YOLOBOAT: Machine learning based water cleaning boat using YOLO algorithm

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***Abstract*— Due to urbanization, solid waste littering is an increasing concern for lakes, possibly threatening human health, ecological integrity, and ecosystem services. Water body management in urban landscapes requires best management practices To tackle this problem in an efficient way, we have developed a YOLOBOAT to detect, collect and segregate floating waste in water bodies in real time and make them garbage-free. It is a vision-based surveillance machine learning boat system that integrates raspberry pi and other sensors for real time debris monitoring and waste collection in relatively calm waters like lakes to replace manual cleaning of lakes. Model is trained on a custom dataset using YOLO v5 for object detection.**

Keywords— **Machine learning, YOLO, intersection of union, dataset, annotation, floating waste.**

I.INTRODUCTION

According to the Central Pollution Control Board (CPCB) of India, around 85% of India's surface water is polluted. In particular, lakes in India are facing severe pollution problems due to human activities and improper waste management. A report by the National Wetland Conservation Programme (NWCP) indicates that out of 115 lakes surveyed in Bangalore, only 17 were in good condition. Similarly, a study by the Indian Institute of Technology (IIT) Bombay found that out of the 23 lakes surveyed in Mumbai, only three were fit for drinking and recreational purposes. These statistics highlight the need for urgent action to address the water pollution issue in India, particularly in its lakes and other water bodies. The accumulation of non-biodegradable pollutants such as plastics, aluminium cans and other waste materials in water bodies has become a major concern, particularly in lakes and other inland water bodies.

To address this problem, there is a need for innovative technologies and approaches that can effectively clean up the water bodies. In this regard, we have developed an autonomous water cleaning boat called YOLOBOAT that uses YOLO (You Only Look Once) object detection algorithm to detect, collect, and segregate waste materials from water bodies. This paper will discuss the design, development, and performance of YOLOBOAT in cleaning up water bodies and its potential to contribute to a cleaner environment.

Object detection is a computer vision technique for locating instances of objects in images or videos. Object detection algorithms typically use machine learning or deep learning to produce accurate predictions. There are various techniques for object detection, they can be split up into two categories, First is the algorithms based on Classifications. CNN and RNN come under this category. In this, we must choose the image's interesting regions and classify them using a convolutional neural network. Because we have to make a prediction for each chosen region, this method is extremely slow. The algorithms based on regressions fall under the second category. This category includes the YOLO approach. We won't pick the image's interesting regions for this. Instead, we use a single algorithm run to predict the classes and bounding boxes of the entire image and use a single neural network to detect multiple objects.

The development of object detection algorithms has been greatly aided by advances in deep learning technology. You Only Look Once (YOLO), single shot multi-box detector (SSD), and faster region CNN (F-RCNN) are three of these algorithms' most popular and widely used methods. You Only Look Once (YOLO) approach is used for object detection and segregation in our model.

Therefore, we use the most recent YOLO algorithm for the boat to detect, collect, and sort wastes in water bodies, primarily lakes. A quality rating for each lake will be assigned based on the quantity of waste and pollutants found in the water body and is uploaded to the cloud so that we can compare the quality and current condition of various lakes.

II. LITERATURE REVIEW

This Section describes the previous works on the water cleaning boats based on different technologies designed by other researchers around the world. Raghavi et al. [2] developed a remote-controlled cleaning bot which integrates a pH sensor to determine the water's chemical constituents' solubility and biological activity. The primary objective of their work was to monitor water quality and collect floating garbage waste.

The paper[9] describes the development of a system called "AQUABOT" that uses Raspberry Pi for monitoring and detecting aquatic debris in water bodies. The system is equipped with a camera, ultrasonic sensor, and Raspberry Pi processor, and it uses machine learning algorithms to detect debris.

Madiha Munir[6] et al. proposed a method to detect plastic waste in water using hyperspectral remote sensing and machine learning techniques. The study used a hyperspectral camera to capture images of water samples containing plastic waste, and then extracted spectral features from these images. The extracted features were used to train machine learning models including Random Forest, Support Vector Machines (SVM), and Artificial Neural Networks (ANN) to classify the plastic waste.

