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# YOLO (YOU ONLY LOOK ONCE) ALGORITHM-BASED AUTOMATIC WASTE CLASSIFICATION SYSTEM

**Seba Maity[1], Tania Chakraborty[2], Ratnesh Pandey[3], Hritam Sarkar[4]**

[1,2,3] Department of Electronics and Communication Engineering

College of Engineering and Management, Kolaghat

Corresponding Author: **Seba Maity**

Email : sebamaity@cemk.ac.in

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**Abstract**

*Our paper presents the design and implementation of an automated waste management system that utilizes the You Only Look Once (YOLO) algorithm and computer vision techniques for efficient waste sorting. The escalating global concern regarding waste management necessitates the development of automated systems to address the challenges associated with waste sorting. By leveraging YOLO's object detection capabilities and the power of computer vision, our system accurately identifies and classifies various types of waste in real time. The YOLO algorithm's efficiency and speed enable the swift processing of waste items, facilitating efficient sorting into predefined placements. This automated system not only improves accuracy but also reduces health risks for workers and minimizes environmental harm. Complemented by public awareness campaigns promoting proper waste separation and recycling practices, our research contributes to advancing waste management technologies and fostering sustainable practices for a healthier environment.*

**Keywords:** Waste management automated system, YOLO algorithm, Computer vision, Image processing, keras. Tensorflow, Dataset, Arduino UNO. Servo motor,

## I. Introduction

The World Bank report showed that there are almost 4 billion tons of waste around the world every year and the urban alone contributes a lot to this number, the waste is predicted to increase by 70 percent in the year 2025 [I] According to [I] in the next 25 years, the less developed countries' waste accumulation will increase drastically. With the increase in the number of industries in urban areas, the disposal of solid waste is becoming a big problem, and solid waste includes paper, wood, plastic, metal, glass, etc. The main method of managing the waste is landfilling, which is inefficient and expensive and pollutes the natural environment. For example, the landfill site can affect the health of the people who stay around the landfill site. Another common way of managing waste is burning waste and this method can cause air pollution and some hazardous materials from the waste spread into the air which can cause cancer [VII]. Hence it is necessary to recycle waste to protect the environment and human beings' health, and we need to separate the waste into different components which can be recycled using different ways. . Waste materials such as plastic, glass, and paper can be segregated into different columns in order to process them to make new products which will save natural resources. The present way of separating waste/garbage is the hand-picking method, whereby someone is employed to separate the different objects/materials. [XI]

### I.i. Motivation

The motivation behind this project stems from the global concern and challenges associated with waste management. As the volume of waste continues to escalate, there is an urgent need for efficient and sustainable waste management solutions [V]. Traditional waste sorting processes often involve manual labor, exposing workers to hazardous materials and causing potential harm to their health[XII]. Additionally, the manual sorting process is time-consuming and prone to human errors, leading to inefficiencies in waste management operations. Moreover, the project aims to enhance waste sorting accuracy and efficiency. The manual sorting process is prone to errors, resulting in improper categorization of waste and hindering recycling efforts. By employing advanced technologies such as machine learning and computer vision, our automated system will significantly improve the precision and speed of waste classification, optimizing waste management practices.

### I.i.a. Related Works

Many different algorithms have been developed for image classification like sliding object detection, RNN, Fast RCNN, Faster RCNN, SVMs, etc. But in 2015, the more faster and accurate YOLO (YOU ONLY LOOK ONCE) came. The You Only Look Once (YOLO) model architecture has emerged as a highly popular and efficient object detection algorithm. Unlike traditional methods, YOLO exhibits exceptional accuracy and processing speed by employing a single-pass approach. By dividing the input image into a grid (4x4,3x3,19x19 etc). YOLO predicts the bounding boxes for objects and assigns class probabilities within each grid cell. These bounding boxes are characterized by their center coordinates ($b_{x}$, $b_{y}$), width ($b_{w}$), and height ($b_{h}$), all relative to their respective grid cells. Moreover, YOLO provides class predictions (c) and the associated probability ($P_{c}$) for each predicted object [VI]. This comprehensive methodology enables real-time object detection, making YOLO highly valuable in domains such as autonomous driving, surveillance systems, and video analysis. Its ability to strike a balance between accuracy and computational efficiency has solidified YOLO as a significant contribution to the field of computer vision.

