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Revolutionizing Urban Waste Management: An AI-Powered Autonomous Solution for Smart Cities

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Abstract:- The escalating global population is exerting significant pressure on the environment, resulting in a continuous surge in daily waste generation. Developing countries particularly face a formidable challenge in efficiently segregating and collecting waste in a timely manner. The lack of proper waste segregation leads to the wastage of valuable resources. If waste is not segregated effectively, it can accumulate and potentially leak harmful substances, causing soil contamination and the release of toxic gases like methane. This paper introduces SmartBin, an innovative waste bin designed to autonomously segregate waste at the source without human intervention. Additionally, SmartBin is equipped to automatically notify waste collection centers when it reaches full capacity. The implementation of SmartBin aims to address waste segregation challenges and contribute to the establishment of a more sustainable and environmentally friendly society.

Keywords: *Artificial Intelligence, Deep learning, Smart dustbin, Autonoumous solutions*

1. Introduction

Increasing urbanization, quick rate of migration to cities and development have resulted in a very steady growth in consumerism. Associate in nursing inevitable facet result of this is often exponential increase in waste generation. Different types of waste got to be handled otherwise for reasons like hygiene, non-spreading of sickness, cleanliness and toxicity. However, within the rush of daily life, waste is carelessly thrown in each nook and corner creating it troublesome for civic employees United Nations agency have to be compelled to manually segregate it, typically with blank hands that could be a risk. Massive piles of undisposed waste square measure dangerous for the general public because of landfills reaching most capability. Healthy setting could be a higher place to measure in. within the gift state of affairs setting is impure by totally different suggests that, one in all that is improper disposal of waste. Inefficient strategies of waste disposal like merchandising of waste within the landfills have adverse effects on setting and human kind. It’d not be wrong to mention that almost all of the cities suffer from issues emanating from either dangerous or nonexistent waste management.

Advances within the field of IoT have created it attainable to boost the prevailing waste management system. Sensor’s implementation within the waste bin alongside IoT property give time period observation, that is absent within the existing waste management system. Information like filling level, temperature, humidity, and any necessary information are often collected from the sensors. This information will then be transferred to the cloud for storage and process. The processed information will then be accustomed study and access the limitation of the prevailing waste management system and so improve the system’s potency as a full. IoT application within the waste bin is one step towards a sensible town. While the utilization goal for a few merchandises containing glass, metal, etc. is clear, it's vital to show that even the rubbish we tend to place outside are often wont to build electricity or are often utilized in alternative helpful merchandise. Whereas action the sturdiness of waste, we've got to place confidence in running the waste cycle expeditiously too. Waste management is over simply assembling waste. It’s the gathering, transport, processing, recycling, disposal and watching of waste materials. Varied factors, like environmental, economic, technical, legislation, institutional and political problems, have to be compelled to be taken into thought. Many necessary choices have to be compelled to be created. Amongst them is that the gap of recent waste management facilities as on the market locations have become progressively scarcer, or the enlargement of a current facility.

In addition, deep learning has provided progressive solutions for comprehensively understanding human behaviors. With the event of deep learning and image process algorithms, the classification of waste is dispensed with higher accuracy and in an exceedingly shorter time. Classification of waste may be a crucial step before the separation of waste is performed. A deep learning methodology like a convolutional neural network permits for the extraction of distinctive options from the image then categorize them into every class with high accuracy. Tensor Flow is AN ASCII text file, deep-learning library.

1.1 Object Detection

Object detection represents a sophisticated evolution of image classification, employing neural networks to anticipate and pinpoint objects within an image through the use of bounding boxes. This process involves identifying and precisely locating objects belonging to a predefined set of classes within the image.

In real-world applications, tasks such as detection, recognition, and localization are of paramount importance, underscoring the significance of object detection, often interchangeably referred to as object recognition, within the realm of Computer Vision.

1.2 Stages of Object detection

Two-stage object detection involves a strategic approach where algorithms address the object detection problem in two distinct stages:

- Identifying potential regions in the image that may contain objects.
- Classifying the contents of those identified regions into specific object classes.

Well-known two-step algorithms such as Fast-RCNN and Faster-RCNN often incorporate a Region Proposal Network, which suggests regions of interest likely to contain objects in the initial stage.