The research article[3]proposes the development of a surface cleaning bot and a water body surveillance system that aims to collect floating debris and monitor water quality parameters in real-time. The system includes a cleaning bot equipped with sensors that can detect water quality parameters such as pH, temperature, and dissolved oxygen. The surveillance system uses an IoT-based platform that can monitor and send real-time data on water quality parameters. The system has the potential to improve water quality by identifying pollution sources and providing prompt interventions.

Thus, the implementation of proper and innovative measures is vital to control garbage littering in lakes and other water bodies. A robot that cleans the waste autonomously can be a good solution to manage garbage littering and collection efficiently. Moreover, Municipal body can start employing this bot in their cleaning activities.

III.MOTIVATION

A. *Environmental protection:* Urban lakes provide a habitat for a variety of plant and animal species, and cleaning them can help protect the local ecosystem and maintain biodiversity.

B. *Recreational use:* Many urban lakes are used for recreational activities such as swimming, boating, and fishing. Cleaning the lakes can make them safer and more enjoyable for people to use.

C. *Aesthetics:* Urban lakes can be important features of the urban landscape, and cleaning them can enhance their appearance and improve the overall beauty of the surrounding area.

D. *Economic benefits:* A clean and healthy lake can attract tourists and new residents, which can have a positive economic impact on the surrounding area.

E. *Public health:* Pollution in urban lakes can be harmful to human health, and cleaning the lakes can help reduce the risk of waterborne illnesses and other health hazards.

IV. METHODOLOGY

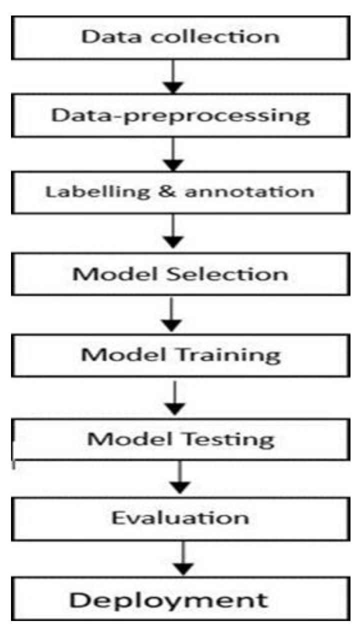

Fig.1

Fig.1 shows the steps involved in building the proposed prediction model for object detection in the water cleaning boat.

DATA COLLECTION:

The first step is to collect dataset of images with objects that need to be detected. Floating wastes were categorized into 8 classes. Under biodegradable category, there are two classes namely leaves and flowers. Under non-biodegradable, there are 5 classes namely aluminum, plastic, glass, mask/cloth. Datasets of each class, containing images, were collected manually from water bodies and from various online open source resources. Each class had around 500-1000 images. The dataset collected is diverse and representative of the various types of floating wastes and scenarios the model will encounter.

DATA PRE-PROCESSING:

Pre-processing images is an essential step in object detection to ensure that the input data is in a suitable format for the model to learn from. Common steps involved pre-processing steps for images in object detection:

A. *Resize:* It is necessary to resize the images to match the input size of the model. The aspect ratio of the image should be maintained to prevent distortion.
B. *Normalize:* Normalization involves scaling the pixel values of the image to a fixed range, typically between 0 and 1 or -1 and 1. This can help improve the convergence speed of the model during training.
C. *Data augmentation:* Data augmentation is a technique used to artificially increase the size of the dataset by applying random transformations to the images, such as flipping, rotation, scaling, or cropping. This can help improve the robustness and generalization ability of the model.
D. *Data transformation*:The input format for labeling is either an image or a batch of images in a specific format, such as JPG or PNG. Therefore, it was necessary to convert the images to the required format before feeding them to the model.

DATA LABELLING AND ANNOTATIONS:

Data labeling is the process of adding metadata, or tags, to raw data to show a machine learning model the target attributes expected to predict. Labeled data highlights data features or properties, characteristics or classifications that can be analyzed for patterns that help predict the target. There are various applications and platforms available for data labeling and annotations such as MakeSense.AI, labellmg, Neptune.ai , LabelBox, CVAT etc.

