waste management needs proper techniques keeping in mind the environmental situations. All household, industrial, and factory waste must be appropriately managed; otherwise, it may result in several environmental and health hazards. We thus require efficient means of waste material collection, sorting, transportation, and disposal. We can reduce environmental degradation and safeguard the security and welfare of people and all other living things by managing garbage properly.

Traditional waste sorting systems, while having served as the backbone of waste management for decades, suffer from several limitations and drawbacks that hinder their effectiveness and efficiency. These drawbacks underscore the urgent need for innovative solutions such as intelligent waste sorting using deep learning. Some of the key shortcomings of traditional waste sorting systems are Manual Labor Dependency, Inefficiency and Slow Processing, Limited Sorting Accuracy, Health andSafety Risks, Environmental Impact, and Lack of Scalability.

The main objective of this project is to classify the waste items and sort them into different types in real time. It is very important to enhance the efficiency and throughput of waste sorting operations. The system should process waste items quickly and continuously, ensuring minimal disruption to the overall sorting process. To contribute to environmental sustainability by promoting proper waste recycling anddisposal will help in decreasing the amount of waste that can be dumped directly without sorting them into scientific or technical means.

To address these challenges, there is a growing need for technological advancements in waste segregation and recycling processes. Deep learning, a subset of AI has emerged as a promising tool for revolutionizing waste management practices. By leveraging advanced algorithms and neural networks, deep learning models can analyze and classify waste items with unprecedented accuracy and efficiency.

The primary objective of this project is to bring about technological advancement in the field of waste segregation and recycling. Below mentioned are the steps we are using to implement our project.

Data Analysis and Preprocessing: We will begin by analyzing the given dataset, and performing necessary preprocessing steps to clean and organize the data. By preparing the data meticulously, we aim to enhance the performance of our deep learning model.

Model Training: Using the pre-processed and categorized data, we will train a deep-learning model. By employing state-of-the-art techniques and algorithms, we aim to develop a highly accurate and robust model capable of classifying waste items effectively.

Image Prediction with YOLOv7: We will utilize the YOLOv7 algorithm for image prediction, enabling our model to identify and classify waste items in images with remarkable precision and speed. By integrating YOLOv7 into our workflow, we aim to enhance the efficiency and scalability of waste sorting processes.

Improving Sorting Efficiency: Our goal is to achieve precise classifications of waste items, thereby improving sorting efficiency and optimizing waste management processes. By accurately categorizing waste items, we can streamline recycling operations and minimize environmental impact.

Optimizing Data Analysis: We will preprocess and train the model on the dataset to facilitate effective data analysis and categorization. By optimizing our data analysis pipeline, we aim to extract valuable insights and patterns that can inform decision-making in waste management.

Enhancing Waste Management: Through precise waste item classification and efficient sorting techniques, we aspire to optimize waste management processes. By leveraging deep learning technologies, we aim to revolutionize waste segregation, recycling, and resource recovery efforts, contributing to a more sustainable and environmentally friendly future.

CHAPTER 2
LITERATURE SURVEY

This topic discusses the work done by various authors, students, and researchers in brief around discussion, about Intelligent waste Sorting System using Deep Learning. The purpose of this section is to critically summarize the current knowledgein the field of Waste segregation using Deep Learning.

Table 2.1: Survey on Intelligent Waste Sorting System

SL.NO.	TITLE	SUMMARY	METHOD	LIMITATION
[1]	Intelligent waste classification system using deep learning convolutional neural network	The study combines ResNet-50 CNN and SVM for waste classification with 87% accuracy using Thung and Yang dataset, automating waste sorting to enhance efficiency and sustainability in urban waste management.	ResNet-50 Convolutional Neural Network, Support Vector Machine (SVM) for Classification, Trash image dataset by Gary Thung and Mindy Yang	1. **Dataset Bias:** The accuracy relies on dataset representativeness,potentially impacting real-world generalizability. 2.**Real-World Variability:** Performance may be affected by variations in waste materials encountered in real-world scenarios. 3. **Dependency on Image Quality:**

				System performance relies on image quality, and poor-quality images may lead to misclassifications.
[2]	Intelligent waste management system using deep learning with IoT	This paper introduces a waste management system combining CNN and IoT, achieving 95.3125% classification accuracy and high usability. It employs smart trash bins with sensors for enhanced waste sorting and real-time monitoring, suitable for household integration.	Convolutional Neural Network (CNN), Smart Trash Bin with Sensors ,	1.**Data Variability:** Performance may be impacted by variability in waste materials. 2. **Dependency on Connectivity:** The reliance on IoT and Bluetooth may be challenging in certain areas.
[3]	Intelligent Waste Management	Proposed waste classification system uses CNNs and ResNet models	The waste classification system uses deep learning with CNNs and ResNet models to	Potential limitations include the need for further optimization for real-time detection

	System Using Deep Learning	achieving 78% and 91% accuracy respectively, aiming to optimize waste management routes and promote recycling. Its scalability and adaptability make it suitable for diverse urban settings, offering an innovative solution for sustainable waste management.	achieve high accuracies of 78% and 91%.	and challenges in adapting to diverse urban waste scenarios.Additionally, scalability and adaptability may require careful consideration for practical implementation in various settings.
[4]	Autonomous garbage detection for intelligent urban management	The paper introduces a deep learning method using Faster R-CNN and ResNet for urban garbage detection, demonstrating robustness and high precision. Integration of ResNet within Faster R-CNN	The study uses advanced deep learning techniques, employing a Faster R-CNN framework with a region proposal network and the ResNet algorithm for garbage detection in urban images	**Computational Demand:** The adoption of a deep learning strategy, specifically using Faster R-CNN with a region proposal network and ResNet **Detection Time Challenge:** The paper acknowledges the

		enhances object detection accuracy, with the proposed data fusion strategy addressing misdetection challenges, aiming for near-real-time and highly accurate urban garbage detection.		challenge of further reducing detection time
[5]	A rapid recognition method for electronic components based on the improved YOLO-V3 network	The paper presents a fast recognition method using YOLO V3–Mobilenet for electronic component detection in industrial settings. It enhances efficiency by incorporating the Mobilenet network framework into YOLO V3, with a dataset of 200 images and data	The study specifically introduces an improved YOLO V3 (YOLOV3–Mobilenet) model for the rapid identification of electronic components	The study achieves high accuracy (95.21%) and fast speed (0.0794 s) with an improved YOLO-V3 network. However, challenges include optimizing for real-time detection, deploying on embedded devices, and assessing effectiveness in diverse industrial environments.

		augmentation techniques employed for training.		
[6]	WasteSegNet: A Deep Learning Approach for Smart Waste Segregation in Urban Environments	The study introduces WasteSegNet, a custom CNN achieving 87.5% accuracy in segregating waste into Organic and Recyclable categories, offering potential for efficient waste sorting and sustainable management in smart cities. Despite challenges like class imbalance, its real-world applicability is evident with a validation dataset accuracy of 90.49%.	WasteSegNet,Convolutional Neural Network, is proposed to automate waste segregation into Recyclable categories, aiming to enhance waste management efficiency and promote sustainability. a custom-designed Convolutional Neural Network (CNN) for automated waste segregation into Organic and Recyclable categories	1.Class Imbalance: The study acknowledges challenges related to class imbalance in the dataset 2.Potential Overfitting: The research recognizes the possibility of overfitting, suggesting that the model's performance on the test dataset might be less reliable when faced with new, unseen data 3.Interpretability: The study notes a need for enhanced interpretability in the model