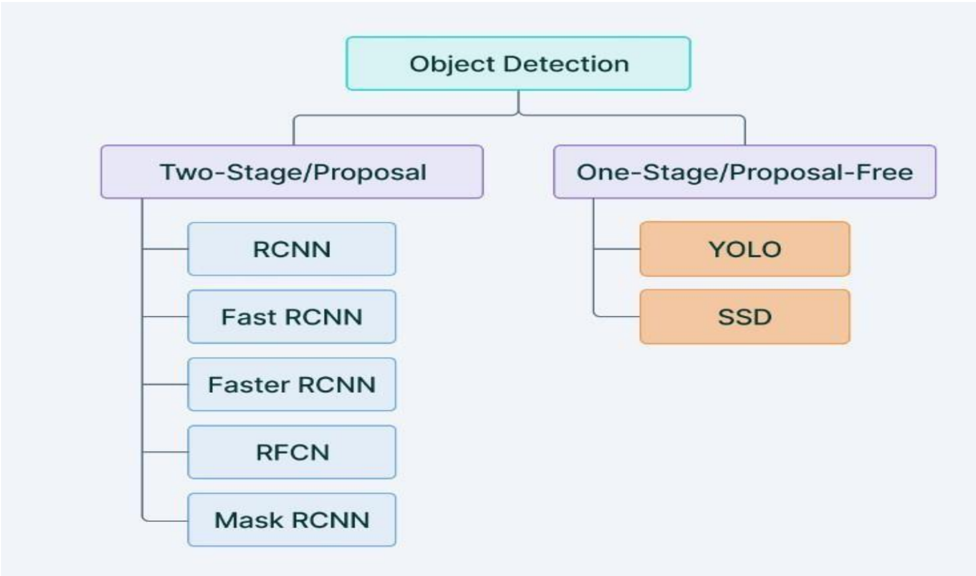

Figure 1. 1 One and Two Stage Detectors

The RPN output is subsequently input into a classifier responsible for categorizing the regions into specific classes. Despite achieving high accuracy in object detection with a notable mean Average Precision (mAP), this approach involves multiple iterations within the same image, leading to a slower detection speed and hindering real-time performance.

1.3 YOLO

YOLO, short for "You Only Look Once," is an algorithm designed for real-time object detection and recognition in images. Unlike traditional methods, YOLO treats object detection as a regression problem, providing class probabilities and bounding boxes for detected objects. Employing convolutional neural networks (CNN), YOLO can swiftly detect objects in real-time, requiring just a single forward propagation through the neural network. This unique approach allows for predicting objects across the entire image in a single algorithm run, simultaneously determining class probabilities and bounding boxes. The significance of the YOLO algorithm lies in its speed, delivering real-time detection, high accuracy with minimal background errors, and robust learning capabilities. The algorithm efficiently learns object representations and applies them to the task of object detection.

The YOLO algorithm operates through three key techniques:

Residual Blocks: The image is initially divided into various grids, each with a dimension of S x S, enhancing the algorithm's ability to detect objects within specific regions.

Bounding Box Regression: YOLO employs bounding box regression to precisely locate the objects within the detected regions, contributing to accurate localization.

Intersection Over Union (IOU): IOU is utilized to evaluate the overlap between predicted bounding boxes and ground-truth bounding boxes, ensuring the accuracy of object detection.