We used MakeSense.AI platform to label/annotate our data. The 5 classes were specified and proper bounding box values were extracted for each classified image. In YOLO labeling format, a .txt file with the same name is created for each image file in the same directory. Each .txt file contains the annotations for the corresponding image file, that is object class, object coordinates, height and width corresponding to all the objects provided with bounding boxes. For each object, a new line is created. Below is an example of annotation in YOLO format

<object-class> <x> <y> <width> <height>

object detection model. There are various techniques for object detection, they can be split up into two categories, First is the algorithms based on Classifications. CNN and RNN come under this category. In this, we must choose the image's interesting regions and classify them using a convolutional neural network. Because we have to make a prediction for each chosen region, this method is extremely slow. The algorithms based on regressions fall under the second category. This category includes the YOLO approach. In Yolo we don't pick the image's interesting regions as we do in other convolutional neural networks. Instead, we use a single algorithm run to predict the classes and bounding boxes of the entire image and use a single neural network to detect multiple objects. YOLO only needs one forward pass through the neural network to detect objects.

MODEL TRAINING:

The preprocessed and labelled data is given for model training..For model training download the pre-trained weights of the YOLOv5 model, which is trained on the ImageNet dataset. Use a deep learning framework like TensorFlow or PyTorch to train the YOLOv5 model on the annotated dataset. The model is trained on a GPU, and the training process involves forward and backward propagation of the loss function, which minimizes the difference between the predicted and ground-truth bounding boxes.The YOLO framework for the proposed model is trained in CUDA environment on the split 80% data reserved for training.

MODEL TESTING:
Evaluate the trained YOLOv5 model on a testing dataset using metrics like mean average precision (mAP), which measures the accuracy of the model in detecting objects at different intersection-over-union (IoU) thresholds. Training dataset consists of 80% of the dataset collected and testing dataset conssits of 20% of dataset.

MODEL DEPLOYMENT
The model is deployed to detect objects in real time efficiently and quickly.

MODEL SELECTION:
As the title suggests, we used the YOLO v5 algorithm for our

IV. HARDWARE REQUIREMENTS

The hardware implementations comprises integration of the power system, Object detection model with the bot and embedding a conveyor belt for trash collection and disposal. This is implemented using Raspberry. The Raspberry Pi performs the following tasks:

A. Run processing algorithm/ trained model on picamera's video input for trash detection and generate control signals for bot's motion and the conveyor belt's operation using YoLo algorithm.
B. Activates the conveyor belt.
C. On collection, the biodegradable and non-biodegradable are dumped into separate bins with respective load sensors/weight detectors placed for each.