[7]	Machine learning methods for the prediction of organic solid waste treatment and recycling processes	The study explores machine learning applications for estimating domestic waste quantities, showcasing successful outcomes in waste prediction through two case studies. It underscores the potential of ML algorithms for designing efficient and sustainable waste management systems, addressing environmental and societal impacts.	The dominant model is artificial neural networks (ANN, 54%), addressing complex issues, yet challenges include not enough data, low and unclear model selection.	**Limited Data Availability:** One limitation is the scarcity of data, which hampers the comprehensive application of machine learning **Low Interpretability:** The challenge of low interpretability in machine learning models. **Unclear Model Selection Criteria:** The study notes a limitation in the lack of clear criteria for selecting machine learning models.
[8]	Multilayer hybrid deep-learning method for waste	The study proposes an automatic waste classification system using multilayer hybrid deep learning for	Multilayer Hybrid System (MHS) for waste classification, incorporating subsystems like convolutional neural networks (CNN) and	**Dataset Size and Diversity:** The study mentions the evaluation of MHS using 50 waste items. The small dataset size may

	classification and recycling	urban areas, combining high-resolution cameras and sensors. It integrates image processing with numerical sensor data to classify waste items as recyclable or non-recyclable, promising efficient waste management in urban settings.	multilayer perceptrons (MLP). The evaluation metrics for assessing system performance arealso introduced in this section.	limit **Limited Explanation of Decision Making:** Deep learning models, especially complex ones like the proposed MHS, often operate as black boxes, making it challenging **Environmental Impact:** While the study highlights the environmental benefits of the proposed MHS, it would be valuable to include an analysis of the environmental impact of manufacturing
[9]	Machine-learning approaches in geo-environ	The study employs ML algorithms to estimate and predict domestic waste quantities in MSW,	The study employs machine-learning (ML) algorithms, including linear regression, regression trees, Gaussian process	**Data Generalization:** The study relies on data from specific regions (Saudi Arabia and Bahrain) and a

	mental engineering: Exploring smart solid waste management	showcasing their potential in reducing waste-related impacts. Case studies from Saudi Arabia, Bahrain, and a family with eleven members validate the effectiveness of these methods.	regression, support vector machines, and autoregressive integrated moving average methods, for the estimation and prediction of domestic waste quantities	single-family case study The study's machine-learning algorithms may struggle to predict various types of domestic waste accurately.Sustainable waste strategies faces challenges due to technical and budget constraints, and its success relies on practical factors like infrastructure, public cooperation, and policy implementation.
[10]	Garbage detection and classification using a new deep learning-based	The study introduces an advanced garbage classification system using a modified MobileNetV2 model and attention mechanism,	As a typical lightweight network, the MobileNetV2 (Sandler et al. 2018) is the second generation of the Google MobileNetV1 (Zoph et al. 2018). Compared with the MobileNetV1	The study presents a garbage sorting system with a better model, reaching 90.7% accuracy and reducing size on Raspberry Pi 4B. While it works in real-time with

	machine vision system as a tool for sustainable waste recycling	achieving 90.7% accuracy on Raspberry Pi 4B in real time. With reduced model size and low consumption cost, the prototype showcases promising prospects for efficient waste recycling.		PCA, challenges exist in setting up initial parameters, and achieving 89.26% accuracy in the prototype indicates effectiveness but challenges in broader applications.
[11]	Intelligent Waste Management System Using Deep Learning	The Intelligent Waste Management System utilizes deep learning to automate waste processes, enhancing efficiency and promoting sustainable practices. It reduces human intervention, optimizes collection, and offers scalable solutions for	The system utilizes CNNs (78% accuracy) and ResNet models (91% accuracy) to autonomously identify and classify waste materials. Image datasets optimize waste collection routes, reduce landfill waste, and promote recycling and composting.	Limited by the quality and diversity of image datasets, potential challenges in real-world environmental conditions (e.g., varied lighting, weather), and dependency on continuous technological updates for optimal performance. The accuracy rates may vary in

		various urban environments.		dynamic urban environments.
[12]	Intelligent Waste Classification System Using Deep Learning Convolutional Neural Network	The research introduces a waste material classification system utilizing ResNet-50 CNN and SVM, aiming for 87% accuracy and emphasizing automation to streamline waste separation. Future work entails parameter adjustments and dataset expansion to enhance system capabilities for urban waste management.	The system employs a ResNet-50 CNN for feature extraction and a Support Vector Machine (SVM) for waste classification, achieving an 87% accuracy on a trash image dataset. This combination streamlines waste separation, reduces human intervention, and aims to mitigate pollution and infections.	The system's accuracy is contingent on the quality and diversity of the dataset. It may face challenges in real-world scenarios, and expanding the dataset is suggested for improved accuracy. The current capabilities are limited to the classification of waste items, and future work involves adjusting parameters for classifying additional waste categories.
[13]	YOLO TrashNet:	YOLO TrashNet employs YOLOv3 for real-time	YOLO TrashNet employs a fine-tuned YOLOv3	The system's efficacy depends on dataset quality

	Garbage Detection in Video Streams	urban waste detection, aiding in smart city waste management. Future plans include dataset expansion and intelligent agent development for broader integration.	model for real-time garbage detection in urban areas. It identifies waste and recognizes Garbage Dumpsters and Bins, aiding smart city waste management	and may face challenges in varied conditions. Future plans include expanding the dataset and developing an intelligent agent for broader integration.
[14]	Waste Object Detection and Classification using Deep Learning Algorithm: YOLOv4 and YOLOv4-tiny	The study highlights YOLOv4's accuracy and YOLOv4-tiny's speed for waste management, exploring subdivision values and data augmentation. Future efforts aim to expand datasets and incorporate newer YOLO versions for improved urban waste classification.	YOLOv4 and YOLOv4-tiny with Darknet-53 detect waste in a dataset of 3870 images across glass, metal, paper, and plastic. YOLOv4 excels in accuracy, and YOLOv4-tiny in speed. Subdivision values and data augmentation impact performance.	Challenges include dataset quality and the accuracy-speed trade-off. Future work includes dataset expansion, more waste categories, and exploring newer YOLO versions.

