IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Automated Waste Segregation System Using Opencv And Image Processing

[1]Atharva Kavade, [2]Anish Katariya, [3]Sushant Katare, [4]Yash Kathoke, [5]Shravan Katore, [6]Utkarsha Kavitake

[1,2,3,4,5,6]Student

[1,2,3,4,5,6]Department of Engineering, Sciences and Humanities

[1,2,3,4,5,6]Vishwakarma Institute of Technology, Pune, Maharashtra, India.

Abstract: Automated Waste Segregation System using OpenCV and Image processing is a transformative approach towards using image processing to segregate waste automatically. It will create ease with detection, recognition, categorization of waste by using deep learning and algorithm. The algorithm will collect the images of waste from the camera module, process it and identify the image into a category like wet or dry waste, plastic, glass, metal, etc. and then send the proper command to respective actuators to segregate the waste properly. The objective is to utilize image processing in different methods according to different situations and revolutionize it.

***Index Terms* - Image processing, OpenCV, YOLO v5, ESP 32 CAM Module, Python.**

I. Introduction

In current state, people do not seem to care about segregating waste into different types before throwing it away. This can be quite harmful to nature as when the waste is thrown in a landfill and is not segregated properly then the mixture of the waste can contaminate the soil. Unsegregated waste can cause bio-hazards as well. The solution to such problem is by automatically segregating the waste. This is to be achieved by using image processing, camera module, micro-controllers, and actuators. An algorithm is programmed using Open CV module in python programming language, which is trained by inputting multiple images (These images are not real time) of one item, then to refine the processing accuracy we show another image (These images are real time) of the same item and then verify if the result is right or wrong. We do this in several rounds. YOLO v5 is used to help with object detection. The algorithm receives the images from a camera module (ESP32-CAM module is used in this case), which then processes it and gives the output. The Arduino acts based on result received from the algorithm and then sends signal to the actuators like servo motors. The correct bin is opened by the servo motor and then the waste falls into its designated bin. The power supply used will be a solar rechargeable battery to make the system self-sustainable.

II. Literature Review

Research is going on in Waste segregation systems. Several people are working in this area. In this section, we present the review of the research work in automated waste segregation system and the related fields which we have used as the fundamental base to design our model. The development of garbage classification system using a YOLOv8 model, Python, and OpenCV to classify waste into wet, dry, metal, or plastic categories via a webcam was done in [1]. The integration of an Arduino Uno to open the appropriate bin and monitor fill levels in real-time were also included. The system effectively demonstrated real-time classification and bin management, optimizing waste disposal processes. The article [2] addresses the waste management crisis and proposes a system that uses AI and robotics for automated waste segregation. It combines a YOLO v5 with a robotic arm to classify and sort waste efficiently. The system is built with Raspberry Pi and Arduino, which processes video to detect and segregate waste in real time. In their experiments using comprehensive dataset for the trained model resulted them with high accuracy. The authors of [3] propose using a Convolutional

