Ocean Surface Cleaning Autonomous Robot (OSCAR) using Object Classification Technique and Path Planning Algorithm

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Abstract. Increasing water pollution is one of the biggest concerns in today’s world. It leads to a variety of problems including an increase in the level of toxic concentration in the water. This paper aims to introduce a concept of an ocean/water body cleaning robot that attempts to classify and separate wastes while collecting them in a carriage attached to the robot so that it can be disposed or recycled on the base station. The robot can be deployed on any water surface thus making it more effective than a largescale ocean pollution cleaning technique. It can be used to clean up oil spills from shipwreck and pipeline leakage and can monitor the water quality of the particular location and send a distress signal to the base station if the readings are abnormal. The water quality data and the information about the type of pollutant from the machine learning model can be used to formulate local laws to reduce pollution and create awareness about the type of material that ends up at the ocean/water body.

Keywords: Environmental Instrumentation; GPS; Marine; Mobile Computing; Neural Network; Robotics; Sensors and Transducers; Solar Energy

1. Introduction

Polluted water, according to the World Health Organization (WHO), is water whose composition has been altered to the point where it is no longer useful. It's poisonous water that can't be consumed or utilized for important purposes like agriculture, and that causes diseases like diarrhoea, cholera, dysentery, typhoid, and poliomyelitis, which kill over 500,000 people every year [1]. Water in the region becomes polluted as a result of pollution of seas and other bodies of water, making the water unfit for human consumption as well as for marine organisms [2]. It causes a slew of issues, including a rise in hazardous concentrations in the water. This hazardous concentration has negative effects on the food chain, which affect human beings [3]. This paper aims to introduce a concept of an ocean/water body cleaning robot that attempts to classify and separate wastes while collecting them in a carriage attached to the robot so that it can be disposed or recycled on the base station.

Machine learning [4] and image classification models [5] were trained and developed to achieve the task of classifying pollutants on water and it is deployed on Raspberry Pi. The machine learning model
was developed, keeping in mind the limitation of computing resource of Raspberry Pi [6][7]. Ultrasonic and Lidar sensors in the robot can be used for collision avoidance [8]. The robot has a path planning algorithm [9][10], that can be used to move the robot to a particular location, feeding the destination coordinates. This means that the robot can navigate its way back to the base station when it is time to return or be called off in case of bad weather. The structure of the robot resembles that of a catamaran for better stability and high operational efficiency. Inside the robot, there are mechanical gates that ensures that the material that is classified using the cameras enter the corresponding compartment, thus making it efficient to recycle at the base station. The mini conveyer belt ensures the smooth flow of ocean wastes into the compartment in the attachable basket. The robot has the potential to clean up the oil spills in the ocean caused due to shipwrecks and pipeline damage. The robot traverse through the water using differential drive technology. The on-board solar panels ensures that there is no stress on the battery for a prolonged period. The robot has water quality monitoring sensors that help to check the quality of water in the location and reports it to the base station if there is abnormality in the values. The water quality data and the information about the type of pollutants from the machine learning model can be used to establish local regulations to decrease pollution and raise awareness about the kind of materials that wind up in the ocean or water body. This makes cleaning of lakes and ponds easier and the water can be used for human consumption, thus water scarcity can be reduced.

