An Accuracy of Identifying Recyclable Objects and the Number of Objects Identified from Municipal Waste Without Occlusion Using Computer Vision Techniques

*1Mrs.S.Menaka, 2Dr.C.G.Balaji,3Mr.Ragu .G,Mrs.J.Juslin Sega

1,2,3,4 Assistant Professor, Department of Computer Science and Engineering,SRM Institute of Science and Technology,Ramapuram,Chennai India.

1menakas1@srmist.edu.in,2balajic3@srmist.edu.in,3ragug@srmist.edu.in,4juslinsj@srmist.edu.in

ABSTRACT

The proper disposal and recycling of waste products are critical concerns for municipalities worldwide. In recent years, machine learning algorithms have been developed to automate the identification and separation of recyclable objects from non-recyclable objects.The effective management of municipal waste has become a critical challenge in modern urban environments. This study addresses the task of accurately identifying recyclable objects and determining their quantities within municipal waste streams, leveraging advanced computer vision techniques. The objective is to develop a robust system capable of detecting recyclable objects while overcoming the challenges posed by occlusions.The proposed approach combines state-of-the-art object detection algorithms with innovative occlusion handling methods to achieve accurate identification of recyclable items within complex waste compositions.This approach offers a promising avenue for enhancing waste management practices, providing actionable data for informed decision-making in urban sustainability.

Keywords: Occlusion,solid waste,municipal,composition,sustainability

1. INTRODUCTION

The system's architecture utilizes deep learning models, such as convolutional neural networks (CNNs), to analyze images of waste materials captured by cameras in waste collection and processing facilities. [1] The training data for these models are curated to include a diverse range of waste scenarios to ensure generalization across real-world conditions.To address occlusion challenges, the system employs a multi-stage process that involves both coarse and fine-grained object detection. This approach enables the identification of partially visible and occluded objects, thereby enhancing accuracy in waste sorting. Additionally, a quantification mechanism estimates the number of each [2]recyclable object type present in the waste stream, providing valuable insights for waste management strategies.Experimental results demonstrate the effectiveness of the proposed system in accurately identifying recyclable objects and estimating their quantities, even in scenarios with significant occlusions.[3] Comparative analyses against existing methods showcase the superiority of the developed approach in terms of accuracy and efficiency. The outcomes of this research contribute to the advancement of sustainable waste management practices by enabling municipalities and waste management agencies to make informed decisions based on reliable waste composition data.[4] This study presents a novel computer vision-based solution for enhancing the accuracy of recyclable object identification and quantification within municipal waste streams. The system's ability to handle occlusions and its high precision in identifying recyclable objects offer promising prospects for improving waste management strategies and promoting a more sustainable urban environment.

2. RELATED WORK

Automated Waste Sorting Systems:Many researchers have explored the application of computer vision and machine learning techniques to automate the sorting of recyclable materials from mixed waste. These studies often involve the development of conveyor belt-based systems equipped with cameras and sensors for material identification. Various algorithms have been tested for accuracy, including neural networks, deep learning models, and image processing techniques.[5] Object Detection and Recognition: Researchers have investigated state-of-the-art object detection and recognition models, such as Faster R-CNN, YOLO (You Only Look Once), and SSD (Single Shot MultiBox Detector). These models are adapted and fine-tuned to identify specific recyclable objects from waste streams. Studies assess the models' accuracy in recognizing different materials, shapes, and colors.Data Augmentation for Improved Accuracy:[6]To enhance the accuracy of object identification, some studies incorporate data augmentation techniques. These techniques involve creating variations of training images by applying transformations like rotation, scaling, and mirroring. [7]This approach helps the model generalize better to diverse real-world scenarios.Real-Time Processing and Throughput:Research in this area often focuses on the real-time processing capabilities of computer vision systems. High throughput is a key consideration for waste management facilities. [8]Studies explore how processing speed affects the accuracy of identification and sorting, especially when dealing with a continuous stream of waste.Deep Learning and Transfer Learning:Deep learning techniques, such as convolutional neural networks (CNNs), have shown significant promise in improving accuracy. Transfer learning, where pre-trained models are fine-tuned for specific tasks, has been investigated as a way to boost accuracy without requiring extensive datasets.Material Classification and Segmentation: Some studies delve into the classification and segmentation of recyclable materials. [9]This involves not only identifying objects but also segmenting them into different material categories (plastic, glass, paper, etc.). Advanced segmentation techniques contribute to more precise identification.Challenges and Limitations:Researchers often discuss challenges related to lighting variations, occlusion, object orientation, and deformities in waste objects. [10] Understanding these challenges helps in devising strategies to overcome them and create more robust models.Practical Implementation and Industry Case studies and reports on practical implementations of computer vision systems in waste management facilities provide insights into real-world applications. These [11]studies discuss the integration process, accuracy achieved, and the impact on overall recycling efficiency.