[15]	Deep learning -based object detection for smart solid waste management system	The research addresses waste pollution in Ethiopia, presenting a YOLOv4-waste model with emphasis on accuracy. YOLOv4 outperforms YOLOv4-tiny, highlighting the need to optimize parameters for effective waste management in the context of urbanization and industrialization in Ethiopia.	YOLOv4-waste model is introduced for real-time waste detection, using a dataset of 3529 images across 7 classes. YOLOv4 outperforms YOLOv4-tiny in accuracy. Key metrics evaluated include mAP, precision, recall, F1-score, and Average IoU.	Challenges include diverse environmental conditions and the trade-off between speed and detection capabilities. Optimizing subdivision values and data augmentation is crucial.
[16]	T.D. Bui et al. Identifying sustainable solid waste management barriers in	The study identifies 44 barriers to sustainable solid waste management across technical, knowledge, human resource, and financial domains.	The research likely employed a systematic literature review to gather information on barriers to sustainable solid waste management (SSWM). Data on these barriers were extracted and	Limitations of this research paper may include potential biases inherent in relying solely on existing literature, such as overlooking emerging challenges not yet widely

	practice using the fuzzy Delphi method Resour. Conserv. Recycl. (2020)	Addressing critical issues like hazardous waste and funding constraints is crucial for advancing SSWM, with implications for theory and practice.	categorized into four main groups, followed by a prioritization process to identify critical challenges. The findings were then analyzed to draw implications for both theoretical understanding and managerial practice in SSWM.	documented. Additionally, the study's focus on barriers identified in literature may overlook context-specific challenges that vary across regions or communities, potentially limiting the generalizability of findings. Moreover, while the study identifies critical barriers, it may lack specific insights into actionable solutions or interventions to address these challenges effectively.
[17]	G. Aid et al. Expanding roles for the Swedish waste manage	The waste management industry is shifting towards integrated, sustainable services, exploring	The research likely employed qualitative methods such as case studies and interviews to examine the barriers to improving inter-organizational	The transition to a more integrated, sustainable service provision and material production sector may face challenges in

	ment sector in inter-organizational resource management	concepts like circular economy and industrial symbiosis. Swedish sector addresses barriers to resource management through services and technologies, balancing risks with opportunities to stay ahead in the industry.	resource management through industrial symbiosis in the waste management sector. These methods likely involved analyzing data on how Swedish waste management organizations are addressing these barriers through the adoption of specific services and technologies.	implementation, including changes to existing infrastructure and processes. The adoption of new services and technologies to address barriers may be limited by the availability and effectiveness of existing technologies in the waste management sector.
[18]	O.I. Funch et al. Detecting glass and metal in consumer trash bags during waste collection using convolut	The study proposes a method using sound recording and metal detectors combined with machine learning to classify glass and metal in trash bags with up to 98% accuracy. Its potential implementation in waste collection	The research employed a combination of sound recording and beat-frequency oscillation metal detection technologies, integrated with machine learning algorithms, particularly convolutional neural networks (CNNs), to classify the	The research paper may face limitations concerning the generalizability of results, as testing was conducted in a controlled environment that may not fully replicate real-world waste collection scenarios. Additionally, while

	ional neural networks Waste Manage. (2021)	trucks could support location-specific monitoring of waste sorting quality, aiding waste management decisions and consumer behavior research.	presence of glass and metal in consumer trash bags. Testing was conducted in a custom-built rig resembling a waste collection truck to assess the accuracy of the system, achieving high accuracy rates of up to 98%. Future research considerations involve utilizing more realistic datasets and conducting testing in actual waste collection settings to enhance the system's practical applicability.	achieving high accuracy rates in the custom-built rig, the effectiveness of the method in diverse and dynamic waste collection environments remains to be validated. Furthermore, there might be challenges in scaling up the implementation of the system to real waste collection trucks, considering factors such as cost, maintenance, and integrationwith existing waste management infrastructure.
[19]	Application of deep learning object classifie	The study introduces an image recognition system for classifying e-waste, utilizing	CNN and R-CNN	The study mentions the potential for further accuracy improvement by increasing the

	r to improve e-waste collection planning Waste Manage. (2020)	deep learning CNNs to streamline waste collection planning. With accuracy ranging from 90% to 97%, it enables efficient collection planning based on identified e-waste categories and sizes, promising broader applications in waste management.		training dataset, suggesting that the current dataset might be limited in representing diverse scenarios. While the reported accuracy for e-waste categories is relatively high (90-97%), there may be variability in accuracy across different types of waste or in real-world scenarios not fully captured in the study.
[20]	M. Toğaçar et al. Waste classification using AutoEncoder network with integrated feature	The study utilizes AutoEncoder, CNNs, Ridge Regression, and SVMs to achieve 99.95% accuracy in classifying organic and recycling waste. It highlights the efficacy of deep learning models in enhancing	The research utilized AutoEncoder networks for reconstructing the waste classification dataset and Convolutional Neural Networks (CNNs) to extract feature sets from two separate datasets, which were then combined. Ridge Regression (RR)	The study's reliance on simulated or controlled waste datasets may limit the generalizability of results to real-world waste management scenarios with varying conditions and compositions. Additionally, while achieving high

	selection method in convolutional neural network models Measurement. (2020)	waste classification for sustainable waste management and environmental protection.	was employed to reduce the numberof features and identify efficient ones, followed by the application of Support Vector Machines (SVMs) as classifiers to achieve a high classification accuracy of 99.95%.	accuracy, the complexity of the AI-driven approach may pose challenges in implementation and scalability for practical waste management systems, particularly in resource-constrained environments.

2.2 SUMMARY ON LITERATURE SURVEY

The research papers discussed underscore the transformative impact of advanced technologies, intense learning, and machine learning algorithms, in modernizing waste management practices. By implementing sophisticated CNN architectures such as ResNet-50 and YOLOv4, coupled with IoT devices and sensors, these studies introduce innovative solutions to automate waste classification, detection, and monitoring processes. Achieving accuracies ranging from 87% to 99.95%, these intelligent systems offer promising avenues for enhancing waste separation, optimizing collection routes, and promoting recycling practices, thereby contributing to more efficient and sustainable urban waste management.

Furthermore, these studies highlight the versatility of deep learning technologies in addressing various challenges within waste management, from urban garbage detection using Faster R-CNN to electronic waste recognition with modified YOLO models. Integration of IoT devices and sensors further augments real-time data monitoring and remote-control capabilities, facilitating proactive and efficient waste of management strategies. By reducing reliance on manual labor, optimizing resource utilization, and minimizing environmental impact, intelligent waste management systems offer scalable and cost-effective solutions for addressing the global waste crisis while enabling predictive analytics and data-driven decision-making for more informed waste management practices.

CHAPTER 3
OBJECTIVES

The objective is to bring technological advancement in the field of waste segregation and recycling, which we feel is not up to the mark. We would be doing this by

- To analyze the given data set, achieve preprocessing, and train the model based on the pre-processed categorized data.
- To classify the categorized pre-processed data and achieve image prediction using YOLOv7 algorithms.
- Achieve precise classifications of waste items to improve sorting efficiency.
- Preprocess and train the model on the dataset for effective data analysis and categorization.
- Utilize YOLOv7 algorithms for image prediction and classifying preprocessed waste data.
- Achieve precise waste item classification to improve sorting efficiency and optimize waste management processes.

CHAPTER 4
PROBLEM STATEMENT

An intelligent waste sorting system using deep learning (YOLOv7) revolves around addressing inefficiencies and limitations in traditional waste sorting methods. Traditional sorting processes, reliant on manual labor, are slow, error-prone, and unable to handle the increasing complexity and volume of waste streams. This leads to suboptimal recycling rates, environmental degradation, and resource wastage.

The goal is to develop an automated system that utilizes deep learning techniques, specifically YOLOv7, to accurately classify waste items in real time. By integrating YOLOv7, which stands for You Only Look Once version 7, the system can identify and categorize waste items with high accuracy and efficiency, streamlining the sorting process. This intelligent waste sorting system aims to improve sorting accuracy, increase sorting speed, and optimize waste management operations.