2. Literature review

The examinations concerned set out in this segment present the definition that identifies with the water cleaning technique, machine learning, and path planning. Raschka [4], briefs a framework to develop, train and deploy machine learning using python mentioning its full potential in smart gadgets and products. Xin and Wang [5], proposes a method that is claimed to be better than traditional machine learning models that are based on multilayer perceptron models. MNIST and CIFAR-10, two deep learning standard datasets, were used to evaluate the M3 CE-CEc. Matthies [6], an interactive system based on geometric scene understanding was developed which was built in such a way that the system reacts to the dynamic environment. Norris and Donald [7], a lightweight machine learning model was trained and developed. The model was deployed on a Raspberry Pi. The model proved to be effective even for a computation limited platform like Raspberry Pi. Luongo and Di Vito [8], an automatic collision avoidance system was designed and developed for a dynamic environment. The model was based on radar only system. Telewcek [9], briefed the path planning algorithm and its associated computation. The research served a basic understanding of path planning and navigation for the robot in a dynamic environment. Esmaeel Khanmirza’s, Morteza Haghbeigi’s [10], article aims to investigate several well-known and significant path planning algorithms, such as D*, A*, RRT, and bidirectional RRT. The study aims to brief the difference and advantages of the algorithms. Pranay and Agrawal [11], have introduced a multi-robot system for lake cleaning. Three robot systems were simulated using MATLAB. The robots are allowed to move randomly, over a period of time it was expected that most parts would be covered. The proposed method proved to be efficient in simulation. Khatib and Qalalweh [12], to get rid of algae, a simple and low-cost photovoltaic-based pumping device is proposed to inject a chemical compound into the artificial pond's water. This compound prevents algae to form a layer on top of the water surface. Needleman and Bellinger [13] health effects of a harmful substance such as lead have been described. The article briefed about the newer biomedical and epidemiological effects of a low dose of lead. S.M. La Valle [14] has proposed and implemented an RRT path planning algorithm; the advantages of the proposed method include consideration of constraints of unmanned vehicles and are suitable for a dynamic environment that makes the model more useful in a multi-robot environment. Taru [15], has proposed an innovative
method for monitoring water quality using Arduino. The setup included pH sensors, a turbidity sensor, and a temperature sensor to monitor the water quality. Bertoand Napoletano [16] has provided a brief study on LoRa based wireless mesh networks. Wireless mesh networks can be used to communicate between the devices and the server. Lenes and Henrick [17] proposed and implemented an autonomous unmanned surface vehicle (USV) using ROS. Recently, Raghavi and Varshini [18] developed an RF-controlled Robot that could also monitor the pH of the water. Akash Sinha, Prashant Bhardwaj [19] proposed a system in which, in the Kalman Filter, both “HSV Color Space” and “SURF” are proposed for measurements, resulting in exceptionally robust pollutant tracking. Shreya Phirke and Abhay Patel [20], have developed a robot in which, to enable autonomous cleaning, the concept incorporates a sturdy mechanical structure, sensor fusion, and computer vision. R Praveen and L Prabhu [21] proposed an RF-controlled beach cleaner robotic vehicle, that can be used to clean the littoral land and designed a 3d model of the robot. Max Washington and Cameron J shear[22], proposed a sustainable and inexpensive method to clean up oil spills in the ocean using a Polysulphide mixture.

3. Proposed methodology

The proposed model of the robot is based on Raspberry Pi as the primary computing board paired with Arduino and LoRa modules. The Raspberry Pi handles image processing, object classification, and motion controls while Arduino is connected to the LoRa module and water testing unit. Based on object classification, the robot can segregate the ocean pollutants and collect them in a different compartment of the basket for easier recycling purpose. The robot can also clean the pond or lake polluted by algae and also oil spills in the middle of the ocean. Path planning algorithms are used to deploy the robot to the particular area that is to be concentrated on and it can also be used to plan the path back to the base station. The robot charges overnight in the base station, solar panels are added onto the robot so that it could harvest some energy from the sunlight and could reduce the strain on the battery. The robot has LoRa based communication system that can be used to communicate between the devices as well as to the gateways at the base station. The robot has water testing sensors like pH and conductivity sensor (EC) that can be used to monitor the water quality in the water body. The robot is completely autonomous and an on-board GPS module is used to locate the robot.