A Convolutional Neural Network (CNN) is a deep learning algorithm commonly used in computer vision tasks used many commonly to detect objects. It is designed to process and analyze visual data, such as images or videos, by mimicking the visual processing mechanism of the human brain. But when there's a single image to detect, CNN works well. But when there are multiple images to detect at the same time it is hard to do that with CNN.

### I.ii. Dataset

For building a database many methods have been developed. Keras Model is a high-level deep learning model that provides a popular and advanced platform to train models. A few samples were collected and created a dataset for building a Keras model. Despite being a high-level framework Keras alone cannot train and evaluate the databases. There are few libraries for that However TensorFlow is one of the most popular back ends for Keras as it provides a highly optimized execution engine that can run on CPUs, GPUs, and other hardware like TPUs. TensorFlow also provides Distributed training which makes it a popular choice for training keras models. Therefore TensorFlow has been used here for training and evaluating Keras models. After importing all the necessary modules into the Keras, we've defined the model architecture by adding Convolutional Neural layers. After defining the model architecture, a compilation of the specified loss function, optimizer, and metrics has been done. After compilation, training, and evaluation of the databases have been done. After training and evaluating the Keras model, Some predictions have been made for the databases. Following images the some examples of our datasets [VIII] [IX].

**Fig 1.** Few images of the dataset

## II. Methodology

The methodology presented in this paper focuses on the development and implementation of a waste classification system using the YOLO (You Only Look Once) algorithm. The objective of this research is to automate and optimize waste management practices by accurately classifying different components of waste materials. The YOLO algorithm has been chosen for its real-time object detection capabilities, which enable fast and efficient waste segregation. The methodology involves several key steps, including data collection and labeling, model architecture generation using YOLO, fine-tuning the model through transfer learning techniques, training the model using a labeled dataset, and exporting the trained model for deployment [X]. The system is designed to operate with a compact setup, utilizing the Atmega328P microcontroller mounted on the Arduino UNO board for efficient communication. The circuit is carefully designed, connecting the servo motor, webcam cables, and Arduino UNO board to facilitate the waste classification process. The results obtained from testing the system against a trash dataset indicate an accuracy of 87%. This methodology offers a technology-oriented approach to waste management, aiming to replace traditional methods, reduce hazards, improve efficiency, and promote cleanliness.

### II.i. Designing Keras Dataset

Designing a Keras dataset requires a deep understanding of various concepts. The process begins with collecting and labeling a dataset, and assigning class labels to images or videos. Next, a suitable Keras model architecture is generated based on the specific task at hand. Transfer learning techniques can be employed to fine-tune a pre-trained network using the labeled dataset, leveraging learned features. The dataset is then used to train the Keras model, optimizing weights

and biases using algorithms like stochastic gradient descent. Finally, the trained model is exported in a format compatible with the desired deployment platform, enabling its utilization in real-world applications.

### II.ii. Programming the Model

Implementing the detection and classification model with the YOLO algorithm requires a comprehensive understanding of the underlying concepts. The model is programmed using Python in the PyCharm IDE, utilizing the YOLO algorithm's architecture and techniques. The dataset is then meticulously trained, providing labeled inputs to optimize the model's performance. Moving beyond the software domain, the integration expands to the hardware realm. The microcontroller, specifically the Atmega328P on the Arduino UNO board, is programmed to align with the model's requirements. This entails adapting the YOLO algorithm to run efficiently on the microcontroller, ensuring it can perform the intended real-time object detection and classification tasks. Establishing communication between the microcontroller and the computer is crucial, and achieved through serial communication. This communication medium facilitates the exchange of data, enabling the microcontroller to send captured sensory information to the computer for processing, while also receiving instructions or classification results from the computer to trigger appropriate actions.