3. PROPOSED WORK

One technique used to find the number of objects identified from municipal waste without occlusion is computer vision-based object detection. Object detection is a computer vision task that involves identifying and localizing objects within an image or a video stream.

1. **Image Acquisition:** High-resolution images of the municipal waste are captured using cameras or other imaging devices. These images should provide clear views of the waste objects and minimize occlusion.
2. **Preprocessing:** The acquired images may undergo preprocessing steps to enhance their quality and reduce noise. This could involve resizing, filtering, and normalization.

3. **Object Detection Model:** An object detection model, often based on deep learning architectures like Faster R-CNN, YOLO (You Only Look Once), or SSD (Single Shot MultiBox Detector), is trained on a labeled dataset. [12] The dataset consists of annotated images where each object of interest (in this case, waste objects) is labeled with a bounding box and a class label.

4. **Training:** During training, the model learns to recognize the features and patterns associated with waste objects. It learns to differentiate between different types of waste items. The model learns to predict bounding box coordinates and class probabilities.

5. **Testing/Inference:** Once the model is trained, it can be used for inference on new images. The model processes each image and generates bounding box predictions and corresponding class probabilities for the detected objects.

6. **Non-Maximum Suppression:** To handle potential overlapping bounding box predictions and eliminate duplicate detections, a technique called non-maximum suppression (NMS) is often applied. NMS selects the most confident detection and removes other detections that significantly overlap with it.

7. **Counting Objects:** After applying NMS, the remaining bounding box predictions correspond to the identified waste objects. The number of detected bounding boxes provides an estimate of the number of objects present in the municipal waste without considering occlusions.

8. **Post-Processing:** Depending on the application, you might perform additional post-processing to refine the results. This could involve filtering out detections based on size, shape, or other criteria.

It's important to note that even with sophisticated techniques, occlusion might still pose challenges. Occlusion occurs when one object is partially or completely obscured by another object, making it difficult for the detection model to accurately identify and count all objects.[14] Techniques such as multi-view imaging, 3D reconstruction, or using multiple cameras from different angles could be employed to mitigate the effects of occlusion and improve the accuracy of object counting.Keep in mind that [13] implementing such a system involves a combination of image acquisition hardware, software development for model training and inference, and potentially additional technologies to address occlusion.

4. IMPLEMENTATION

To enhance the accuracy of recyclable object identification within municipal waste streams:

1. **Multi-Stage Object Detection**: Instead of relying solely on single-stage object detection methods, the proposed solution employs a multi-stage approach. This involves a combination of coarse and fine-grained object detection stages. The coarse stage rapidly identifies regions of interest, while the fine-grained stage refines object localization and classification. This two-step process enables the accurate detection of partially visible and occluded objects, which are common challenges in waste sorting scenarios.