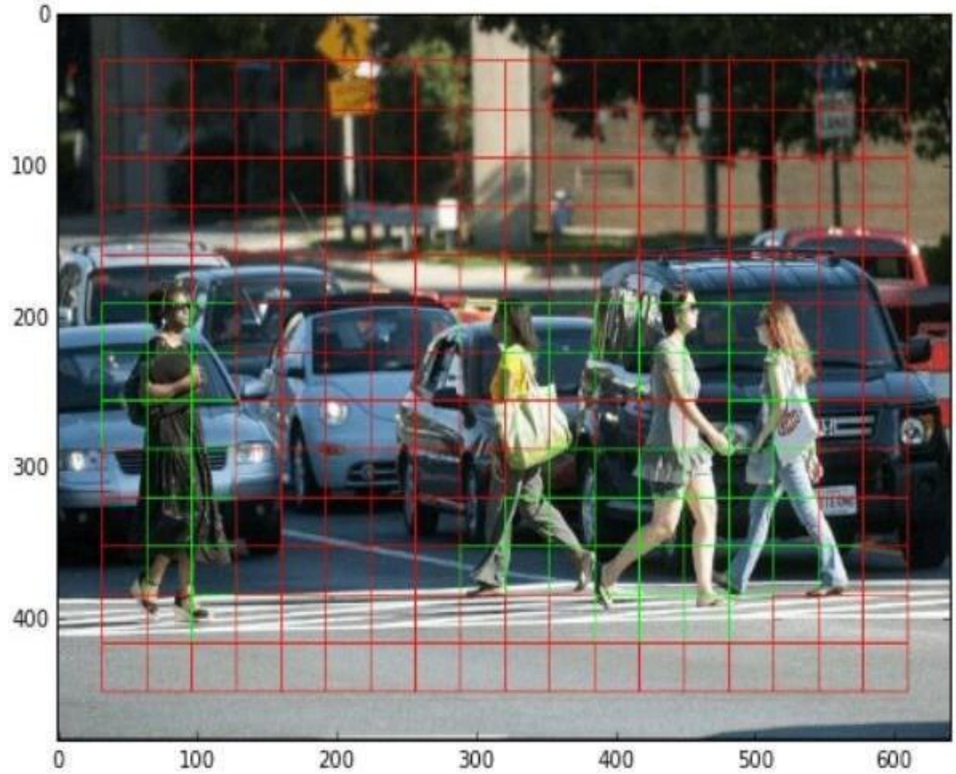

Figure 1. 2 Images divided into grids

2. Literature Review

Several research papers were reviewed to compile relevant information for the project. One notable implementation involved the creation of a Smart Dustbin based on IoT, utilizing an Arduino Uno board, ultrasonic sensor, and a GSM modem. Researchers identified challenges related to durability, maintenance, and cost-effectiveness in the design of these bins.

Another proposed solution focused on garbage management and disposal. This system incorporated a microcontroller, IR systems, and a central system displaying the current weight and waste level in the bin. Some variations allowed users to monitor the dustbin's status through a mobile-based web page using Wi-Fi.

The author also proposed a method for coordinating garbage collection in different city locations and common living areas. Ultrasonic sensors detected the trash level in the dustbin, relaying this information to the relevant authority via a GSM module. Some systems featured a MATLAB-based GUI.

A city-wide waste management system utilized embedded devices in bins, each assigned a unique ID. The system, divided into transmitter and receiver sections, employed sensors and a microcontroller to monitor waste levels. The RF transmitter sent this data to a control room, where the RF receiver collected and relayed the information to personnel, facilitating prompt emptying of the bins..