V. PERFORMANCE EVALUATION

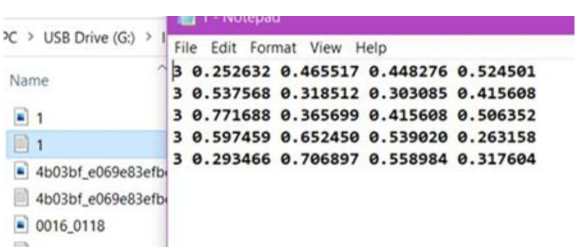

Fig.2 1.txt file for image 1.png

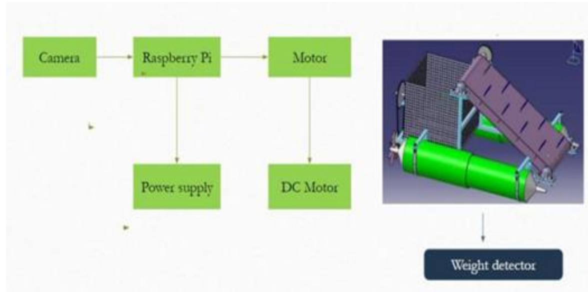

Fig : 3 Block Diagram of the embedded system

VI. APPLICATION

A. Clean Water Bodies: The system can be effectively used to autonomously clean water bodies like lakes, ponds, rivers etc.
B. Segregation of collected waste : The model also is useful in segregating different waste classes collected from the water bodies.
C. Surveillance of water bodies : The Camera module can further be used for surveillance systems around the water bodies.
D. Analysis of Water bodies: Data collected about the amount of wastes present and collected can be used for quantitative and qualitative analysis.
E. Commercial use: For commercial use it can be deployed by individuals for cleaning swimming pools, water tanks etc. Water cleaning boats can also be used for aquatic weed control in lakes and ponds. They can remove or harvest invasive plants that can harm the ecosystem, obstruct water flow, and impede recreational activities.

VII. RESULTS

Datasets for different classes were collected, annotated, labelled and trained for the model. Yolo algorithm with 0.25 object confidence threshold and 0.45 IOU threshold for NMS was set for object detection. Different classes of wastes were detected and segregated.

Fig 4.Confusion matrix

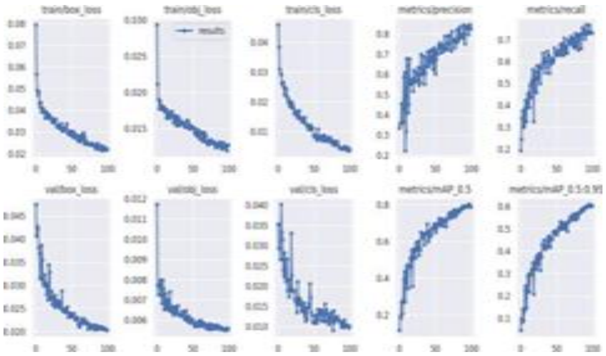

Fig 5. Loss and mAP graph

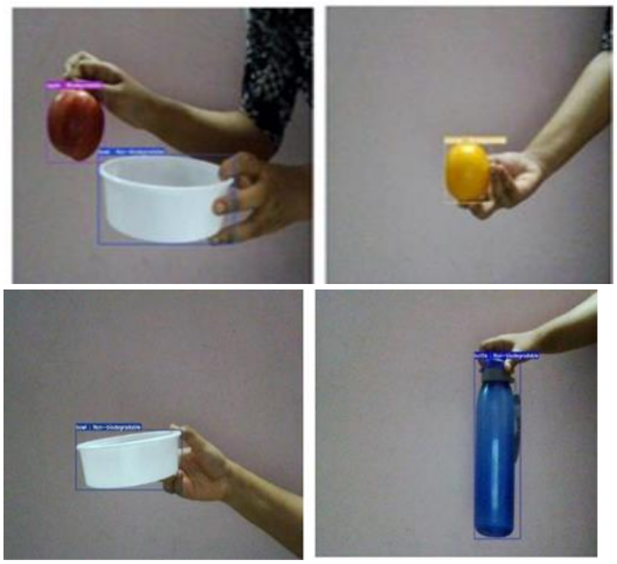

Fig 6.Detected objects

VII. CONCLUSION

The proposed model detects, collects and segregates biodegradable and non-biodegradable objects efficiently. Yoloboat was successful in collecting and segregating the detected waste. Using YOLO for object detection in water cleaning boats has several advantages. YOLO is popular and efficient object detection algorithm that can quickly and accurately detect various classes of wastes in real-time in water bodies. By integrating YOLO into water cleaning boats, the boats can quickly and efficiently identify and collect debris and waste from water bodies, improving water quality and reducing the environmental impact of pollutants. This can lead to healthier and safer water bodies for aquatic life and recreational activities. Its versatility allows for the detection and tracking of other objects such as aquatic weeds and invasive plants, helping to maintain the ecosystem's balance. The use of YOLO in water cleaning boats also improves the boats' overall efficiency, reducing the need for manual labor and improving the boats' accuracy in detecting and collecting debris. Thereby, integration of YOLO into water cleaning boats is a promising and innovative approach to improving water quality and maintaining the sustainability of water bodies. YOLOBOAT has the potential to revolutionize water cleaning practices, making them more efficient, effective, and environmentally friendly.

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