Neural Network (CNN) to classify waste into six types, leveraging an updated dataset to automate sorting. They claim that CNNs, like VGG16, are effective for image recognition and classification, identifying waste and guiding it to the correct bin. According to them fac- tors like data augmentation and pre-processing are crucial for enhancing the model's accuracy and performance. The smart waste management system of [4] includes modules like processors, sensors (ultrasonic, IR, moisture), software (Arduino IDE, ThingSpeak), and DC motors. The study by the authors of [5] introduces an enhanced YOLOv5 method tailored for robot recognition which focuses on improving flexibility and precision. In [6] the study developed an optimized YOLOv4 model for detecting floating debris in rivers, using advanced techniques like Bag of Specials (BoS), CSP, and DIoUNM for the river monitoring system. [7] describes an IoT system that makes use of a Raspberry Pi board, sensors, and a camera module. Additionally, it supports the TensorFlow Lite, open CV, and lobe deep learning libraries. The CNN learning model uses ResNet and MobileNet algorithms for speed, accuracy, and compatibility in [8] research paper, the waste is transported by using conveyor belt with servo motor attached to it. The setup brings about robotization and ultrasonic sensors with python programming. The whole system is powered by Arduino Uno micro-controller. The [9] paper presents implementation of an automated waste management system that uses the (YOLO) algorithm for efficient waste sorting. YOLO's fast and accurate object detection to classify and sort waste in real time, enhancing efficiency and reducing worker health risks and environmental damage. The [10] article creates a smart trash can that classifies recyclables using a webcam and Raspberry Pi's YOLO real-time object detection. In ideal conditions, YOLO attained 91% accuracy, whereas on the Raspberry Pi, it only managed 75%. IoT hardware, such as ultrasonic sensors controlled by an Arduino Uno, is incorporated into the system. Using the ESP8266 Wi-Fi module, data is posted to Firebase and seen via a mobile app made with MIT App Inventor. The study [11] suggests utilizing a robotic arm and the YOLOv6 item identification model to create an intelligent garbage sorting system. Some of its characteristics are a 3D model of a 4 DOF robotic arm created using CAD software. Tested on an altered TrashNet dataset, the system outperforms current YOLO models in terms of speed, accuracy, recall, and F1 score, sorting items in a matter of milliseconds. The [12] paper proposes an economical waste tracking system with an integrated sorting mechanism to segregate domestic waste into metal, plastic, and glass. The system also tracks and reports household waste production to a server, facilitating efficient recycling and im-proved waste management for a cleaner environment. In [13] paper, they have used YOLOv8 model to detect waste. A dataset of waste images was collected to train the YOLOv8 model. The expected results of this study are that YOLOv8 will achieve better accuracy for waste classification. IoT technology forms the basis of the waste management system in the [14] paper. Three primary subsystems make up the system: the hardware is comprised of a garbage can with sensors installed. Data management and data visualization are the two subsystems that are used for management and analysis in order to empty the bin. The system described in [15] article employs deep learning, GPS, GSM, image processing, and drones to identify waste and relay position data to authorities. Multi-object detection and picture classification are used in the trash segregation process. The enhanced system reaches a mean average precision of 87.4% and 95% accuracy. This [16] paper, introduces an automatic material sorting machine that uses image processing techniques to sort materials by shape and color, utilizing a webcam mounted above a conveyor belt. The system is implemented with the OpenCV library, programmed in Python 2.7 IDLE, and controlled by an Arduino Uno micro-controller. The research described in [17] paper intends to create an automated waste segregation system that separates waste into groups that are recyclable and non-recyclable using image processing techniques. The software employs an image classification technique based on machine learning, while the hardware configuration consists of a conveyor, camera, L-shaped clamp, and Arduino UNO for control. The goal of the [18] paper's authors is to effectively separate household wastes. The software is an image categorization method based on machine learning, and the hardware is a garbage bin framework built around the Raspberry Pi core module. The authors of [19] paper, uses Automatic sorting systems, using robotic manipulators, minimize human intervention by separating recyclable materials. This study employs a depth camera and image processing techniques to determine both the type and 3D location of waste. GC-YOLOv5, an object detection network-based garbage categorization model, is presented in the [20] publication. Five common types of trash were chosen, and a garbage dataset was created after the data was cleaned, categorized, and assembled. We used our datasets to build and train GC-YOLOv5. They deployed the garbage classification model in the cloud. In [21] research paper, they have used the concept of deep learning to segregate waste into all possible categories. They have used EfficientNet-B2 to detect waste. A litter localization detector is also presented by using EfficientDet-D2. Classify waste datasets benchmarks was also introduced in this paper. [22] The system used in this paper is built on a convolutional neural network. After creating data sets and data labels, the ResNet and MobileNetV2 algorithms are used to test the trash classification data. To get the best outcomes, a raspberry pie microcomputer is also utilized. In order to identify and locate trash in pictures and videos, a Garbage Detection System employing deep learning and object detection algorithms is presented in the research paper [23]. To find the best model for garbage detection, it contrasts five models: YOLOv5M, SSD ResNet-50, Faster R-CNN ResNet-101, CenterNet ResNet-101, and EfficientDet-D1. The best performance was attained by YOLOv5M, with a Mean Average Precision (mAP@0.5) of 0.613. In project [24], an Internet of Things (IoT) smart bin is installed. A Raspberry Pi with an ultrasonic rubbish detecting sensor is included with the bin. Waste is separated using servo motors and the pi camera yolo algorithm. An app on a smartphone is linked to the system to allow for complete process monitoring.