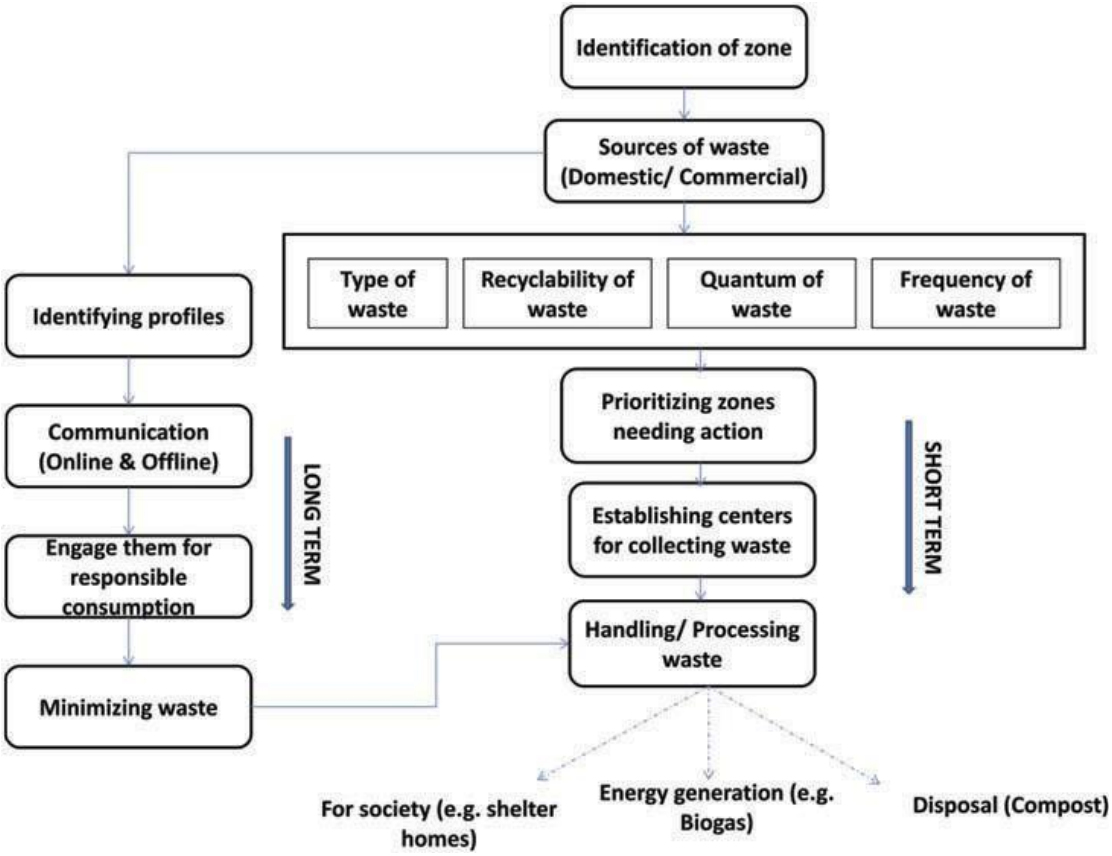

Figure 2. 1 Flow diagram of Literature Survey

2.1 Literature Review on COCO

Object detection involves identifying, localizing, and classifying objects in an image, playing a crucial role in vision-based software systems. This paper conducts a comprehensive survey of contemporary object detection algorithms leveraging deep learning. The exploration covers diverse algorithms, quality metrics, speed/size tradeoffs, and training methodologies. The focus lies on two types of object detection algorithms: the SSD class of single-step detectors and the Faster R-CNN class of two-step detectors. Additionally, the paper delves into techniques for constructing detectors that are both portable and fast on low-powered devices, including the investigation of new lightweight convolutional base architectures. Through a meticulous examination of the strengths and weaknesses of each detector, the paper provides insights into the current state of the art.

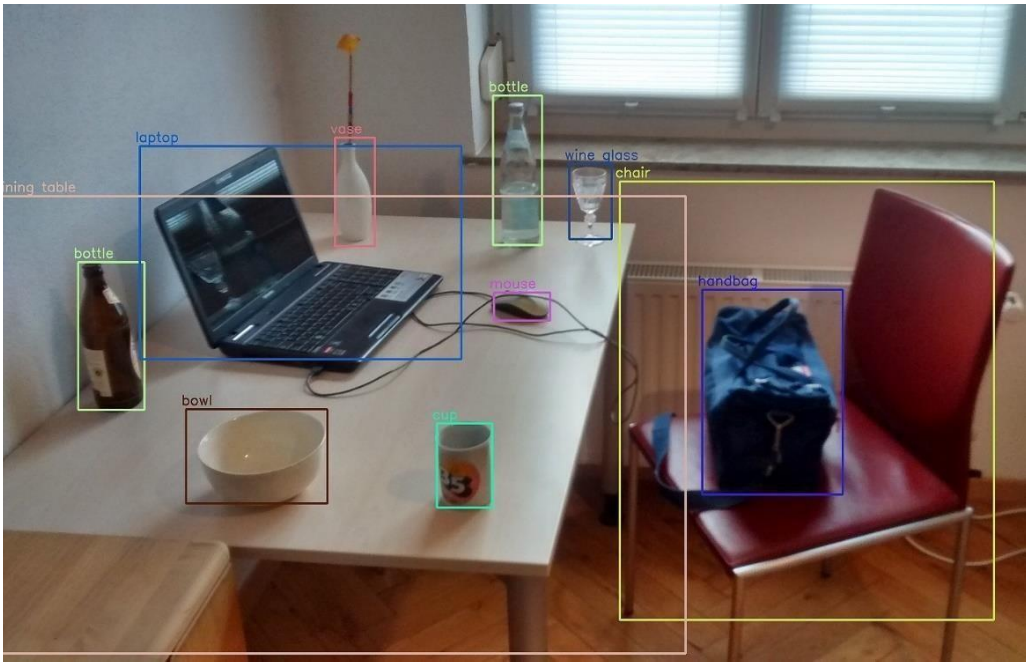

Figure 2. 2 Image Detection using COCO

Microsoft introduced COCO as a visual dataset, standing out with an extensive collection of photos portraying common objects in intricate daily scenarios. Unlike other datasets that may focus on specific sectors of artificial intelligence, such as image classification or object bounding box localization, COCO spans a broader range.

COCO boasts 2.5 million labeled instances across 328,000 images, making it a vast and versatile dataset suitable for various applications. However, in terms of sheer volume, it falls short compared to Google's OID, which impressively contains 9 million annotated images.

One specific task facilitated by COCO is object detection, where the model is tasked with providing bounding boxes for objects. This involves returning a list of object classes along with the coordinates of rectangles around them. Objects, often referred to as "things," are discrete entities with distinguishable parts, such as humans and cars. The official dataset for object detection also includes supplementary data for object segmentation.

Figure 2. 3 instance segmentation

Object/instance segmentation involves a more intricate task for the model. In addition to providing bounding boxes for objects, the model is required to generate segmentation masks. These masks consist of coordinates outlining polygons that closely encompass the objects, offering a more detailed representation of their shapes.