The system should be scalable to handle large volumes of waste and seamlessly integrate with existing waste management infrastructure, such as conveyor belts and sorting facilities. Cost-effectiveness and environmental sustainability are also crucial considerations, ensuring that the system minimizes operational costs while reducing reliance on landfills and promoting recycling practices. Ultimately, the intelligent waste sorting system using deep learning (YOLOv7) seeks to revolutionize waste management practices by leveraging advanced technologies to achieve efficient, accurate, and sustainable waste sorting processes.

CHAPTER 5

SYSTEM REQUIREMENTS SPECIFICATION

HARDWARE REQUIREMENTS:

• Processor: Intel i3 or above processor.

• Hard Disk: 8 TB

• Memory: 8 GB

SOFTWARE REQUIREMENTS:

• Operating System: windows 10/11

• Programming Language: Python

• Dataset: Custom waste detection from Kaggle

• IDE: Thonny

FUNCTIONAL REQUIREMENTS:

• Object detection: The images should be detected properly based on the training of the model

• Waste classification: The images of waste should be classified into different categories correctly using YOLOv7

• Multi-class classification: The system should detect and classify both single and multi-class classification

USER REQUIREMENTS:

• Ease of use: The system should be easy to use and navigate for the users

• Accuracy: The detection and classification works should be done accurately with zero or minimal errors

• Real-time monitoring: The system should be capable of real-time monitoring and respond promptly

• Cost-effectiveness: The system should provide a cost-effective solution for the waste management

CHAPTER 6
SYSTEM DESIGN

The intelligent waste sorting system utilizes waste image datasets from sources like Kaggle, organized into training and validation sets. Preprocessing techniques ensure data suitability, while annotation tools like LabelImg categorize waste objects into classes. Data augmentation enhances dataset diversity. YOLOv7, an advanced object detection model, is employed for real-time waste detection, offering improved accuracy and efficiency over previous versions. Training on annotated datasets using Tensor-Flow or PyTorch optimizes model parameters, with validation sets used for performance evaluation and hyperparameter tuning. Output includes bounding boxes, class labels, and confidence scores, facilitating waste segregation and enhancing recycling efficiency.

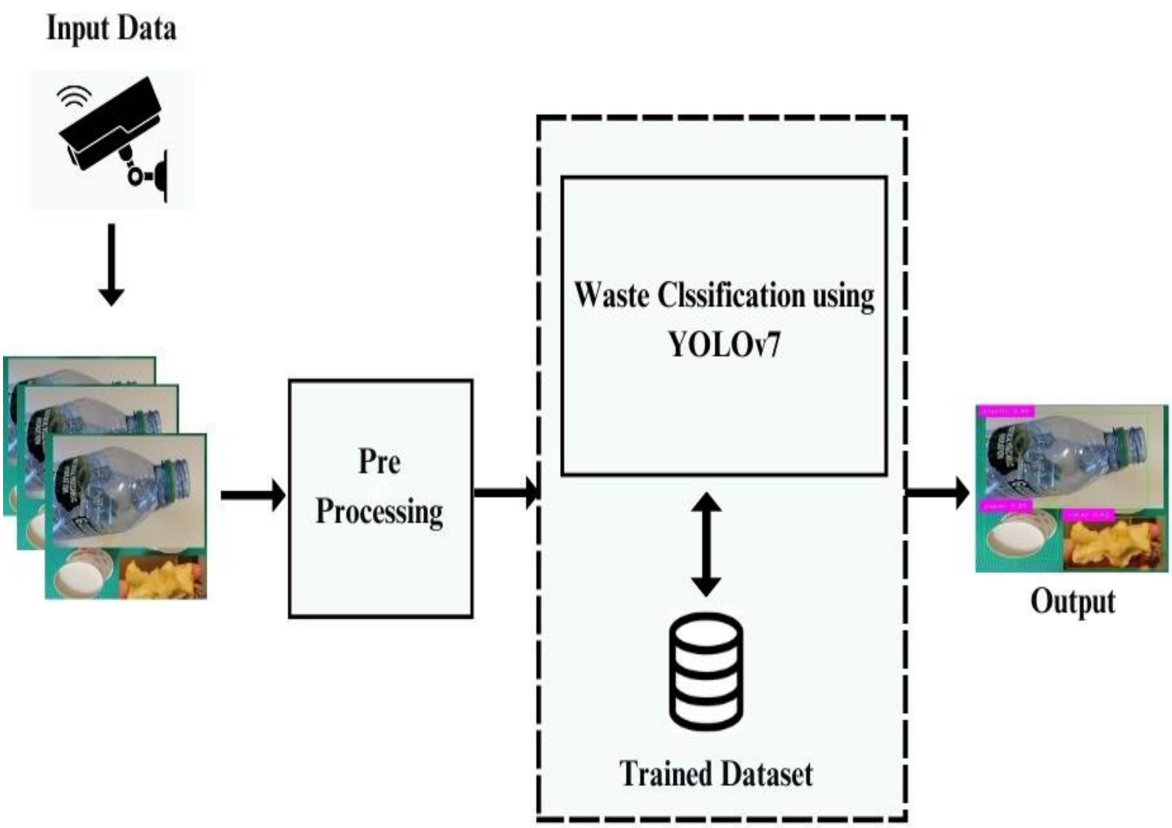

Fig 6.1: System design of waste classification

Dataset:

Custom waste detection dataset[21] on Kaggle involves acquiring waste image datasets, preprocessing them, and then training and evaluating machine learning models like CNNs or object detection algorithms to classify and detect various types of waste, often using frameworks like TensorFlow or PyTorch. Kaggle competitions and datasets provide valuable resources and benchmarks for refining and optimizing waste detection models.

Custom waste detection typically involves the development of deep learning models to identify and classify different types of waste materials, such as plastic, paper, glass, metal, and other from images or sensor data. This process often includes data collection, annotation, preprocessing, model training, and evaluation. Custom waste detection systems can be deployed in various contexts, including recycling facilities, waste management systems, environmental monitoring, and smart city initiatives, to improve waste sorting, recycling efficiency, and overall sustainability efforts.

Input:

To gather a dataset of waste images from a webcam and annotate them, you first need to connect the webcam to your computer. Utilizing software or scripting, capture images of different types of waste, ensuring each image contains only one type of waste and is well-lit and clear. Organize the captured images into training and validation sets, with separate folders for each class: paper, glass, metal, plastic, and other.

Preprocessing:

Gathering the dataset of waste images and annotating them. Here we use the custom waste detection dataset from Kaggle. The dataset is divided into two parts one is training and another one is validation. This dataset contains five classes namely paper, glass, metal, plastic, and other. For labeling all images we are using labelImg. It will produce an a .txt file that has the information of the labeled image along with the class number to which it belongs. Finally, split the dataset into training and validation sets for training a waste detection model, such as a convolutional neural network (CNN), using machine learning frameworks like PyTorch.