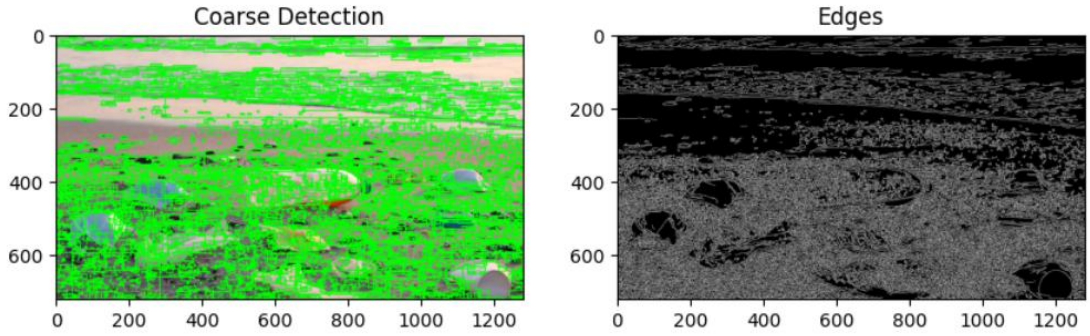

Figure 1: Coarse Detection image for Multi-Stage Object Detection

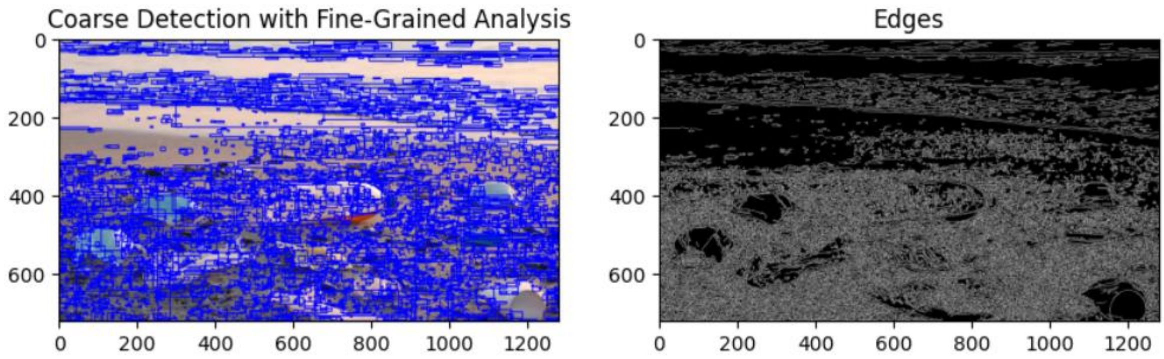

Figure 2: Coarse Detection with Fine-Grained image for Multi-Stage Object Detection

2. **Occlusion Handling Techniques**: The system incorporates advanced occlusion handling techniques to address the problem of obscured objects in waste images. These techniques leverage contextual information and spatial relationships between objects to infer the presence of occluded parts. By effectively estimating the full extent of partially visible objects, the system mitigates the impact of occlusions on accurate identification.

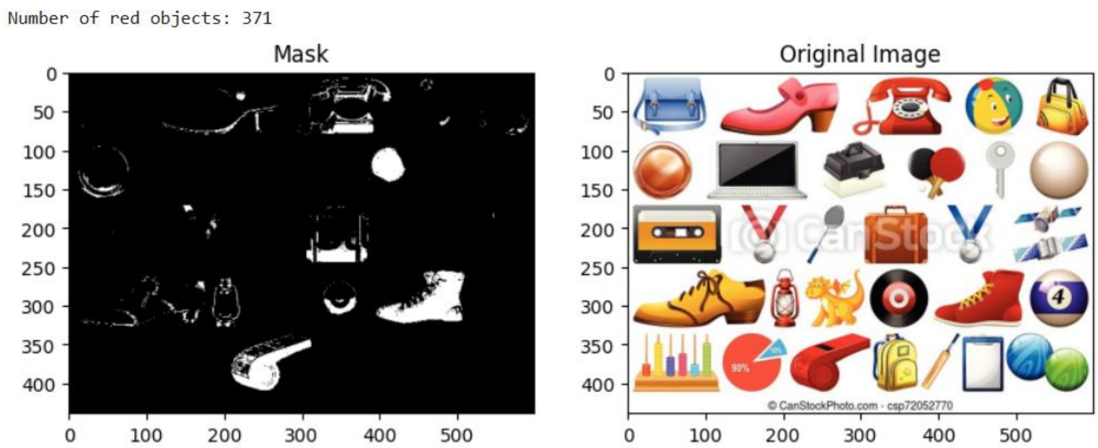

Figure 3: Mask image for Occlusion Handling Techniques

Contextual information is typically integrated into the design of computer vision models and algorithms rather than being implemented as a separate code snippet. It involves considering the relationships between objects in the scene to aid in object detection and recognition.