Figure 2. 4 Stuff segmentation

Stuff segmentation goes beyond object segmentation by focusing on continuous background patterns like grass or sky, instead of individual discrete objects. The model is tasked with delineating these background patterns, providing a comprehensive understanding of the visual elements in the scene.

3. Methodology

When delving into deep learning-based object detection, you'll encounter three main object detectors:

• R-CNN and its variations, including the original R-CNN, Fast R-CNN, and Faster R-CNN.

• Single Shot Detector (SSDs).

• YOLO.

R-CNNs, as one of the initial deep learning-based object detectors, represent a two-stage detection approach.

In the pioneering R-CNN publication, "Rich feature hierarchies for accurate object detection and semantic segmentation" (2013), Girshick et al. proposed an object detector that relied on an algorithm like Selective Search to propose candidate bounding boxes containing objects.

These regions were then fed into a CNN for classification, marking one of the early applications of deep learning in object detection.

However, the standard R-CNN approach faced challenges, being slow and lacking an end-to-end design.

To address these issues, Girshick et al. introduced "Fast R-CNN" in 2015, enhancing accuracy and forward pass speed. Nevertheless, it still depended on an external region proposal algorithm.

The true end-to-end deep learning object detector emerged in Girshick et al.'s 2015 paper, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks." Faster R-CNN eliminated the need for Selective Search, employing a fully convolutional Region Proposal Network (RPN) to predict bounding boxes and objectness scores. The RPN outputs were then passed to the R-CNN for final classification.

While R-CNNs offer high accuracy, their major drawback lies in speed, achieving only 5 FPS on a GPU.

To address speed concerns, Single Shot Detectors (SSDs) and YOLO adopt a one-stage detection strategy. These algorithms treat object detection as a regression problem, simultaneously learning bounding box coordinates and class label probabilities.

In general, single-stage detectors sacrifice some accuracy for speed, making them significantly faster than their two-stage counterparts.

3.1 Interfacing Arduino Uno with NodeMCU

NodeMCU excels in cloud connectivity, while Arduino is adept at interfacing with various sensors. Despite NodeMCU having only one analog pin, this blog explores the seamless connection between Arduino and NodeMCU for posting data to an MQTT broker. Arduino takes temperature readings and transmits them to NodeMCU via a serial connection. For each reading, NodeMCU dispatches an MQTT message. If monitoring a single sensor, you can directly utilize the analog input on NodeMCU, as detailed in this blog.

On the Arduino side, periodic sampling occurs, and JSON messages are transmitted over soft serial to NodeMCU. It's crucial to note that Arduino Uno operates at 5V, while NodeMCU operates at 3.3V. Therefore, a level shifter is recommended to link Arduino's soft serial pins to NodeMCU's UART port. On the NodeMCU side, it is essential to receive messages sent by Arduino in JSON format over the serial connection.

The Ultrasonic sensor, particularly the HC-SR05, plays a pivotal role in various projects. In this tutorial, we will establish the interface between an Ultrasonic sensor HC-SR05 and Arduino Uno. The key aspects covered in this project include:

• Connecting an Ultrasonic Sensor HC-SR05 to Arduino.

• Reading the sensor data and converting it to length.

• Displaying the length on the Serial Monitor.

HC-SR05 Overview:

Before delving into the project, it's essential to understand the functioning of the Ultrasonic Sensor HC-SR05. This sensor comprises an ultrasonic transmitter and an ultrasonic receiver. Initially, the ultrasonic transmitter emits an ultrasonic wave, which collides with an object, causing the signal to reflect. The receiver then captures the reflected signal, and the distance is determined by calculating the time taken for the signal to return, considering the speed of sound in the air.

4. Results and Discussions

Figure 4. 1 Hardware Interfacing

The hardware components, comprising Raspberry Pi 3B+ for Python-based image processing, Arduino Uno for the ultrasonic sensor, motor driver circuit, and GSM SIM28 module, along with NodeMCU for WiFi connectivity, are interconnected for seamless operation. To enhance the project's aesthetics and conceal any unnecessary wiring, the complete setup can be housed within a container or enclosed box.