4. Component description

Raspberry Pi is a series of tiny SBCs developed by the Raspberry Pi Foundation. The Raspberry Pi is a low-cost, Raspberry Pi SBCs have a SOC manufactured by Broadcom with an ARM-compatible CPU. The Raspberry Pi runs on a Linux-based Operating System. A generic USB camera is used to provide a video feed to the Raspberry Pi. The solar panels convert the energy from sunlight into electrical energy that can be used to reduce the burden on batteries and increases the capability of the robot to work for more time before it needs to be charged. Arduino nano is used to read the sensor data from the water quality monitoring unit and is interfaced with the LoRa module. Nano is preferred over Uno because of its compact size that makes it easier to fit on a PCB. TP4056 is a voltage regulator, that regulates the voltage from a solar panel and then sends it to the battery to ensure no harm done by overvoltage. HC-SR04, by generating ultrasonic sound waves and converting the reflected sound wave into an electrical signal, this ultrasonic sensor detects the distance of the object in front of it. The transmitter and receiver are the two basic components of ultrasonic sensors (encounters the sound after it has travelled to and from the target). L298N, motor driver module is used for driving DC motors. This module consists of an L298N motor driver IC and a 5V regulator. L298N Module can control the direction and speed of the motors as it is an H-bridge bipolar motor driver. GPS Module, antennas on
GPS modules receive data directly from satellites through specific RF frequencies. The signal from each visible satellite, as well as other data, is received. The satellite transmits the precise moment the signals are sent. The distance between each satellite may be calculated using the difference between the time the signal was broadcast and the time it was received. The pH sensor can be used to determine the alkalinity and acidity of water. The ion exchange from the sample solution through the glass membrane to the internal solution of the glass electrode (pH 7 buffer) is the general operating concept of pH sensors. Continued use will reduce the porosity of the glass membrane, thus reducing the performance of the probe. The conductivity sensor (EC sensor) is a device that measures the conductivity of a solution; this gives the measurement of ions in water. EC can be converted to TDS. LoRa, it is a Long-Range communication device that is used to transmit data to the base station or the peer robot. PWR-SNS, it is an embedded multi-meter unit that is used to monitor the battery voltage. D.O Sensor, is used to measure dissolved oxygen in the water. Dissolved oxygen diffuses from the sample through an oxygen-permeable membrane and into the sensor in an electrochemical DO sensor. The pH sensor can detect this signal. MPU6050, it is an accelerometer and gyroscope unit, it gives an orientation of the robot. When the mass comes into contact with each other due to the force created by vibration or a change in motion (acceleration), the piezoelectric material produces an electrical charge proportionate to the force applied to it. Servo Motor, it is used in the valve gates to channel the debris onto the right bin. Servo motor is used because the precise angle of rotation of the motor can be controlled. The motor has a potentiometer, the resistance of which varies with the change in angle of rotation. The DC motors are used to propel the robot in the desired direction and are used on the conveyor belt. Lidar, it is used in addition with HC-SR04, Lidar has more resolution than ultrasonic sensors and has more range. The Lidar unit sends a ray of light and calculates the distance based on the time that the light takes to bounce back. Lights, to illuminate the location of operation in the dark and for transmitting signals through Morse code.

5. Discussion of the workflow

![Flow diagram of the proposed system](image_url)
Figure 1 represents the flow diagram of the robot. The object classification model was trained using Edge Impulse and is deployed on a Raspberry Pi. Raspberry Pi is connected to a USB camera for the video feed. Lidar and the ultrasonic sensor are connected to the Raspberry Pi for collision avoidance. L298N motor driver is connected to Raspberry Pi that can be used to control the motor direction and speed. In case, if an obstacle comes in the way of the robot, the collision avoidance system comes into play and steers away from the obstacle. Servo motors are connected to Raspberry Pi and are used to channel the pollutant into their respective compartments. Arduino is connected to the LoRa module that receives and transmits data to the base station as well as to the peer robots and repeaters. Arduino nano is connected to Raspberry Pi through USB, this enables Raspberry Pi and Arduino to communicate with each other. pH sensor, EC sensor, and D.O sensor are connected to the Arduino, these sensors help to monitor the quality of the water. Arduino nano is connected to a Lora module, for communication. Lora technology can transfer short data over a great distance with very little power consumption.

5.1. Machine Learning model for object classification
A classifier is a technique that employs a collection of characteristics that characterize things to identify the object's class. The dataset containing the sample images and labels is used for training the classifier algorithm. The training set is a collection of known items that classification systems use to learn how to classify them. The training set consists of sample images from various classes of pollutants like plastic bags, plastic bottles, Styrofoam, algae, metals, oil spills. After the training set is loaded, the learning rate is set and suitable classification model is chosen and the number of neurons is chosen. Figure 2 shows the training data that was uploaded for the object classification algorithm to process on.