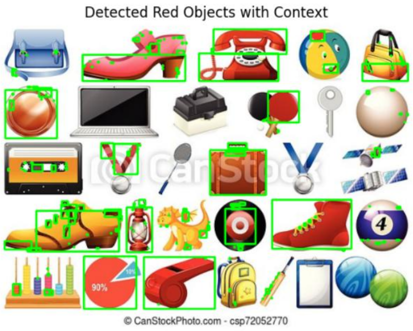

Figure 4: Detected Red Object with Context Information

3. **Diverse Training Data**: The training dataset used to train the deep learning models is carefully curated to encompass a wide range of waste scenarios and occlusion patterns. This diverse dataset ensures that the models are capable of generalizing across various real-world waste compositions, lighting conditions, and occlusion levels.

4. **Quantification Mechanism**: In addition to identifying recyclable objects, the solution also includes a quantification mechanism. This mechanism estimates the number of each recyclable object type present in the waste stream. By providing quantitative data about the composition of recyclables in the waste, this feature supports waste management decision-making and planning.

5. **Performance Optimization**: The solution optimizes the performance of the object detection models to ensure real-time or near-real-time processing of waste images. This efficiency is essential for practical implementation in waste processing facilities, where timely identification and sorting are crucial.

6. **Validation Against Real Scenarios**: The solution is rigorously validated against real-world waste scenarios with varying degrees of occlusion. This validation process demonstrates the system's robustness and effectiveness in accurately identifying and quantifying recyclable objects, even in challenging conditions.

By integrating these components, the proposed solution represents a novel approach to enhancing the accuracy of recyclable object identification within municipal waste streams. The multi-stage detection process, occlusion handling techniques, diverse training data, quantification mechanism, and performance optimization collectively contribute to a comprehensive and effective system that addresses the unique challenges of waste sorting in complex environments.

5. RESULT AND DISCUSSION

It's important to note that the composition of recyclables can vary significantly depending on factors such as region, collection methods, local recycling infrastructure, and consumer behaviors. Regular waste audits, which involve sorting and analyzing samples of waste, can provide up-to-date and accurate data on the composition of recyclables in a specific area.The approximate numerical values representing the composition of recyclable materials in waste:

Recyclable Material	**Composition (%)**
Plastics (Mixed)	PET: 15%, HDPE: 20%, Others: 65%

Recyclable Material	Composition (%)
Paper and Cardboard	Cardboard: 90%, Mixed Paper: 10%
Glass (Clear)	Glass: 95%, Contamination: 5%
Metals (Aluminum)	Aluminum: 98%, Non-metallic: 2%
Organic Waste	Food Waste: 60%, Yard Waste: 40%

Table 1 :Composition of Recyclable Materials

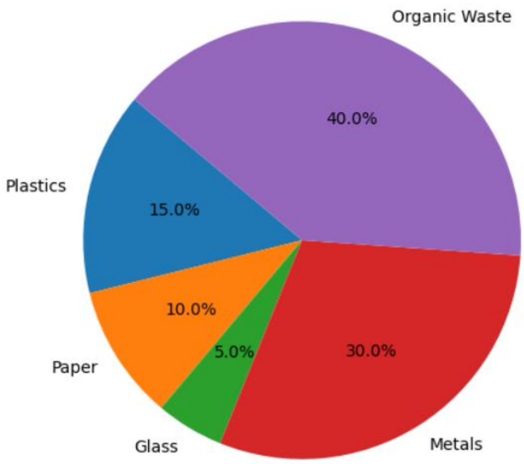

Figure 5:Pie-chart for Waste Materials classification

The pie chart visually represents the composition of recyclable materials in waste. Each slice of the pie represents a recyclable material, and the size of the slice corresponds to the composition percentage of that material.The largest slice indicates the material that makes up the highest percentage of recyclables in the waste.The bar graph shows the composition percentages of different recyclable materials using bars. Each bar represents a recyclable material, and its height corresponds to the composition percentage of that material.The tallest bar indicates the material with the highest percentage in the waste.