III. Methodology

*A. **Components** and 3-D Model*

1. Components:

1) Arduino Uno: This is the micro-controller board that acts as the brain of the hardware. It takes the input in the form of data from the algorithm then acts accordingly to predefined situations and commands the actuators.

2) Open CV: It is an open-source library for computer vision and can be used for machine learning, image processing, etc. ESP 32 CAM Module: It is a camera module that will provide real time images to the algorithm.

3) YOLOv5: It is a module that is used in object detection with great accuracy. Servo Motor: Servo motor is an actuator which causes movement by rotating in single axis up to 180 degrees. It is used to control the flaps.

2. 3-D Model Visualisation:

Fig. 1. Plastic Bottle on the lid of the bin. POV of ESP 32 CAM Module

Fig. 2. Plastic Bottle on the lid of the bin

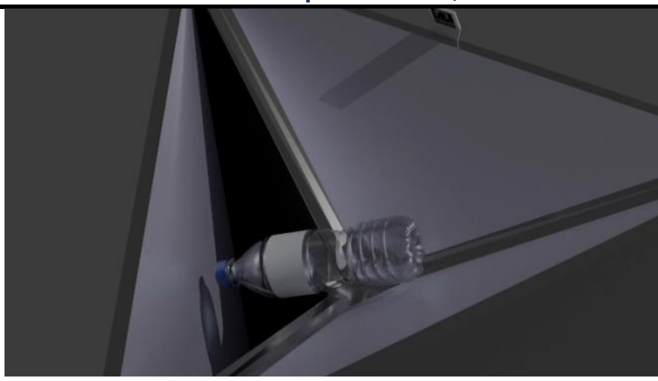

Fig. 3. Bottle falling after a flap is opened

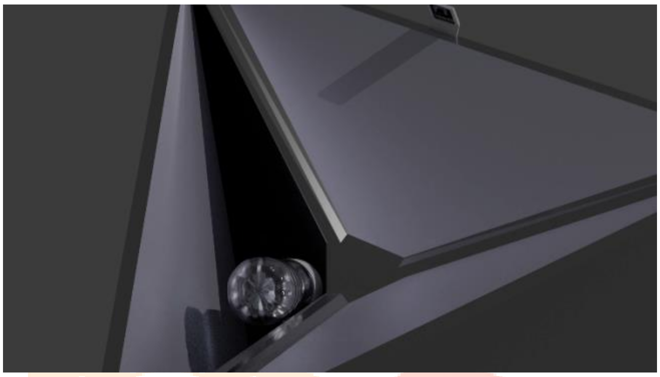

Fig. 4. Bottle falling after a flap is opened

B. *Code*

```python
import yolov5

# load model
model = yolov5.load('keremberke/yolov5m-garbage')

# set model parameters
model.conf = 0.25
# NMS confidence threshold
model.iou = 0.45
# NMS IoU threshold
model.agnostic = False
# NMS class-agnostic
model.multi_label = False
# NMS multiple labels per box
model.max_det = 1000
# maximum number of detections per image

# set image
img = 'https://www.image.com'
# In above line there is an image reference link.
# Right now it is an example & not an actual link

# perform inference
results = model(img, size=640)

# inference with test time augmentation
results = model(img, augment=True)

# parse results
predictions = results.pred[0]
boxes = predictions[:, :4] # x1, y1, x2, y2
scores = predictions[:, 4]
categories = predictions[:, 5]

# show detection bounding boxes on image
results.show()

# save results into "results/" folder
results.save(save_dir='results/')
```

Fig. 5. Code for garbage detection model

IV. Results And Discussions

In this section, we present our results obtained through testing our system and discuss the working of our system. Some results are–