![Dataset uploaded for training the model](image)

After this process of uploading training data, feature extraction is done. Feature extraction is a step in the dimensionality reduction process, which involves dividing and compressing a large amount of original data into smaller groups. Therefore, the processing and computation will be greatly reduced.
The next step in the object classification process is model testing. If the accuracy is less than the desired value, the parameters are varied and the model is retrained. Figure 3 shows the model classifying the object in the image uploaded in the test set with great accuracy.

![Figure 3. Testing the model using sample images](image)

After ensuring the proper functioning of the model, it would be deployed on the Raspberry Pi. Figure 4 shows the deployment of the custom object classification model on an android phone for testing.

![Figure 4. Machine learning Model identifying the pollutants](image)
5.2. **Discussion on Movement of the robot**

The robot moves using Differential Thrust Technology, this is very similar to the Differential Drive Technology that most land robots and rovers use. The system moves depending on the relative thrust from the motors. If both motors (left and right) spin in the same direction, considering both spins clockwise, the robot moves forward. If both the motors spin in an anticlockwise direction, then the robot moves backward. To turn the robot sideways, differential thrust technology would be employed. In this, in order for the robot to turn left, the motors on the right would spin but the motors on the left do not spin. This causes more force to be exerted on the right side of the robot, thus causing the robot to drift towards the left. And vice versa in order to turn right. Figure 5 depicts the movement of the robot.

![Figure 5](image)

**Figure 5.** Visualisation of robot movement

6. **Circuit design overview**

The circuit design and the components are carefully selected in order to maximize efficiency at the same time, it does not consume too much power and does not weigh too much. The robot is divided into three major subsystems, namely the control subsystem, water quality monitoring subsystem, and communication subsystem. The following lines elaborate the subsystems in detail.

6.1. **Control subsystem**

The electronics would be placed at the top of the robot so as to avoid water contact even in case of accidents. Raspberry Pi handles the object classification part, so a generic USB camera is connected to it for the video feed. Lidar and ultrasonic sensors are connected to the Raspberry Pi, for obstacle avoidance system. Two servo motors are connected to the Raspberry Pi that controls the bin at which the pollutants are channelled into, the command would be sent by the Raspberry Pi depending on the output from object classification model. The robot is powered by a 12v battery; motor driver is connected to the battery. The motor driver controls the direction and speed of the motors. The motor driver receives the motion control command from the Raspberry Pi. The motor driver consists of an H-bridge. The H-bridge is an electrical circuit that allows the polarity of the voltage delivered to the motor to be changed. This enables the robot to use differential thrust technology, using which the robot can change its direction. The accelerometer on the robot sends the orientation of the robot. In case the robot topples, a message can be sent to the base station depending on the accelerometer data.
PWR-SNS is connected to the battery; it is an embedded multi-meter device. It is used to monitor the battery voltage. In case of any abnormality, it sends an alert to the Raspberry Pi, which then communicates the message to the base station. The solar power would be harnessed and utilized in order to reduce the strain on the battery. The voltage from the solar panel would be regulated by the TP4056 regulator. Figure 6.1 and Figure 6.2 shows the circuit design and the schematic layout of the control subsystem.

![Figure 6.1. Circuit design of control subsystem](image1)

![Figure 6.2. Schematic layout of the control subsystem](image2)
6.2. Water quality monitoring subsystem
The robot has an on-board dissolved oxygen sensor, electrical conductivity sensor, pH sensor, and waterproof temperature sensor. A dissolved oxygen sensor helps to understand the oxygen levels in the water that is available for the aquatic species and plants. An electrical conductivity sensor measures the ability of the water to conduct electric current. This helps in understanding the concentration of ions in the water thus, as a result, gives the value of salt concentration. EC can be converted into TDS by multiplying the EC value by 1000 and then dividing the obtained result by 2. pH sensor measures the activity of hydrogen in the water. The acidity or alkalinity of the sample solutions is determined by comparing them to pure water (a neutral solution) on a pH scale of 0 to 14. DS18B20 is used to measure the temperature of the water that helps in understanding the warmth and capability of water to support aquatic life. The figure 7 shows the circuit connection of the water quality monitoring unit.

