Robotic fish

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***Abstract*—Garbage and debris produced by humans are commonly found in various water environments such as lakes, ponds and rivers. Removal of marine debris is required to prevent threats to marine and human life and to maintain a sustainable environment. Detecting and collecting debris is hard due to unique difficulties of the water environment. Autonomous vehicular technology can be helpful to detect and collect debris in the water sources. In this paper, a robotic fish which is remotely controlled, pilot less vehicle, is used to detect floating marine trash and to remove them. This intelligent robotic fish could very well contribute in solving the problem of water debris by finding and eventually removing the trash. YOLO (You Only Look Once) algorithm, which uses Convolution Neural Networks (CNN), is used in detection of debris in the water environment. The system contains a garbage bin to collect the debris. Conveyor belt, which is driven by motors, is responsible for movement of trash from the surface of water to the garbage bin.**

***Index Terms*—Water debris, CNN, YOLOv3**

I. Introduction

Trash deposits in aquatic environments have a destructive effect on marine ecosystems and pose a long-term economic and environmental threat. This vast amount of trash in the water sources which kills and injures aquatic life and contaminates the water must be removed. An effective strategy for removing debris from marine environment is the use of Autonomous underwater vehicles for trash detection and removal.

An autonomous underwater vehicle is a robot that travels on the surface and underwater which is used to conduct underwater research. Remotely Operated Underwater Vehicle (ROV) is unoccupied vehicle, which is fitted out with sensors and other tools to collect various types of data. These vehicles provide a safe alternative to explore dangerous areas. ROVs, equipped with many tools, have applications in many fields including military and science.

Trash enters water bodies in various ways and contaminates the water. Maintaining clean water is essential and involves the removal of debris more frequently. Out of various types of marine trash, plastic wastes are the most dominant waste material found on the water surface. Recycling and other activities to keep debris out of the water reservoirs are also very important but there is a need for an efficient strategy to remove the debris which are already in the water resource. One of the widely used techniques for collecting plastic from water source is refuse-removal vessel method. However, this method is appropriate only to large rivers with a significant accumulation of plastic and cannot be implemented to clean small water sources with low-density waste. Hence, a robotic system may be helpful to clean small water bodies like water tanks, swimming pools, small ponds, etc.

The three main objectives are robotic fish should be able to float on surface of water smoothly, it should be controlled remotely using radio frequency technology and it should be able to detect and collect the various kinds of marine trash like plastic, cap, and water bottle.

II. Literature Survey

Bionic or biologically inspired engineering is covering all the fields and there has been a rapid increase in research and development of the bio-inspired mechatronic system. Robotic fish is an example of bio-inspired AUV's and it is found that robotic fish performs better and are more competent than current AUV's in the field of underwater explorations [1]. Since 1993, unmanned surface vehicle has been evolving for various missions such as testing of navigation and control systems, ocean exploration, fish tracking, or military applications. Robotic fishes have better propulsion capabilities, stability, efficiency and exhibits their vast potentials for researches.

Robotic technology is making exploration cheaper and more accessible with their ability to withstand harsh environments, tides and ocean currents [2]. Safety is the main advantage of utilizing robotics, so that there will be no risk of human life. Robot fish can take video images and pictures and control mechanisms. It can collect the artifacts and gather information about the debris.

A. Robotic fish swimming modes

Generally, there are two ways of designing robots for moving on the water surface. The first technique employs fish like swimming modes which propels using fins attached to it. The second method is more like robotic boat equipped with mechanical propellers for smooth motion.

1) Propulsion using fins: In nature, fish propels by undulatory motion in either of the two ways:

- Using body and/or caudal fin (BCF) movements.
- Using median and/or paired fin (MPF) propulsion.

BCF provides greater thrust and accelerations. Unlike rotatory propellers used in ships or AUV's, robotic fish depends on the undulation movements to produce the main propel energy. This kind of propulsion is less noisy, more effective and

manoeuvrable than the propeller-based propulsion.
The swim patterns of fish can be periodic or steady (cyclic repetition of the propulsive movement for a long distance) or unsteady (includes, fast start, sharp turns and brakes). The project mainly focuses on periodic swim patterns with uniform velocity. Basic swim patterns can be divided as follows [3]:

- Cruise-straight: The fish swims along a straight line at a constant speed.
- Cruise-in-turning: Fish is turning in a small angular speed with constant linear speed.
- Coast: fish body is kept motionless and straight.
- Brake: The fish generates a sudden straight deceleration.

All the swim patterns are generated by special tail motion and pectoral fin motion. Caudal/tail fin is used to produce propulsion. Pectoral fins are found in pairs which are used to maintain depth in water, turn and stop quickly [4].