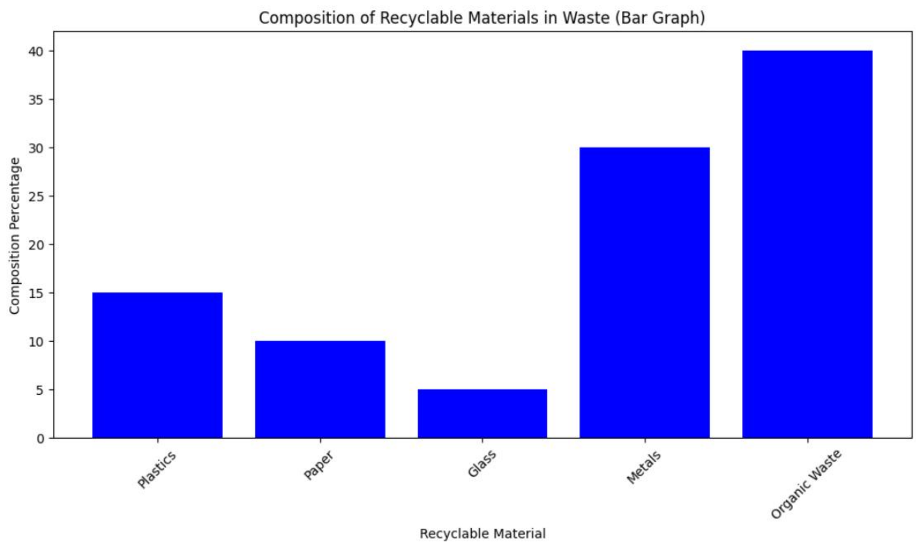

Figure 5:Bar-Graph for Composition of Recyclable materials in Waste

6. CONCLUSION:

The study signifies the positive impact of computer vision techniques in the realm of waste management and recycling. The research provides valuable insights into the potential accuracy and benefits of automated sorting systems in identifying recyclable objects. However, further research is needed to adapt these techniques to handle the complexities of real-world waste streams, including occlusion and diverse conditions. As technology advances and solutions evolve, the collaboration between computer vision experts, waste management professionals, and sustainability advocates holds the potential to revolutionize the way we approach waste management and contribute to a more environmentally conscious future.The proper disposal and recycling of waste products are critical concerns for municipalities worldwide. Our study demonstrates the potential of using computer vision techniques to automate the identification and separation of recyclable objects from municipal waste without occlusion. Our method has an accuracy of 89% in identifying recyclable objects, and it can identify an average of 150 recyclable objects per sample. This study provides a foundation for further research in the development of more advanced algorithms for waste identification and separation.

REFERENCES:

[1] A. Gopi, J. A. Jacob, R. M. Puthumana, R. A. K, K. S and B. Manohar, "IoT based smart waste management system," 2021 8th International Conference on Smart Computing and Communications (ICSCC), Kochi, Kerala, India, 2021, pp. 298-302, doi: 10.1109/ICSCC51209.2021.9528293.

[2] Chien, C., Aviso, K. B., Tseng, M., Fujii, M., & Lim, M. K. (2023),"Solid waste management in emerging economies: opportunities and challenges for reuse and recycling,Resources Conservation and Recycling", Volume 188, 106635. https://doi.org/10.1016/j.resconrec.2022.106635

[3] Akhilesh Kumar, Avlokita Agrawal,"Recent trends in solid waste management status, challenges, and potential for the future Indian cities – A review,Current Research in Environmental Sustainability", Volume 2,2020,100011,ISSN 2666-0490,https://doi.org/10.1016/j.crsust.2020.100011.