1) Automated Waste Segregation System improves waste management systems by efficiently sorting and separat- ing different types of waste, allowing for proper disposal and recycling. This helps minimize the risk to public health and the environment, as well as optimize the economic value of waste.
2) Waste Segregated in Multiple Categories - The system successfully categorizes waste into multiple categories with high accuracy due to robustness of YOLO v5 for object detection. During the experiments, the system consistently identified and sorted waste items into cor- rect bins, demonstrating the feasibility of multi-category waste segregation.
3) Versatile placement thanks to the adjustable device: One of the system's primary features is its adaptability, which enables it to be put on any trash can. This adaptability is made possible by a modular design that is simple to modify to fit various bin shapes and sizes. The device can be used in a variety of settings, from homes to public waste collection locations, thanks to its portability and simplicity of installation.
4) Environmental Benefits: By guaranteeing that garbage that is both biodegradable and non-biodegradable is properly separated, the system supports environmental sustainability. Once separated, biodegradable garbage can be used for productive purposes like composting and farming. This lessens the load on landfills and lowers the biohazards and soil contamination that come with disposing of mixed garbage.
5) Integration of New Age Technologies - By combining Python with IoT and machine learning technologies, our trash segregation system becomes more intelligent and functional. Real-time monitoring and remote device control are made possible by IoT connectivity, which also provides useful data for streamlining garbage collection and disposal procedures.

The testing of this prototype on various type of waste has obtained the results and checked the efficiency of the prototype to detect the type of waste correctly. It primarily detected the waste in three categories. The categories are Biodegradable waste, plastic waste, and the Metal waste. Here are some results obtained after testing the prototype –

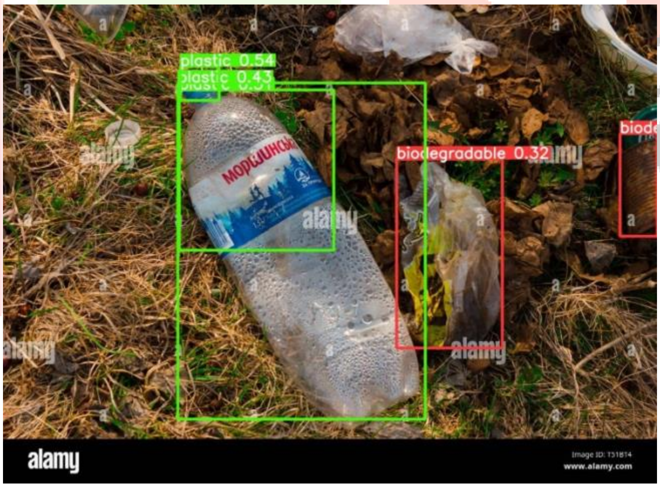

Fig. 6. A plastic bottle beside a biodegradable waste

In figure 6, the system detected the plastic waste and biodegradable waste. There is a plastic bottle in the image and some biodegradable material and the prototype has correctly detected it.

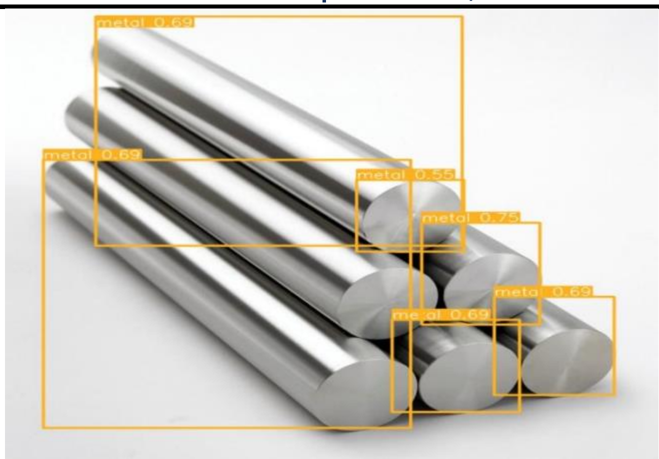

Fig. 7. Metal Rods

In figure 7, there are metal rods and the prototype has detected it accurately. Also, it has detected each metal rod separately.

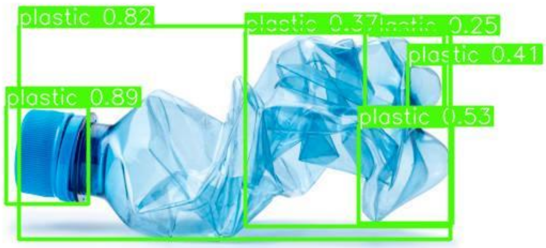

Fig. 8. Crumbled plastic bottle

In figure 8, there is a crushed plastic bottle and regardless of being crushed, the prototype has detected it as plastic.