2) Propulsion using mechanical propellers: Underwater vehicles achieve transmission with thrusters and propellers. These mechanical devices drive the underwater robot forward or backward which depends on the direction of rotation or pitch of the propeller [5]. Propellers are attached to the robot body via shaft arrangement. As shown in Figure 1, propellers consists of radiating blades which when rotated exerts linear thrust on the water. The blades are shaped in such a way that their rotational motion through the water causes a pressure difference between the two surfaces of the blade.

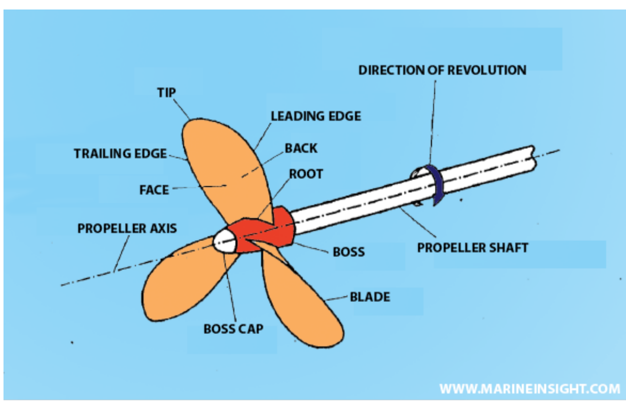

Fig. 1. Parts of propeller.

As motor rotates the propeller, rotational motion is converted into thrust (linear in nature). The resulting force imparts momentum to the water and pushes the robot forward. In order to have backward motion, the motor and hence the propeller is rotated in opposite direction so that the thrust is reversed.

B. Mechanism for Debris Collection

Robotics has got wide scope in industrial automation as robotic manipulators and automatic guided vehicles improve efficiency of industrial automation. A robotic arm is a widely used efficient and preferred electromechanical machine for many applications in most of the industrial and dangerous areas [8]. Most of the floating debris are small and deformable. Therefore, it is ineffective to use robot manipulator to pick the trash one by one.
Conveyor systems are reliable, durable and less expensive component to move or carry various things. This system is labor saving and used in automated distribution and warehousing. The system consists of two or more pulleys. The belt rotates about them and forms a closed loop [10]. Figure 2 shows the conveyor system in which pair of tongs helps to move trash to the front of conveyor belt. The belt lifts the trash and dumps it in the garbage bin. The conveyor belt mechanism has the advantages of being simple, easy to control, suitable for collecting different types of waste and cost effective.

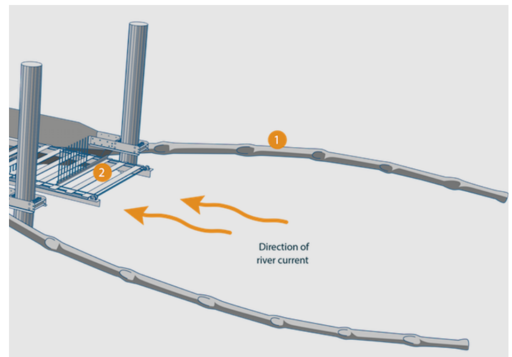

Fig. 2. Conveyor System.

C. Object detection using CNN

Wide applications like scene understanding, video surveillance, robotics, and self-driving systems triggered vast research in the domain of computer vision [6]. Visual recognition systems, which is the core for all these applications, includes image classification, localization and detection. Due to significant development in neural networks especially deep learning, these visual recognition systems have attained remarkable performance. Object detection is one of these domains witnessing great success in computer vision.
Convolutional neural network is a class of deep, feed-forward artificial neural network that has been utilized to produce an accurate performance in computer vision tasks, such as image classification and detection [7]. CNNs are like traditional neural network, but with deeper layers. Figure 3 shows the CNN architecture, it is composed of convolutional layer, pooling layer and fully connected layer. Convolutional layer and pooling layer are typically alternated and the depth of each filter increases from left to right while the output size (height and width) are decreasing. The fully connected layer is the last stage which is similar to the last layer of the conventional neural networks. The input is an image that will hold pixel values. The convolutional layer will compute the output of neurons that are connected to local regions in the input. The layer's parameters are composed of a set of learnable filters (or kernels), which convolved across the width and height of the input volume extending through its depth, computing the dot product between the entries of the input and the filter. This produces a 2-dimensional activation map of that filter and as

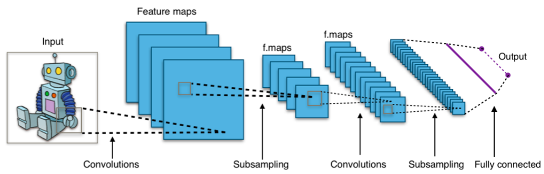

Fig. 3. CNN Architecture.

a result, the network learns filters that trigger when it detects some particular type of feature at some spatial position in the input.