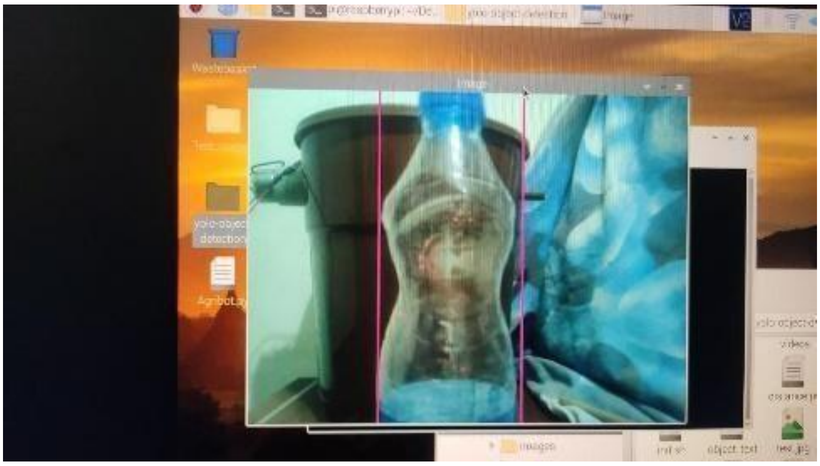

Figure 5. 2 Test Case:1

To identify plastic waste, a plastic water bottle is employed as the detection target. The image capture process involves manual commands for the Pi camera. Subsequent image processing is carried out by the Raspberry Pi 3B+ utilizing the YOLO algorithm and the COCO dataset, which encompasses images of various objects, including bottles.

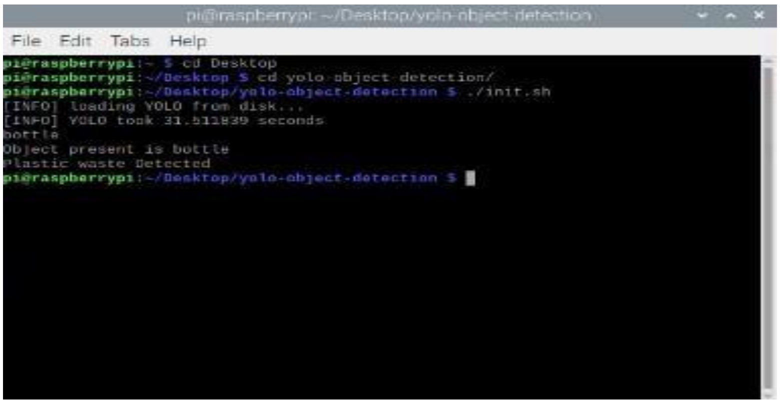

Figure 5. 3 Command Lines

Figure 5. 4 Test Case:2

To identify electronic waste, a mobile phone is utilized as the detection target. The image capture process involves manual commands for the Pi camera. Subsequent image processing is carried out by the Raspberry Pi 3B+ using the YOLO algorithm and the COCO dataset, which contains images of various objects, including bottles.

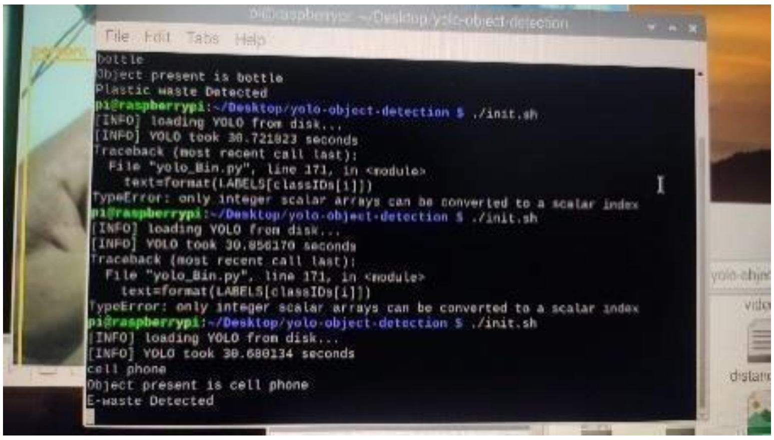

Figure 5. 5 Command Lines

The mobile phone is detected by Pi camera and sent to Raspberry Pi. The given image is processed and it's categorized as e-waste.

5. Conclusion

The concept of Smarter Cities is echoing across various discussions, and for good reasons. The quest for smoother traffic flow, enhanced security, and optimal energy utilization is at the forefront of urban development goals. While smart technology is offering solutions to these challenges, it's important to recognize that we're only beginning to explore the full potential of what can be achieved. Efficient waste management significantly impacts our daily lives, and Guard force, a trailblazer in smart city solutions, is playing a crucial role in enhancing waste management through Smart Bins. These intelligent waste bins integrate cloud-based software with state-of-the-art Internet of Things (IoT) sensors, enabling real-time monitoring of bin conditions and timely alerts for waste managers when bins are nearing capacity. The Guard force Smart Bins stand out due to four key elements that elevate their intelligence beyond standard bins.