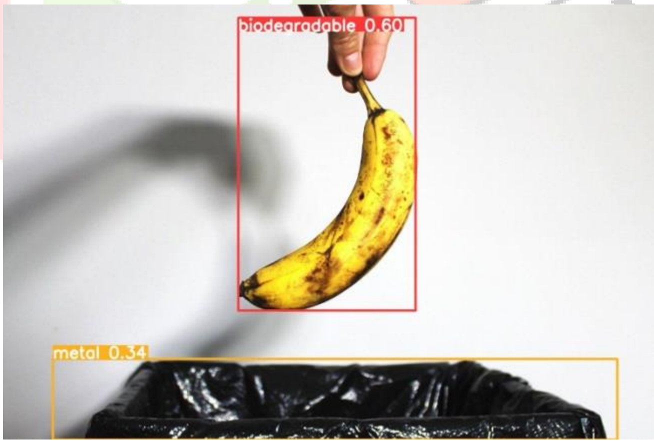

Fig. 9. Banana

Figure 9 shows a Banana and the prototype has detected it as a biodegradable waste accurately.

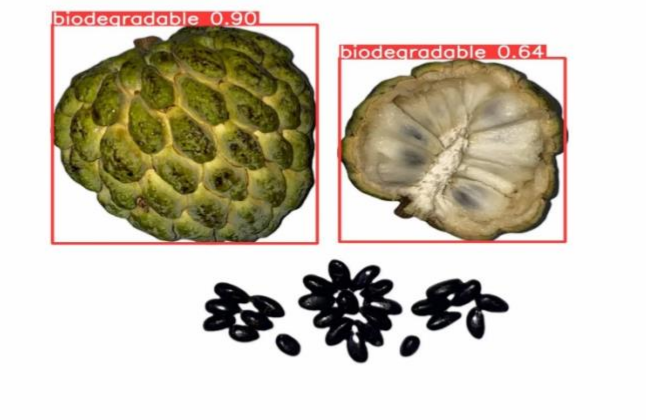

Fig. 10. Custard Apple

In figure 10, there is a fruit Custard apple and the prototype has detected it accurately as biodegradable waste.

Fig. 11. Metal Can

In figure 11, a metal can is there and prototype has detected it in the category of metal waste.

V. Conclusion

1. Advanced Waste Management Technology: The Auto- mated Waste Segregation System uses OpenCV and YOLOv5 for accurate waste identification and classification, combining hardware integration and machine learning.
2. Hardware-Software Synergy: Utilizes ESP 32 CAM module for real-time image capture and Arduino-controlled actuators for segregation, offering a scalable solution for diverse waste management scenarios.
3. High Accuracy with Challenges: Deep learning algorithms ensure high accuracy, though issues like misclassification due to lustre and transparency need addressing.
4. Versatility and Broader Applications: Beyond waste management, the system can be applied in other domains, such as industrial fruit segregation based on optical properties.
5. Advantages for the Environment and Future Prospects: Encourages effective recycling and lessens the load on landfills, promoting environmental sustainability. provides a basis for additional study and advancement in automated sorting systems.

Acknowledgement

Special thanks to Prof. (Dr) Rupali Deshpande and Prof. (Dr) Sachin Sawant for their valuable guidance.

References

[1] Rizwana S, Abinaya J, Harshada G, Sampada S, Shreya M, "Waste Segregation Using Image Detection and IOT", International Journal of Creative Research Thoughts, Volume 11, Issue 6 June 2023.

[2] Jayanti Lahoti et al, "multi-class waste segregation using computer vision and robotic arm", PeerJ Computer Science, May 10, 2024.

[3] Nirupa Savaj, Shweta Patil, Rajiv Sahal Shikha Malik, "Automated Waste Management System", International Research Journal of Engineering and Technology, Volume: 09 Issue: 01, Jan 2022.

[4] Shwetashree Vijay, Pilla Nitish Kumar, Sam Raju, Vivekanandan S, "Smart Waste Management System using Arduino", International Journal of Engineering Research & Technology, Vol. 8 Issue 11, November-2019.

[5] Qisong Song et al, "Object Detection Method for Grasping Robot Based on Improved YOLOv5", Micromachines 2021, 12, 1273.

[6] Nur Athirah Zailan, Muhammad Mokhzaini Azizan, Khairunnisa Hasikin, Anis Salwa Mohd Khairuddin1, Uswah Khairuddi, "An automated solid waste detection using the optimized YOLO model for riverine management", Front. Public Health, Volume 10, 12 August 2022.