1) YOLO v3: YOLO is a object detection algorithm. It uses single convolutional neural network which simultaneously predicts multiple bounding boxes and class probabilities for these boxes. It separates an image into a grid. Each grid cell predicts some number of boundary boxes referred as anchor boxes around objects. Each boundary box has a respective confidence score of how accurate it assumes that prediction should be and detects only one object per bounding box. The boundary boxes are generated by clustering the dimensions of the ground truth boxes from the original dataset to find the most common shapes and sizes. YOLO v3 performs better and trains faster when pretrained network is used.

III. Methodology

The proposed system has mainly three parts. First part is the robot design which includes motion control of the robot. Second part is to detect the debris and the third part is to collect the debris based on the detection results. The overall block diagram is show in Figure 4.

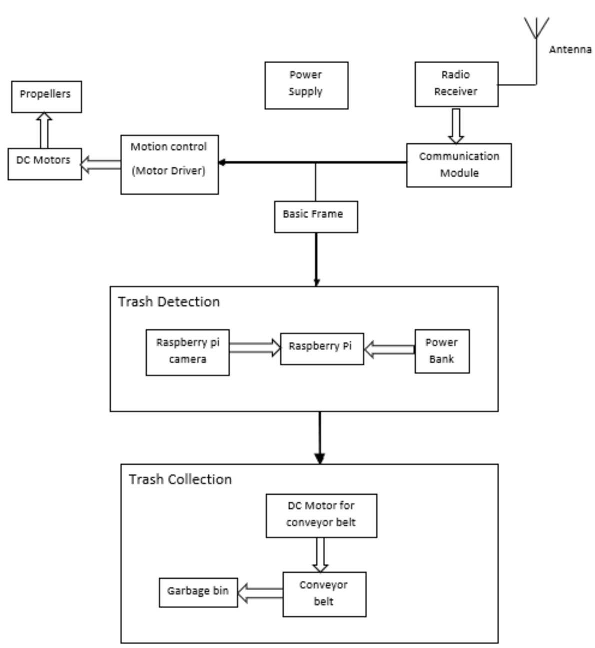

Fig. 4. Block Diagram

A. Propulsion Control

Pair of boat propellers connected to either side of the robot are responsible for the movement of robot. Propellers are driven by 60 rpm DC motors. As the motors rotate, propellers also rotate and the blades exerts linear thrust on the water. This leads to pressure difference between the surface in front and back of the propeller. As a result, water is accelerated in one direction creating a reactive force which makes the body attached to the propellers to move. Similarly, for backward movement, the propellers are made to rotate in opposite direction and hence, reverse thrust is applied which leads to backward movement. In case of left and right turn, one of the two propellers is made stationary and other propeller is rotated. Hence, displacement of water occurs only on one side which results in the turning of the body. Figure 5 depicts the forces acting on the propeller blades in a 3 blade propeller. DC motors convert electrical energy into mechanical energy. DC motor driver acts as an interface between the motors and the control circuits.

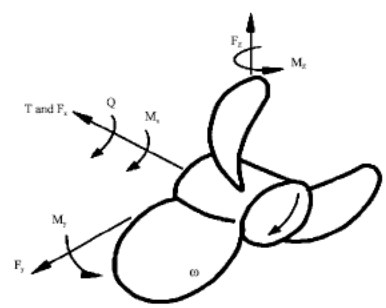

Fig. 5. Forces and moments for marine propeller.

B. Communication Module

Robotic fish is remotely controlled using radio technology. The block diagram of the remote module is shown in Figure 6. There are four control switches to control the movement of the fish. Whenever one of these switch is pressed by the user, the corresponding information is transmitted at a frequency of 2.4 GHz through antenna. The radio receiver receives the transmitted message through its antenna. Based on the control information required action is taken to change the direction of the robot. Four control switches to change the direction of the robot are forward, backward, right and left.

C. Debris Detection

Python, openCV and deep learning is used for the real time object detection. Algorithm is given below.

1) Check to see if there is a frame in our input queue.
2) Grab the frame from the input queue, resize it, and construct a blob from it.
3) Set the blob as input to our deep learning object detector and obtain the detections and write the detections to the output queue.
4) Construct the argument parse and parse the arguments using argparse.

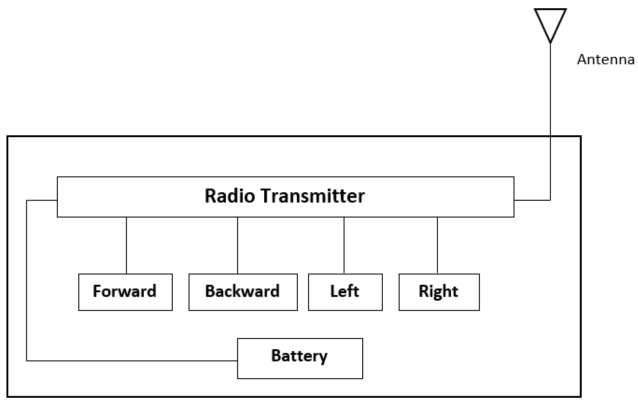

Fig. 6. Remote Module.