![Figure 7. Circuit design of water quality monitoring unit](image)

6.3. Communication subsystem
The robots need to communicate among themselves and to the base station, for proper functioning. To accomplish this LoRa technology has been employed. This LoRa technology can be used to send bi-directional data over a great distance with little power consumption [15]. Radio Head Packet Method is used to enable communication between two LoRa devices. The figure 8 depicts the flow diagram of the communication system.

![Figure 8. Communication design of the robot](image)
A Radio Module and a Microprocessor make up a LoRa Node. The Microprocessor reads data from the sensor and sends it into the air through the Radio module, where it is picked up by a LoRa Gateway [16]. The LoRa Gateway also contains a Radio Module and a Microprocessor, however, they are often powered by AC mains due to their higher power requirements. A single LoRa Gateway may listen to numerous LoRa nodes, and a single LoRa node could also send information to several gateways, ensuring that the information from the node is not lost. The figure 9 shows the connection between LoRa module and Arduino Nano inside the robot.

Figure 9. Connection between LoRa and microcontroller.

6.4. Solar Panel
The solar panel is used to harness the energy from the sunlight and turn it into electrical energy which can then be stored on a battery. The solar panel consists of solar cells. On average, a solar cell can produce up to 0.6V. Thus, in order to increase the voltage, solar cells are connected in series. The number of solar cells to be connected depends on the specific application [23], cost factor, and are available to fit a solar panel. In this robot, a 40W solar panel was considered optimum because it weighs less, it is cost-effective, it requires less space to fit, and has a current capability of 2.06 A at maximum power and an open circuit voltage of 19.5v.

Connecting solar cells in series to increase the voltage would be fine on a bright sunny day. But on a cloudy day, when the sunlight is partially covered by the clouds, only the remaining sunlight falls on the panel, this leads to increased resistance to the whole system as the cells are connected in series. In order to overcome this, bypass diodes are fit in parallel to every junction of the solar panel. The diodes let the current pass through them thus, problems regarding increase of resistance when the panel is partially covered could be overcome. The same solution applies in case one cell in the array of cells fails, this prevents the entire solar panel from malfunctioning even if only one cell is not working.

7. Obstacle avoidance and Path Planning Algorithm
The system uses data collected from the ultrasonic sensor and the Lidar, to calculate the distance between the incoming obstacles. The ultrasonic sensor works on the principle that when sound waves are sent and if there is an obstacle; it bounces on hitting the obstacle. This bounced wave can be used to detect if there is an obstacle and the time it took for the sound to bounce back gives the distance travelled by the sound from the sensor to the obstacle and back to the sensor. By dividing the distance obtained by 2 gives the actual distance between the sensor and the obstacle. The formula for calculating the distance has been given below.
Distance (in cm) = time taken for the sound wave to bounce back * 0.0344/2

The simulation of the collision avoidance system using the robotics toolbox in MATLAB is shown in the figure 10.

Figure 10. Implementation of collision avoidance system in MATLAB

The robot has a path planning algorithm based on a **Rapidly exploring Random Tree** (RRT) [14]. Using this algorithm, the robot can move to any coordinate in the given map knowing the coordinates that the robot is currently in. Using random samples from the search space, an RRT generates a tree rooted at the original pose. As each sample is drawn, a link is established between it and the state closest to it in the tree. This results in the adding of the new state to the tree if the link is viable (does not pass through an obstacle). This process continues until the robot reaches the goal pose. This method is preferred over the generic path planning algorithm and A* because of its low memory and computing requirements.

The figure 11 shows the tree growing from start to the goal pose and avoiding obstacles. A smaller green circle is the start pose and a larger green circle is the goal pose simulated using PYTHON visualized using PYGAMES environment. The probabilistic road map has been highlighted in pink.