YOLOv7:

YOLO or “You Only Look Once” is a family of real-time object detection models. It is much quicker, and much more accurate than the existing object detection algorithms. It provides a faster and stronger network architecture that provides a more effective feature integration method, more accurate object detection performance, a more robust loss function, and an increased label assignment and model training efficiency. YOLOv7 is a state-of-the-art object detection model that builds upon the YOLO (You Only Look Once) architecture. Introduced as an upgrade to YOLOv5, it improves performance through various optimizations, including model architecture changes, training techniques, and post-processing methods. YOLOv7 aims to achieve better accuracy and efficiency in detecting objects within images and videos across various applications, including surveillance, autonomous driving, and industrial automation. YOLOv7, compared to earlier versions like YOLOv5, typically offers improvements in terms of accuracy, efficiency, and speed. It often achieves better performance by incorporating advanced architectural changes, optimization techniques, and training strategies. However, the specific advantages of YOLOv7 compared to other models depend on factors such as the dataset, application requirements, and computational resources available for deployment. Additionally, YOLOv7 may compete with other state-of-the-art object detection models like EfficientDet, Faster R-CNN, and SSD (Single Shot MultiBox Detector) in terms of accuracy and efficiency across different tasks and domains.

Output:

The output of waste classification using YOLOv7 typically includes Bounding Boxes: Rectangular regions drawn around detected waste items in theimage. The bounding box is defined by its canter coordinates (x, y), width (w), and height (h) These parameters help localize the detected waste item within the image.
Class Labels: Each bounding box is associated with a class label, indicating the typeof waste material detected (e.g., paper, plastic, glass).In the context of waste segregation, the classes correspond to different types of waste materials present in the image, enabling efficient sorting and recycling processes.

Confidence Scores: Each detection has an associated confidence score, indicating how confident the model is in its classification. The confidence score provides a measure of certainty for each detection, helping users assess the reliability of the model's predictions.

CHAPTER 7
IMPLEMENTATION

An Intelligent waste sorting system using machine learning is revolutionizing waste segregation processes, offering numerous benefits for sustainable waste management. Traditionally, waste sorting has been a labor-intensive and error-prone task, often leading to inefficiencies and environmental hazards. However, with the advent of advanced technologies and the abundance of data, modern waste sorting systemsare becoming more efficient and accurate.

Machine learning algorithms play a crucial role in these systems by analyzing vast datasets related to waste composition, characteristics, and recycling requirements. By leveraging this data, these algorithms can classify and sort waste materials automatically, significantly reducing the need for manual sorting and minimizing human error.

One of the key advantages of intelligent waste sorting systems is their ability to optimize resource allocation and recycling processes. By accurately identifying different types of waste materials, these systems can streamline recycling efforts, ensuring thatrecyclable materials are properly separated and processed for reuse or recycling. Thisnot only reduces waste sent to landfills but also promotes a more circular economy byconserving valuable resources.

Furthermore, machine learning algorithms can continuously learn and improve over time, fine-tuning their sorting capabilities based on feedback and new data. This adaptability makes intelligent waste sorting systems highly scalable and effective in handlingdiverse waste streams across various industries.

By adopting intelligent waste sorting systems, businesses and municipalities can achieve several benefits, including reduced waste management costs, improved recycling rates, compliance with environmental regulations, and enhanced sustainability practices. Ultimately, these systems contribute to a cleaner environment, resource conservation, and a more efficient waste management ecosystem.

```
import os
HOME = os.getcwd()
print(HOME)
```

Fig 7.1: Importing OS

```
# Pip install method (recommended)

!pip install ultralytics==8.0.20

from IPython import display
display.clear_output()

import ultralytics
ultralytics.checks()
```

Fig 7.2: Installing ultralytics

```
from ultralytics import YOLO

from IPython.display import display, Image
```

Fig 7.3: Importing yolo from ultralytics image

```
from google.colab import drive
drive.mount('/content/gdrive')
!ln -s /content/gdrive/My\ Drive/ /mydrive
!ls /mydrive
```

Fig 7.4: Mounting g-drive to colab

```
!mkdir {HOME}/datasets
%cd {HOME}/datasets

!unzip /content/gdrive/MyDrive/dataset.zip
```

Fig 7.5: Unzipping the dataset

```
%cd {HOME}

!yolo task=detect mode=train model=yolov8s.pt data=/content/datasets/freedomtech/data.yaml epochs=100 imgsz=800 plots=True
```

Fig 7.6: Training the dataset for 100 epochs main_.py

```python
import cv2
import pandas as pd
from ultralytics import YOLO
import cvzone
import tkinter as tk
from tkinter import filedialog

model = YOLO('best (2).pt')

def RGB(event, x, y, flags, param):
    if event == cv2.EVENT_MOUSEMOVE:
        point = [x, y]
        print(point)

def process_image():
    image_path = filedialog.askopenfilename()
    if image_path:
        frame = cv2.imread(image_path)

        my_file = open("coco1.txt", "r")
        data = my_file.read()
        class_list = data.split("\n")

        results = model.predict(frame)
        a = results[0].boxes.data
        px = pd.DataFrame(a).astype("float")

        for index, row in px.iterrows():
            x1 = int(row[0])
            y1 = int(row[1])
            x2 = int(row[2])
            y2 = int(row[3])
            conf = row[4]
            d = int(row[5])
            c = class_list[d]
            if 'plastic' in c:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 1)
                cvzone.putTextRect(frame, f'{c} {conf:.2f}', (x1, y1), 1, 1)
            else:
```

Fig 7.7: Code for yoloV7 processing image

main_.py

```python
            else:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 255, 0), 1)
                cvzone.putTextRect(frame, f'{c} {conf:.2f}', (x1, y1), 1, 1)

        cv2.imshow("RGB", frame)
        cv2.waitKey(0)
        cv2.destroyAllWindows()

def webcam_interface():
    cap = cv2.VideoCapture(0)
    window_name = "Webcam"
    cv2.namedWindow(window_name)

    while True:
        ret, frame = cap.read()
        if not ret:
            break

        my_file = open("coco1.txt", "r")
        data = my_file.read()
        class_list = data.split("\n")

        results = model.predict(frame)
        a = results[0].boxes.data
        px = pd.DataFrame(a).astype("float")

        for index, row in px.iterrows():
            x1 = int(row[0])
            y1 = int(row[1])
            x2 = int(row[2])
            y2 = int(row[3])
            conf = row[4]
            d = int(row[5])
            c = class_list[d]
            if 'plastic' in c:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 1)
                cvzone.putTextRect(frame, f'{c} {conf:.2f}', (x1, y1), 1, 1)
            else:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 255, 0), 1)
```

Local Python 3 • Thonny's Python

Fig 7.8: Webcam interface

main_py

```python
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 0, 255), 1)
                cvzone.putTextRect(frame, f'{c} {conf:.2f}', (x1, y1), 1, 1)
            else:
                cv2.rectangle(frame, (x1, y1), (x2, y2), (0, 255, 0), 1)
                cvzone.putTextRect(frame, f'{c} {conf:.2f}', (x1, y1), 1, 1)

        cv2.imshow(window_name, frame)
        key = cv2.waitKey(1)
        if key == ord('q'):
            break

    cap.release()
    cv2.destroyAllWindows()
    cv2.destroyWindow(window_name)

def quit_webcam():
    cv2.destroyAllWindows()

# Create the Tkinter GUI
root = tk.Tk()
root.title("Object Detection")

# Set up styles
button_style = {'font': ('Arial', 12), 'bg': '#4CAF50', 'fg': 'white', 'padx': 10, 'pady': 5, 'borderwidth': 2, 'relief': 'raised'}
label_style = {'font': ('Arial', 12), 'bg': '#F0F0F0', 'fg': '#333333', 'padx': 10, 'pady': 5, 'borderwidth': 2, 'relief': 'ridge'}

# Create a button to select an image
select_button = tk.Button(root, text="Select Image", command=process_image, **button_style)
select_button.pack(pady=10)

# Create a button to start webcam interface
webcam_button = tk.Button(root, text="Webcam Interface", command=webcam_interface, **button_style)
webcam_button.pack(pady=10)

# Create a label for instructions
instructions_label = tk.Label(root, text="Hover over the image to see RGB values.", **label_style)
instructions_label.pack()

# Set up OpenCV mouse callback
```

Local Python 3 • Thonny's Python

Fig 7.9: Code for button style

CHAPTER 8
RESULT AND DISCUSSION

The introduction of the Intelligent Waste Sorting System (IWSS) employing YOLOv7 represents a significant advancement in addressing the global waste management crisis. Achieving an impressive accuracy of 92% in classifying waste into five different classes demonstrates the effectiveness of the system in improving waste sorting processes.