5) Initialize the list of class labels MobileNet SSD was trained to detect, then generate a set of bounding box colors for each class.
6) Initialize the input queue (frames), output queue (detections).
7) Initialize the video stream, allow the camera sensor to warmup, and loop over the frames from the video stream. Grab the frame from the threaded video stream, resize it, and grab its dimensions. If the input queue is empty, give the current frame to classify. If the output queue is not empty, grab the detections and draw the detections on the frame. Otherwise, extract the index of the class label from
8) Show the output frame and stop the timer.

D. Debris Collection

Conveyor belt mechanism is used to collect the floating debris. Conveyor belt brings small sized trash which is present on the surface of water into the garbage bin. Conveyor system consists of a head pulley, a tail pulley and mesh-like belt as shown in Figure 7. A DC motor drives the head pulley. Mesh-like belt is used in order to reduce weight. During the process of collecting trash, mesh-like structure helps to avoid water from entering the bin.

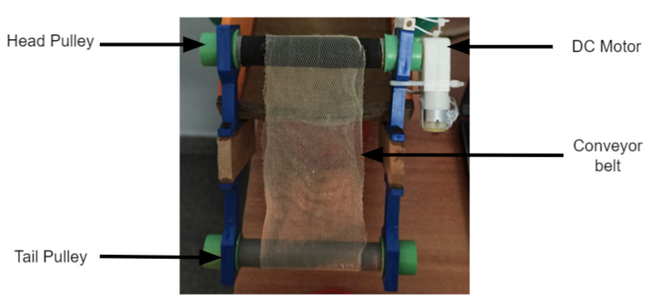

Fig. 7. Remote Module.

TABLE I
ROBOT SPECIFICATIONS

Sl No	Specification	Value
1	Weight	600grams
2	Overall size	32*25*16 (cms)
3	Size of garbage bin	14*15*16 (cms)

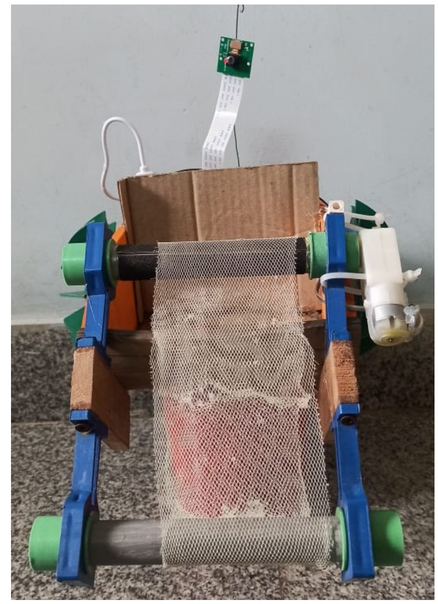

Fig. 8. Front view of robot module.

IV. RESULTS

The robot system is tested in water tank with calm water. Robot is powered on by connecting the power supply. The robot starts moving as soon as it receives command from the remote module operated by the user. Figure 8 is the snapshot of robot module. System can be used only in still water, without any high waves. Based on the control switch pressed, the robot changes its direction of motion. The remote module is shown in Figure 9. Real time object detection by the model is shown in Figure 10.

V. CONCLUSION

A robotic fish for Water surface cleaning task is developed and tested in an experimental water tank setup. The robot, with the use of mechanical propellers, has an undulating motion on calm water surface. Robot is capable of detecting trash like water bottles, plastic caps and plastic bags floating on the water. The model collects small sized trash like small plastic covers and bottle caps. The detection of trash is achieved through YOLOV3 model which is based on deep neural network. The conveyor system aids in collecting the trash.

VI. SCOPE FOR FUTURE WORK

1) The motion of the robot is manually controlled. Obstacle avoidance mechanism can be implemented to make the robot autonomous.

Fig. 9. Remote module.

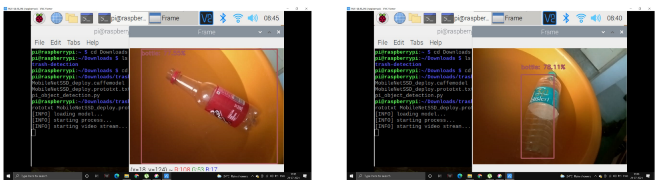

Fig. 10. Real time object detection results.

2) The detection and collection mechanism can be extended to more variety of trash.
3) The project is confined to detection and collection of floating water debris. The problem of submerged marine debris can be addressed by making the robot capable of diving inside the water.

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