Figure 11. RRT path planning algorithm simulated using python.
8. Mechanical Design Ergonomics of the robot

The robot chassis would be made with Polyethylene terephthalate glycol (PETG). PETG is chosen because of its high impact resistance, moisture resistance, it is cost-effective and are the simplest plastics to recycle. PETG would be a good choice for eco-friendly products as a result of this. The stability of an item floating in a fluid depends on knowing where the centre of buoyancy is located. When the robot is floating in the sea, the weight of the robot and the buoyant force operating on the robot are equal, and these forces are acting through the centre of buoyancy and the centre of mass. If the two locations are too far apart, the robot will rock more and the chance of capsizing will be more.

The design of the robot was carefully analyzed and modified such that both centre of mass and the centre of buoyancy is as close as possible to increase stability. The figure 12 shows the centre of buoyancy of the robot.

![Figure 12. Centre of buoyancy of the robot.](image)

The software generated mass of the chassis with PETG as the build material is 15611.17 grams
Centre of mass:
\[
X = -0.48 \\
Y = 527.50 \\
Z = -81.28
\]
with respect to the camera position.
The design consists of a wide inlet, conveyer belt, separator, carriage.

8.1. Inlet design
The main focus while designing the inlet design was to cover optimum angular flow of water, this indeed would cover most of the contaminants (confined only to the bot’s identification) that are being collected in a single-serve. As the garbage tends to enter the bot through the inlet it moves in a narrow flow which would make separation of the collected garbage and suitable flow of the garbage materials
into the bin which is located at the back. Hence the inlet has a narrow-pointed entry. The figure 13 shows the waste inlet design.

![Waste inlet design](image1)

**Figure 13.** Waste inlet design.

**8.2. Conveyer belt**

The main purpose of the conveyer belt is to have the continuous flow of collected garbage from the inlet point to the carriage through the separation system, the reason being that the bot is controlled by the classification algorithm where most of the parameters are with respect to the types of pollutant, choosing a continuous system (conveyer belt) would eliminate the additional parameters such as the collector speed and robot’s speed. At the same time choosing conveyer belt system would have less energy consumption compared to most of the other present stringent separating systems for pollutants. The figure 14 shows the sectional view of the robot.

![Sectional view of the robot](image2)

**Figure 14.** Sectional view of the robot depicting the conveyer belt.
8.3 Separator
The proposed segregation system is being designed to separate two major water contaminants - plastics and metals. So, the separator tends to have only two state of working, one is when it encounters a plastic waste like bottle, bag, Styrofoam, it would channel it to one compartment, on the other hand when it encounters metal waste it directs through the other compartment. The mechanism for this system involves two long levers that are being hinged to either side of the robot, these hinges are further being connected through a servo motor whose input is being controlled by the Raspberry Pi. This also ensures that the debris won’t get stuck in between. The figure 15 shows the separator to channel the waste into the corresponding bin.

![Separator design to channel the waste into their corresponding bin](image1)

Figure 15. Separator design to channel the waste into their corresponding bin

8.4 Carriage system
As already stated, the robot classifies the waste and channels the waste into the destined bin. The plastic waste and metals are separated into their corresponding carriage bins. Styrofoam, bottles, and bags are classified as plastics, scrap metals, and metal tins are classified as metals. Algae and oil spill don’t exist at the same location, since oil spill occurs at seas and ocean, while algae formation occurs at lakes and ponds. The mixed composition of algae and plastics is impossible to separate on the robot itself as it requires sophisticated machines and techniques to separate. The figure 16 shows the carriage that collects the pollutant.