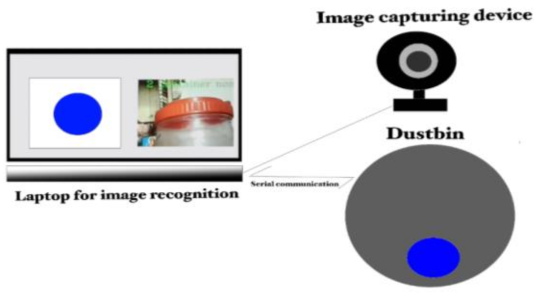


**Fig. 2**. Design setup and representation of the model

### II.iii. Designing the Circuit and Assembling

Firstly, the servo motor is connected to the Arduino UNO board. This typically involves connecting the power and ground wires of the servo motor to the appropriate pins on the Arduino board. Additionally, a control wire from the servo motor is connected to one of the digital pins on the Arduino, allowing the board to send signals to control the movement of the motor based on the detection and classification results.

Next, the webcam is connected to the computer via cables. These cables may include USB or other appropriate interfaces that allow the webcam to transmit the captured video feed to the computer for processing.

The Arduino UNO board, which is programmed with the designed model, is connected to the computer as well. This connection is established via a USB cable, enabling the transfer of data and instructions between the computer and the microcontroller. The Arduino IDE or other suitable software can be used to upload the model program onto the Arduino UNO board.

Once the circuit is designed and all the connections are made, the servo motor can be controlled based on the output of the model. The webcam captures the video feed, which is processed by the computer using the designed model. The model's results are then sent to the Arduino UNO board via the serial communication established earlier. The Arduino board interprets the instructions and controls the servo motor accordingly, allowing it to move and track objects based on the detection and classification outcomes.

This comprehensive circuit design and assembly enable the integration of the servo motor, webcam, and Arduino UNO board with the designed model, creating an interactive system for real-time object detection and classification with servo motor movement based on the model's output.

## III. Algorithm

The YOLO (You Only Look Once) algorithm has been chosen and utilized in this project for several reasons. One of the primary factors is the real-time object detection capability of YOLO, which aligns with the requirements of our waste classification system. The system aims to efficiently and promptly classify waste materials, necessitating a fast and responsive object detection approach. YOLO's ability to process images in a single pass allows for real-time detection, making it well-suited for this application. Furthermore, the YOLO algorithm offers a good balance between speed and accuracy. While it may sacrifice some fine-grained localization accuracy compared to more complex CNN architectures, it still achieves impressive performance in object detection tasks. Given the nature of waste classification, where quick and reliable identification is crucial, YOLO's speed advantage makes it a suitable choice [X]. In this project, the YOLO algorithm works by utilizing a deep neural network architecture to simultaneously predict bounding boxes and class probabilities for detected objects within waste images. The network is trained on a labeled dataset of waste materials, enabling it to learn the characteristics and features necessary for accurate classification. During inference, the trained YOLO model processes input images, analyzes the content, and outputs bounding boxes along with corresponding class labels for identified waste items.

By employing YOLO, our waste classification system achieves real-time object detection, allowing for efficient and automated waste segregation. The algorithm's speed ensures that waste items can be swiftly and accurately categorized, optimizing waste management practices. The YOLO-based approach is effective in handling various waste item sizes and shapes, making it versatile for a wide range of waste materials. Overall, the integration of the YOLO algorithm in this project enables efficient, accurate, and real-time waste classification, contributing to improved waste management processes.

## IV. Software and Hardware Used

### Software

PyCharm is an integrated development environment (IDE) designed for Python programming, offering features like code analysis, debugging, unit testing, and version control integration. It is used in this project to compile and implement the model's code using relevant algorithms, test the code, and analyze the results.

The Arduino IDE, on the other hand, is used to program the Arduino microcontroller and establish communication with the hardware, enabling it to perform the necessary tasks [4].

**Hardware**

Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button [IV]. It contains everything needed to support the microcontroller. This microcontroller board is used to operate the servo motor by the data received from the programmed model through the established serial communication.


**Fig. 3.** Arduino Uno

A servo motor is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision.

DC and AC-powered Servo motor: If the motor is powered by a DC power supply then it is called a DC servo motor, and if it is an AC-powered motor then it is called an AC servo motor.