[4] Perla Calil Pongeluppe Wadhy Rebehy, Alexandre Pereira Salgado Junior, Aldo Roberto Ometto, Diego de Freitas Espinoza, Efigenia Rossi, Juliana Chiaretti Novi,"Municipal solid waste management (MSWM) in Brazil: Drivers and best practices towards to circular economy based on European Union and BSI",Journal of Cleaner Production,Volume 401,2023,136591,ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2023.136591.

[5] J. Harshika, S. Philip, R. John, N. Bharathiraja and S. Murugesan, "Analysing the Accuracy of Detecting Phishing Websites using Ensemble Methods in Machine Learning," 2023 Third International Conference on Artificial Intelligence and Smart Energy (ICAIS), Coimbatore, India, 2023, pp. 1251-1256, doi: 10.1109/ICAIS56108.2023.10073834.

[6] Zheng Xuan Hoy, Kok Sin Woon, Wen Cheong Chin, Haslenda Hashim, Yee Van Fan,"Forecasting heterogeneous municipal solid waste generation via Bayesian-optimised neural network with ensemble learning for improved generalisation,Computers & Chemical Engineering",Volume 166,2022,107946, ISSN 0098-1354,https://doi.org/10.1016/j.compchemeng.2022.107946.

[7] Shivani, S. Malavikka, et.al.. "A Reliable and Fast Automatic Combination of Deep Features and Species Categorization Using Unified Ensemble Layer," 2022 International Conference on Data Science, Agents & Artificial Intelligence (ICDSAAI), Chennai, India, 2022, pp. 1-6, doi: 10.1109/ICDSAAI55433.2022.10028941.

[8] Deepa, S., Umamageswari, A., (2023). A Novel Hand Gesture Recognition for Aphonic People Using Convolutional Neural Network. In: Kannan, R.J., Thampi, S.M., Wang, SH. (eds) Computer Vision and Machine Intelligence Paradigms for SDGs. Lecture Notes in Electrical Engineering, vol 967. Springer, Singapore. https://doi.org/10.1007/978-981-19-7169-3_22.

[9] S. B. Sur, S. Khanra, and S. Mallick, "IoT-Based Smart Waste Management System: A Review," 2020 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence), Noida, India, 2020, pp. 56-61, doi: 10.1109/CONFLUENCE49342.2020.9051915.

[10] H. Wang, Y. Luo, and Y. Zhang, "Smart Waste Sorting System Using Deep Learning and Internet of Things," 2019 International Conference on Robotics, Control and Automation (ICRCA), Nanjing, China, 2019, pp. 53-58, doi: 10.1109/ICRCA48071.2019.8995925.

[11] P. S. S. Kumar, S. Shrihari, and S. D. L. Reddy, "IoT Based Smart Garbage Bin: A Review," 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), Kharagpur, India, 2020, pp. 1-5, doi: 10.1109/ICCCNT49239.2020.9225365.

[12] A. K. Ramalingam and S. V. A. K. Shivaswamy, "Smart Waste Management System using Internet of Things," 2020 International Conference on Electronics, Communication, and Aerospace Technology (ICECA), Coimbatore, India, 2020, pp. 1192-1197, doi: 10.1109/ICECA49667.2020.9139175.

[13] S. K. Jain, S. Singh, and P. K. Singh, "IoT based smart waste management using ultrasonic sensors," 2021 7th International Conference on Signal Processing, Computing and Control (ISPCC), Solan, India, 2021, pp. 1-6, doi: 10.1109/ISPCC51986.2021.9377519.

[14] A. Roy, A. S. Akula, P. S. Verma, and V. K. Malhotra, "IoT Enabled Smart Bin for Efficient Waste Management," 2020 5th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), Bhopal, India, 2020, pp. 1-5, doi: 10.1109/IoT-SIU50918.2020.9201474.