[7] V Rajesh et al, "Waste Segregation using CNN & IoT", Natural Volatiles & Essential Oils Journal, Volume: 8 Issue: 5, 2021.

[8] Atharva Tangadi, Amar Sangalage, Soham Suryaanshi, Vidya Mali, "Waste Segregation System", International Research Journal of Modernization in Engineering Technology and Science, Volume:05 Issue:11, November,2023.

[9] Seba Maity, Tania Chakraborty, Ratnesh Pandey, Hritam Sarkar, "YOLO (You Only Look Once) Algorithm-Based Automatic Waste classification system", Journal of Mechanics of Continua and Mathematical Sciences, Vol. 18, No. 18, August 2023.

[10] Aria Bisma, Wahyutama, Mintae Hwang, "YOLO-Based Object Detection for Separate Collection of Recyclables and Capacity Monitoring of Trash Bins", Electronics, Volume 11 Issue 9, 17 March 2022.

[11] Azza Elsayed Ibrahim, Rasha Shoitan, Mona M. Moussa, Heba A. Elnemr, Young Im Cho, Mohamed S. Abdallah, "Object Detection- based Automatic Waste Segregation using Robotic Arm", (IJACSA) International Journal of Advanced Computer Science and Applications, Volume 14, No. 6, 2023.

[12] Adi Suvarnamma, Jangampalli Adi Pradeepkiran, "SmartBin system with waste tracking and sorting mechanism using IoT", Cleaner Engineering and Technology, November 2021.

[13] V S Rajkumar, Mathivanan M, Kavin M, Jaiwin Raj S, "Automated Waste Management System Using Object Detection", International Jour- nal of Advance Research and Innovative Ideas in Education, Vol-9 Issue-5 2023.

[14] Prathikshith Jain, Sowmya K, Ganesh Prasad Navada V, "Smart Trash Bin", International Journal of Scientific Research in Computer Science, Volume 7, Issue 4, 13, July 2021.

[15] Gayathri Rajakumaran, Shola Usharanim, Christie Vincent, Sujatha M, "Smart Waste Management: Waste Segregation using Machine Learn- ing", Journal of Physics Conference Series 2471, April 2023.

[16] A. Sriramguru, A. Vishwa, D. Yogeshwaran, B. S. Yogesh, "Arduino based Automatic Material Sorting Machine Using Open CV and Python 2.7 IDLE", International Re-search Journal of Engineering and Technology, Volume: 07 Issue: 04, April 2020.

[17] Haritha K N, Gopika S Pillai, Jyothi Krishnan M, "Automated Waste Segregation System Using Image Processing", International Journal of Novel Research and Development, Volume 8, Issue 6 June 2023.

[18] J Sanjai, V Balaji, K Pranav, B. Aravindan, "Automated Domestic Waste Segregator Using Image Processing", International Research Journal of Engineering and Technology, Volume: 06 Issue: 04, April 2019.

[19] Kenan Erin, Bu¨nyamin Bingo¨l, Barıs¸ Boru, "YOLO – Based Waste Detection", Journal of Smart Systems Research, Volume: 3 Issue: 2, 3-November-2022.

[20] Ziliang Wu et al, "Using YOLOv5 for Garbage Classification", 4th Inter- national Conference on Pattern Recognition and Artificial Intelligence (PRAI), August 2021.

[21] Sylwia Majchrowska et al, "Deep learning-based waste detection in natural and urban environments", Waste Management, Volume 138, 1 February 2022, Pages 274-284.

[22] Xiaobo Yan et al, “A Garbage Classification Method Based on Improved YOLOv5”, 2022 International Conference on Networks, Communications and Information Technology (CNCIT), June 2022.

[23] Deep Patel et al, “Garbage Detection using Advanced Object Detection Techniques”, Proceedings of the International Conference on Artificial Intelligence and Smart Systems (ICAIS), 12 April 2021.

[24] D. Vinodha, J. Sangeetha, B. Cynthia Sherin, M. Renukadevi, “Smart Garbage System with Garbage Separation Using Object Detection”, International Journal of Research in Engineering, Science and Management, Volume-3, Issue-5, May-2020.