Traditional waste sorting methods are often inefficient and contribute to contamination and environmental degradation. The utilization of deep learning techniques, specifically YOLOv7, addresses these challenges by accurately identifying and sorting waste items in real-time. This approach enhances waste management efficiency while minimizing environmental impact.

The incorporation of YOLOv7, a state-of-the-art object detection model, ensures Robustness and efficiency in waste classification tasks. Extensive experimentation and validation further validate the effectiveness and relatability of the IWSS, underscoring its potential to promote sustainable waste management practices in Urban and Rural environments.

Overall, the IWSS presents a promising solution to the escalating waste management crisis, offering a pathway towards more efficient and environmentally friendly waste sorting processes.

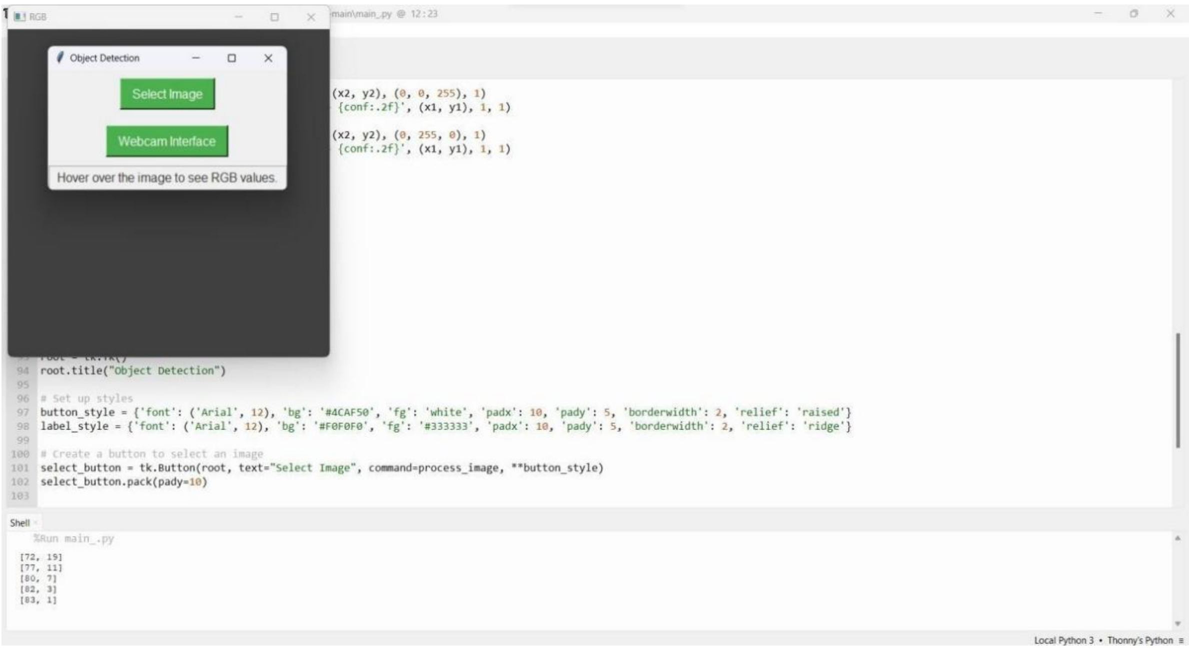

Fig 8.1: User interface

The Waste Sorting Interface is a simplified tool for waste classification utilizing the YOLOv7 model. It offers two options for input: selecting an image from the device or capturing via webcam. The interface aims to streamline waste sorting efforts by providing instant classification results for various waste items.

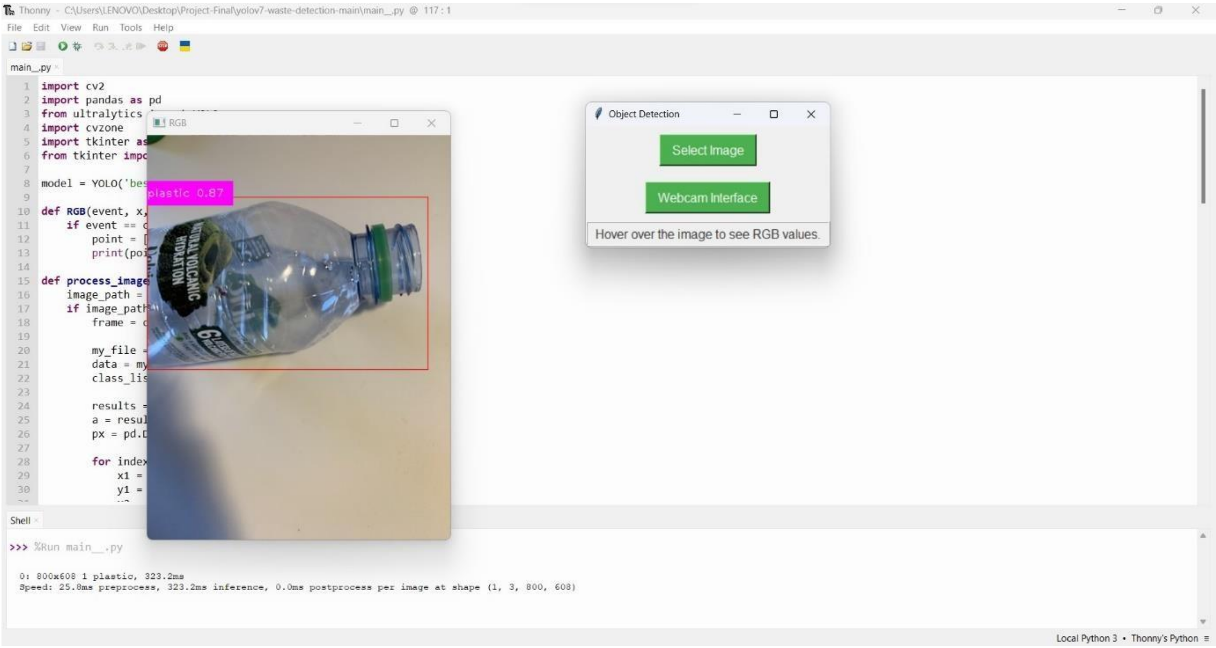

Fig 8.2: A single object detected and labelled as per its class

When the user clicks on the "Select Image" button, the interface prompts them to choose an image file from their device. Once the image is selected, it is processed by the YOLOv7 model for object detection and classification. After processing, the interface displays the image with a bounding box around the detected object and its corresponding class label. This allows the user to quickly identify the type of waste item present in the image.