.Refrences

[1]G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. (references) M. Sardogan, A. Tuncer and Y. Ozen, "Plant Leaf Disease Detection and Classification Based on CNN with LVQ Algorithm," 2018 3rd International Conference on Computer Science and Engineering (UBMK), 2018, pp. 382-385.

[2]D. Bini, D. Pamela and S. Prince, "Machine Vision and Machine Learning for Intelligent Agrobots: A review" 2020 5th International Conference on Devices, Circuits and Systems (ICDCS), 2020, pp. 12- 16.

[3]G. M. Sharif Ullah Al- Mamun et al., "Performance Analysis of Multipurpose AGROBOT," 2019 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE), 2019, pp. 1-4.

[4]H Durmuş, E. O. Güneş, M. Kırcı and B. B. Üstündağ, "The design of general purpose autonomous agricultural mobile-robot: "AGROBOT"," 2015 Fourth International Conference on Agro- Geoinformatics (Agro- geoinformatics),2015,pp.49-53.

[5]N G. Kurale and M. V. Vaidya, "Classification of Leaf Disease Using Texture Feature and Neural Network Classifier," 2018 International Conference on Inventive Research in Computing Applications (ICIRCA),2018,pp. 1-6.

[6] H. Girish, T. G. Manjunat and A. C. Vikramathithan, "Detection and Alerting Animals in Forest using Artificial Intelligence and IoT," 2022 IEEE Fourth International Conference on Advances in Electronics, Computers and Communications (ICAECC), 2022, pp. 1-5, doi: 10.1109/ICAECC54045.2022.9716679.

[7] A. Devipriya, H. Girish, V. Srinivas, N. Adi Reddy and D. Rajkiran, "RTL Design and Logic Synthesis of Traffic Light Controller for 45nm Technology," 2022 3rd International Conference for Emerging Technology (INCET), 2022, pp. 1-5, doi: 10.1109/INCET54531.2022.9824833.

[8] S. Vaddadi, V. Srinivas, N. A. Reddy, G. H, R. D and A. Devipriya, "Factory Inventory Automation using Industry 4.0 Technologies," 2022 IEEE IAS Global Conference on Emerging Technologies (GlobConET), 2022, pp. 734-738, doi: 10.1109/GlobConET53749.2022.9872416.

[9] T G Manjunath , A C Vikramathithan , H Girish, "Analysis of Total Harmonic Distortion and implementation of Inverter Fault Diagnosis using Artificial Neural Network", Journal of Physics: Conference Series, Volume 2161, 1st International Conference on Artificial Intelligence, Computational Electronics and Communication System (AICECS 2021) 28-30 October 2021, Manipal, India. https://iopscience.iop.org/issue/1742-6596/2161/1

[10] GIRISH H , "Internet of Things Based Heart Beat Rate Monitoring System", © September 2022 | IJIRT | Volume 6 Issue 4 | ISSN: 2349-6002 IJIRT 156592 INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY 227

[11] Dr Girish H, Dr. Mangala Gowri , Dr. Keshava Murthy , Chetan Naik J, Autonomous Car Using Deep Learning and Open CV, PAGE NO: 107-115, VOLUME 8 ISSUE 10 2022, Gradiva review journal, ISSN NO : 0363-8057, DOI:10.37897.GRJ.2022.V8I8.22.50332

[12] Girish H. "Intelligent Traffic Tracking System Using Wi-Fi ." International Journal for Scientific Research and Development 8.12 (2021): 86-90.

[13] Girish H, Shashikumar D R, "Emission monitoring system using IOT", Dogo Rangsang Research Journal, UGC Care Group I Journal, ISSN: 347-7180, Vol – 8 Issue-14, No.6, 2020.

[14] Girish H, Shashikumar D R, "Display and misson computer software loading", International journal of engineering research & Technology (IJERT), ISSN: 2278-0181, Vol – 10 Issue-08, No.13, August 2020.

[15] Girish H, Shashikumar D R, "A Novel Optimization Framework for Controlling Stabilization Issue in Design Principle of FinFET based SRAM", International Journal of Electrical and Computer Engineering (IJECE) Vol. 9, No. 5 October 2019, pp. 4027~4034. ISSN: 2088-8708, DOI: 10.11591/ijece.v9i5.pp.4027-4034

[16] Girish H, Shashikumar D R, "PAOD: a predictive approach for optimization of design in FinFET/SRAM", International Journal of Electrical and Computer Engineering (IJECE) Vol. 9, No. 2, April 2019, pp. 960~966. ISSN: 2088-8708, DOI: 10.11591/ijece.v9i2.pp.960-966.