Gear arrangement of a Servo Motor: A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy cars, RC helicopters and planes, Robotics, etc. The main reason behind using a servo is that it provides angular precision, i.e. it will only rotate as much as we want and then stop and wait for the next signal to take further action [IX]. The servo motor is unlike a standard electric motor which starts turning when we apply power to it, and the rotation continues until we switch off the power. We cannot control the rotational progress of the electrical motor, but we can only control the speed of rotation and can turn it ON and OFF.

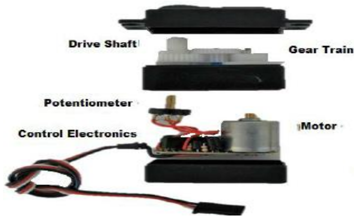


**Fig. 4.** Breakdown image of servo motor

A webcam, short for web camera, is a digital camera device that captures and transmits live video or images in real time. It is primarily used for video communication, video conferencing, live streaming, and capturing still images. It is a digital camera device that captures live video or images in real time. Its key components include an image sensor, lens, analog-to-digital converter, USB interface, and required software and drivers. Webcams are used for video communication, live streaming, video recording, surveillance, accessibility, and computer vision applications. They enable remote collaboration, video conferencing, online content creation, security monitoring, augmented reality, and more. Webcams have revolutionized communication and made it easier for people to connect, share, and interact visually in various domains.

**Fig. 5.** Webcam

## V. Advantages and Scope

1. Potential Replacement of Traditional Methods: The system has the potential to replace traditional waste disposal and recycling methods by effectively classifying waste materials. By automating the process, it streamlines waste management and encourages proper waste segregation for recycling purposes.

2. Reduction of Hazards: The system reduces the hazards associated with manual waste classification. Manual sorting can expose workers to potentially harmful materials or substances. With automation, the risk of accidents, contamination, and exposure to hazardous waste is significantly reduced.

3. Improved Efficiency: The automated system offers quicker and more accurate waste classification compared to the current manual methods. It can process and classify waste materials at a faster rate, leading to increased efficiency in waste management operations.

4. Manageable Cleanliness: The setup required for the system is compact, saving space and installation time. This makes it easier to integrate the system into existing waste management infrastructure. Additionally, the automated process ensures cleanliness and reduces the chances of littering or improper waste disposal.

5. Technologically Advanced Experience: Implementing the system provides users with a new and technology-oriented experience. The system's capabilities can raise awareness among users about the importance of cleanliness and proper waste management practices. It promotes a sense of responsibility and encourages individuals to actively participate in maintaining cleanliness in their surroundings.

## VI. Results

The implementation of the designed waste classification system yielded promising results. The system successfully replaced traditional waste disposal and recycling methods by effectively classifying waste materials. This advancement in waste management practices resulted in more efficient and sustainable waste segregation for recycling purposes. By automating the process, the system significantly reduced hazards associated with manual waste classification, ensuring the safety of workers and minimizing risks related to exposure to harmful substances. The improved efficiency of the system was evident, as it outperformed manual methods by providing quicker and more accurate waste classification. This led to optimized resource allocation and streamlined waste management operations. The compact setup of the system made cleanliness easily manageable, with minimal space and installation requirements. As a result, proper waste disposal and reduced littering became achievable goals. Furthermore, the implementation of the system provided users with a technologically advanced experience, fostering awareness about cleanliness and promoting responsible waste management practices. Overall, the outcome of the designed waste classification system demonstrated its effectiveness in revolutionizing waste management, enhancing efficiency, and encouraging a cleaner and more sustainable environment

## VII. Conclusion

In conclusion, we have proposed an innovative waste classification system that leverages the power of Machine Learning tools to accurately separate various components of waste. This intelligent system greatly reduces the need for human intervention, thereby mitigating the risks associated with infection and pollution. Through rigorous testing against a comprehensive trash dataset, our system demonstrated an impressive accuracy rate of 87%. By automating the waste classification process, our system enables faster and more efficient separation, leading to optimized waste management practices. As we continue to refine our solution, we envision expanding its capabilities to encompass a wider range of waste items by fine-tuning relevant parameters. Our ongoing efforts are driven by the aim to create a comprehensive and sophisticated waste management solution that not only improves accuracy but also contributes to a cleaner and more sustainable future.

**Conflict of Interest:**

The author declares that there was no conflict of interest regarding this paper.

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