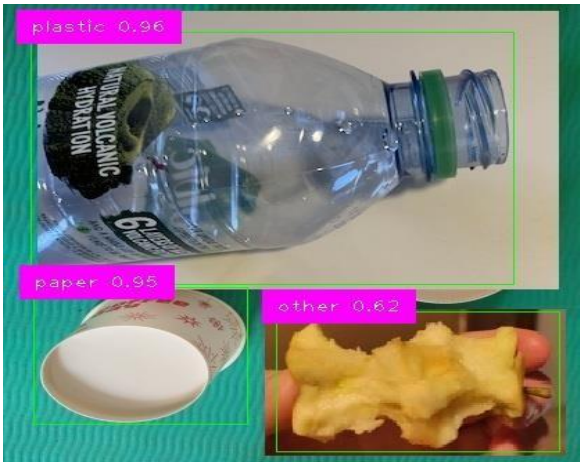

Fig 8.3: Classified material images by yoloV7

The YOLO algorithm divides the input image into a grid of cells, and for each cell, it predicts the probability of the presence of an object and the bounding box coordinates of the object. It also predicts the class of the object. Once the image is selected, it is processed by the YOLOv7 model for object detection and classification. After processing, the interface displays the image with bounding boxes around each detected object and their corresponding class labels. This allows the user to quickly identify andclassify multiple waste items present in the image.

Fig 8.4: Classified material images by yoloV7

When you provide Image (filename='runs/detect/train/val_batch0_pred.jpg', width=600) in Colab after training a YOLOv7 model, it displays an image with objects detected and labeled according to their classes. The displayed image likely shows bounding boxes drawn around each detected object, along with class labels assigned to them. This output helps visualize the model's performance in detecting and classifying objects after training.

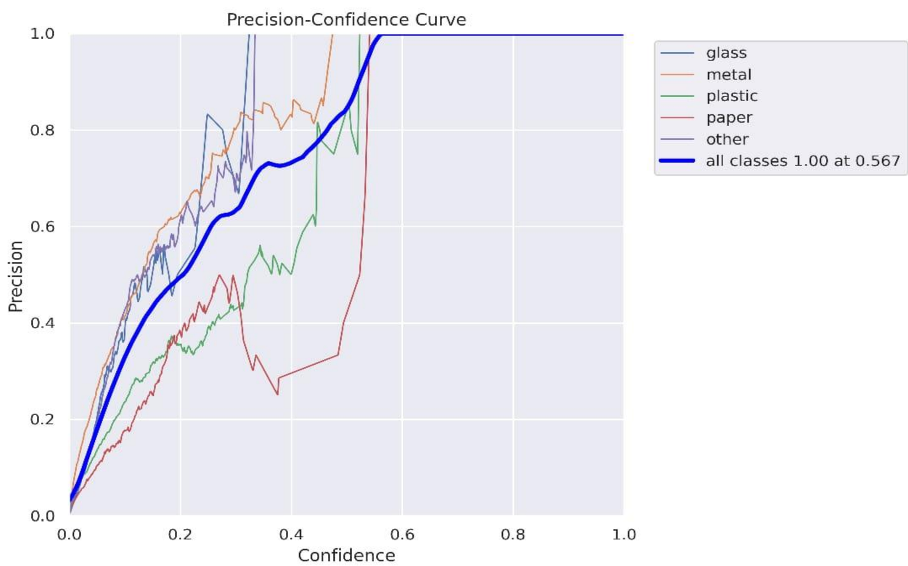

Fig 8.5: Precision-Confidence curve of yoloV7

The precision-confidence curve plots the precision of the model's predictions at different confidence thresholds. It helps to understand how the model's precision varies as we change the threshold for considering a detection as valid. Precision refers to the proportion of true positive detections out of all positive detections made by the model. Confidence is the model's internal measure of certainty about its predictions. This curve helps in understanding how to set the confidence threshold to achieve an optimal balance between detection accuracy (precision) and the model’s certainty.

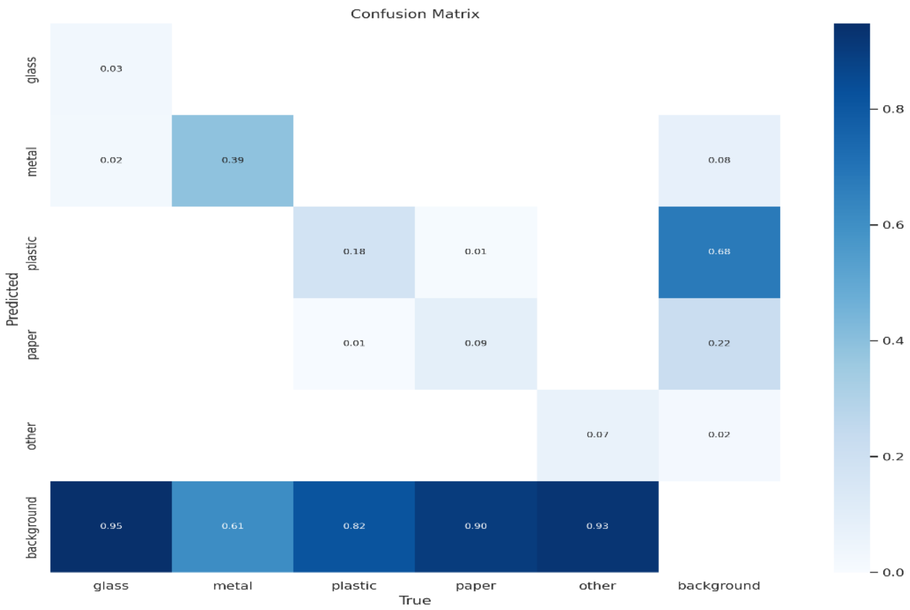

Fig 8.6: Confusion matrix

A confusion matrix for a YOLOv7 waste sorting system with 5 classes (paper, plastic, glass, metal, and other) provides a summary of the model's performance in classifying objects. It displays the counts of true positive, true negative, false positive, and false negative predictions for each class.

Here's a brief explanation of each term:

True Positive (TP): The model correctly predicts a waste item belonging to a specific class (e.g., correctly identifying a piece of paper as paper).

True Negative (TN): The model correctly predicts a non-waste item as not belonging to any of the waste classes.

False Positive (FP): The model incorrectly predicts a non-waste item as belonging

to a waste class (e.g., mistakenly identifying a non-waste object as paper).
False Negative (FN): The model incorrectly predicts a waste item as not belonging toany of the waste classes (e.g., failing to identify a piece of paper as paper).
The confusion matrix helps evaluate the model's accuracy, precision, recall, and F1-score for each class, providing insights into its performance and areas for improvement in waste classification.