[17] Girish H, Shashikumar D R, "SOPA: Search Optimization Based Predictive Approach for Design Optimization in FinFET/SRAM", © Springer International Publishing AG, part of Springer Nature 2019 Silhavy (Ed.): CSOC 2018, AISC 764, pp. 21–29, 2019. https://doi.org/10.1007/978-3-319-91189-2_3.

[18] Girish H, Shashikumar D R, "Cost-Effective Computational Modelling of Fault Tolerant Optimization of FinFET-based SRAM Cells", © Springer International Publishing AG 2017 R. Silhavy et al. (eds.), Cybernetics and Mathematics Applications in Intelligent Systems, Advances in Intelligent Systems and Computing 574, DOI 10.1007/978-3-319-57264-2_1.

[19] Girish H, Shashikumar D R, "A Survey on the Performance Analysis of FinFET SRAM Cells for Different Technologies", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-4 Issue-6, 2016.

[20] Girish H, Shashikumar D R, "Insights of Performance Enhancement Techniques on FinFET-based SRAM Cells", Communications on Applied Electronics (CAE) – ISSN: 2394-4714, Foundation of Computer Science

FCS, New York, USA .Volume 5 – No.6, July 2016 – www.caeaccess.org

[21] Girish H, Shashikumar D R, "DESIGN OF FINFET", International Journal of Engineering Research ISSN: 2319-6890) (online), 2347-5013(print) Volume No.5 Issue: Special 5, pp: 992-1128, doi: 10.17950/ijer/v5i5/013 2016.

[22] Dr. MANGALA GOWRI S G, Dr. SHASHIDHAR T M, Dr. SUNITHA R, SHYLAJA V, Dr. GIRISH H, "DESIGN OF 3-BIT CMOS WALLACE MULTIPLIER" , Seybold report, ISSN 1533-9211, Volume 18, Page No: 1260-1271 DOI: 10.5281/zenodo.8300481

[23] Dr. Mangala Gowri S G, Dr. Girish H, Ramesh N, Dr. Nataraj Vijaypur, "IOT based plant monitoring system and smart irrigation using new features" ResMilitaris, vol.13, n°2, January Issue 2023 https://resmilitaris.net/menu-script/index.php/resmilitaris/article/view/3312/2608

[24] Girish H.2023, Smart Theft Securityvehicular System Using Iot. Int J Recent Sci Res. 14(02), pp. 2881-2884. DOI: http://dx.doi.org/10.24327/ijrsr.2023.1402.0591

[25] Dr. Mangala Gowri S G, Dr. Girish H, Dr. Santosh Dattatray Bhopale, Weed Detection based on Neural Networks, International Journal of All Research Education and Scientific Methods (IJARESM), ISSN: 2455-6211 Volume 11, Issue 3, March-2023, Impact Factor: 7.429, Available online at: www.ijaresm.com DOI: https://doi.org/11.56025/IJARESM.2023.11323351

[26] Shashidhara, K.S., Girish, H., Parameshwara, M.C., Rai, B.K., Dakulagi, V. (2023). A Novel Approach for Identification of Healthy and Unhealthy Leaves Using Scale Invariant Feature Transform and Shading Histogram-PCA Techniques. In: Shetty, N.R., Patnaik, L.M., Prasad, N.H. (eds) Emerging Research in Computing, Information, Communication and Applications. Lecture Notes in Electrical Engineering, vol 928. Springer, Singapore. https://doi.org/10.1007/978-981-19-5482-5_47.

[27] Rajkamal R, Anitha V, Gomathi Nayaki P, Ramya K, Kayalvizhi E, "A Novel Approach for Waste Segregation at Source Level for Effective Generation of Electricity – GREEN BIN," International Conference on Science, Engineering and Management 2014.

[28] Boudhayan Dev, Aditya Agarwal, Chinmay Hebbal, Aishwarya H S, Kiran Agarwal Gupta. (2018). Automatic Waste Segregation using Image Processing and Machine Learning, International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN 2321-9653, Volume 6, Issue-III.

[29] Apoorva S, Chaithanya, Rukuma S. Prabhu, Saiswaroop B. Shetty, Denita D'Souza. "Autonomous garbage collector robot" International journal of Internet of Things"-2017.

[30] Shikha Parashar, Pankaj Tomar," waste management by a robot-A Smart and Autonomous Technique", IOSR JOURNAL OF ENGINEERING-2018.

[31] Amrutha Chandramohan, Joyal Mendonca, Nikhil Ravi Shankar, Nikhil U Baheti, Nitin Kumar Krishnan*, Suma M, "Automated Waste Segregator," 2014 Texas Instruments India Educators' Conference.