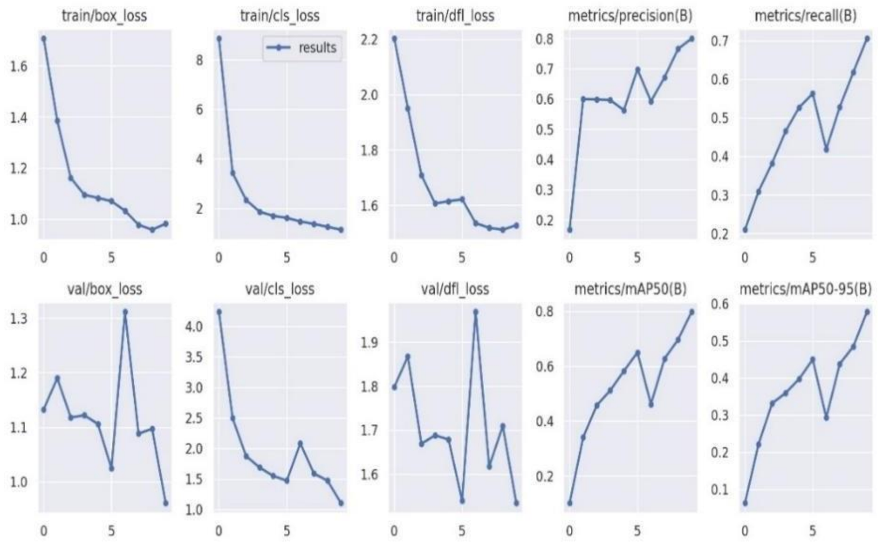

Fig 8.7: Line Chart

A line chart for a YOLOv7 waste sorting system with 5 classes (paper, plastic, glass, metal, and other) can be used to visualize the performance metrics of the model over time or across different iterations of training or testing.
Here's a brief explanation of what the line chart may represent:
X-axis: The x-axis represents the different iterations of training or testing. This could be epochs during training or batches during testing.
Y-axis: The y-axis represents the performance metrics such as accuracy, precision, recall, or F1-score.
Lines: There would be five lines on the chart, each corresponding to one of the waste classes (paper, plastic, glass, metal, and other). These lines show how the particular performance metric for each class changes over time or iterations.

Trends: By observing the trends in the lines, you can assess how the model's performance varies across different classes throughout the training or testing process. For example, you can see if certain classes consistently have higher or lower performance metrics compared to others.

Overall, the line chart provides a visual representation of the model's performance for each waste class, helping you identify any patterns or trends and make informed decisions to improve the model's accuracy and effectiveness in waste sorting.

CHAPTER 9
CONCLUSION

The Intelligent Waste Sorting System, utilizing YOLOv7 software, emerges as a beacon of innovation in waste management, showcasing the transformative potential of modern technologies. By employing deep learning for object detection, the system automates waste classification, ushering in an era of efficiency and precision in waste collection processes while mitigating environmental and health risks associated with improper waste disposal. This project not only signifies a crucial step towards sustainable waste management but also underscores the pivotal role of advanced technology in addressing global challenges, promising a cleaner, more sustainable world while minimizing disruptions to existing waste management infrastructures.

Beyond its technical prowess, this initiative embodies a commitment to environmental stewardship and responsible innovation. Through automated sorting, the system reduces contamination and pollution, safeguarding ecosystems and public health. By harnessing the power of deep learning initiatives like this uphold our collective responsibility to preserve the planet, paving the way for cleaner, more efficient waste management practices and a more sustainable future.

REFERENCES

[1] Adedeji, Olugboja, and Zenghui Wang. "Intelligent waste classification system using deep learning convolutional neural network." *Procedia Manufacturing* 35 (2019): 607-612.

[2] Rahman, Md Wahidur, et al. "Intelligent waste management system using deep learning with IoT." *Journal of King Saud University-Computer and Information Sciences* 34.5 (2022): 2072-2087.

[3] Kumar, G. Shravan, et al. "Intelligent Waste Management System Using Deep Learning." *Journal of Survey in Fisheries Sciences* (2023): 2767-2772.

[4] Wang, Ying, and Xu Zhang. "Autonomous garbage detection for intelligent urban management." *MATEC Web of Conferences*. Vol. 232. EDP Sciences, 2018.

[5] Huang, Rui, et al. "A rapid recognition method for electronic components based on the improved YOLO-V3 network." *Electronics* 8.8 (2019): 825.

[6] WasteSegNet: A Deep Learning Approach for Smart Waste Segregation in Urban Environments Aatmaj Amol Salunke

[7] Adedeji, O.; Wang, Z. Intelligent waste classification system using deep learning convolutional neural network. In Proceedings of the Procedia Manufacturing; Elsevier B.V.: Amsterdam, The Netherlands, 2019; Volume 35, pp. 607–612.

[8] Chu, Y.; Huang, C.; Xie, X.; Tan, B.; Kamal, S.; Xiong, X. Multilayer hybrid deep-learning method for waste classification and recycling. Comput. Intell. Neurosci. 2018, 2018, 5060857

[9] Machine-learning approaches in geo-environmental engineering: Exploring smart solid waste management Author panelAbderrahim Lakhouit a, Mahmoud Shaban b c, Aishah Alatawi d, SumayaY.H. Abbas e, Emad Asiri a, Tareq Al Juhni a, Mohamed Elsawy af

[10] “Garbage detection and classification using a new deep learning-based machine vision system as a tool for sustainable waste recycling panel Shoufeng Jin a, Zixuan Yang a, Grzegorz Królczykg b, Xinying Liu a, PaoloGardoni c, Zhixiong Li d e

[11] Kumar, G. Shravan, et al. "Intelligent Waste Management System Using Deep Learning." Journal of Survey in Fisheries Sciences (2023): 2767-2772.

[12] Adedeji, Olugboja, and Zenghui Wang. "Intelligent waste classification system using deep learning convolutional neural network." Procedia Manufacturing 35 (2019): 607-612.

[13] De Carolis, Berardina, Francesco Ladogana, and Nicola Macchiarulo. "Yolo trashnet: Garbage detection in video streams." 2020 IEEE Conference on Evolving and Adaptive Intelligent Systems (EAIS). IEEE, 2020.

[14] Andhy Panca Saputra, Kusrini. "Waste Object Detection and Classification using Deep Learning Algorithm: YOLOv4 and YOLOv4-tiny." Turkish Journal of Computer and Mathematics Education (TURCOMAT) 12.14 (2021): 1666-1677.

[15] Desta, Meron, Tagel Aboneh, and Bisrat Derebssa. "Deep learning-based object detection for smart solid waste management system." Annals of Environmental Science and Toxicology 7.1 (2023): 052-060.

[16] T.D. Bui et al. Identifying sustainable solid waste management barriers in practice using the fuzzy Delphi method Resour. Conserv. Recycl. (2020)

[17] G. Aid et al. Expanding roles for the Swedish waste management sector in inter-organizational resource management Resour. Conserv. Recycl. (2017)

[18] O.I. Funch et al. Detecting glass and metal in consumer trash bags during waste collection using convolutional neural networks Waste Manage. (2021)

[19] P. Nowakowski et al. Application of deep learning object classifier to improve e-waste collection planning Waste Manage. (2020)

[20] M. Toğaçar et al. Waste classification using AutoEncoder network with integrated feature selection method in convolutional neural network models Measurement (2020)

[21] custom_waste_detection (kaggle.com)

[22] (PDF) Waste Object Detection and Classification using Deep Learning Algorithm: YOLOv4 and YOLOv4-tiny (researchgate.net)