![Carriage design to collect the pollutants](image2)

Figure 16. Carriage design to collect the pollutants.
9. Description of the Operation
The proposed robot would be deployed in the region where the concentration of pollutants is high. And the base station is set up near the location so that the robot and the base station can constantly communicate, and also the robot can return to base station in the evening or in bad weather or if the basket is full. It also makes charging the robot much easier. The Raspberry Pi acts as the brain of the robot. The camera is connected to the Raspberry Pi that helps it to view the surroundings. Object classification is done on Raspberry Pi, and the object is channelled into the corresponding bin depending on the type. The channelling of the waste into the bin is done through the servo motors that act as separator. The robot can classify most of the common pollutants like plastic bags, plastic bottles, Styrofoam, metals, algae, and oil spill.

![Figure 17. Deployment of the model on Raspberry Pi](image)

The figure 17 shows the model running on Raspberry Pi with great accuracy, and printing the output on a terminal window. This data can be used to extract the information about the type of pollutant and control the servo motors accordingly.

Typically, oil spills and algae will not be in the same water body. An oil spill occurs on seas and oceans while algae formation occurs on lakes and ponds. While cleaning algae, it is almost impossible to separate plastics from it inside the robot itself, as the plastics will be trapped into the algae and therefore, other treatment methods will be employed to separate it at the base station. To clean up an oil spill from a shipwreck or a pipeline break, Low-density polysulphide is sprayed throughout the region using an airplane. The polysulphide absorbs the oil on top of the water [22], and the robot can collect the mixture, removing up to 90% of the oil. Mechanical compression can be employed to extract the oil, and the polysulphide can be reused later.

![Figure 18 Clearwater](image)  ![Figure 19 Oil spill on water](image)
The figure 18 shows the clear water that is used as the subject of the test, figure 19 shows the oil spill on water, and figure 20 show the process of oil cleaning using a sorbent material. This is an efficient method that not only cleans up oil spill but also avoids harming marine life. The robot moves using differential thrust technology, which can be also be used to steer the robot. The robot has a collision-avoidance system that can be used to steer away from the robot in case of an incoming obstacle. GPS module on the robot constantly communicates with the satellite, knowing the location it is in precisely at any given point. A robust separating and debris clearing mechanism is modelled in the robot so as to ensure the debris doesn’t get stuck inside the gates of the robot, therefore, clearing any possible jam. Knowing the location of the robot, the path planning algorithm can be used to deploy the robot to any place that might have a high concentration of pollutants, provided a map of the environment is known. The robot constantly monitors the water quality of the water body and sends distress to the base station if there is abnormality in the readings. Thus, actions can be taken against the organization or the individual who is contributing to the pollution and awareness can be created. In order to alert other ships or boats that the robot is operating in a particular region, the LEDs on the robot, blink at a particular interval generating Morse code that reads “ON DUTY”. This code can be interpreted by the pilot of the boat or ship and can navigate their way around the region. The figure 21 shows the rendered image of the robot.
10. Discussion on water quality in various water bodies
Natural water quality in rivers, lakes, and reservoirs, as well as below the ground surface, is determined by a variety of linked variables. Water has the capacity to react with minerals in the earth and rocks, as well as dissolve a wide range of things, as it moves over and through the surface of the heart, thus its natural condition is never pure. There is usually a mix of soluble inorganic, soluble organic, and organic molecules in it. In addition to this, water has the ability to transport vast volumes of insoluble compounds in suspension. The amount and kind of contaminants present in natural water vary by location and time of year and are influenced by a variety of variables. Geology, climate, geography, biological processes, and land use are some of these variables. A water body's properties are determined by its pollutants.

Rainwater, ocean, river water, and groundwater all have extremely diverse chemical compositions and varying total dissolved solids contents (TDS). Rainwater has a TDS of 7 mg l⁻¹, river water has a TDS of 118 mg l⁻¹, and saltwater has a TDS of 34 400 mg l⁻¹. TDS levels in groundwater vary much too much to be used as an average. TDS is an excellent indication of water quality, and maximum TDS levels have been established for drinking water and water utilized in other ways.

11. Waste Management
There are 5.25 trillion macro and micro pieces of plastic in the ocean and every day around 8 million pieces of plastic make their way to the ocean. Already these numbers are at alarming rates, if this continues this may lead to a major threat to the planet. Trends, prospects, and policy responses attribute the lag in plastic recycling to the very fact that it's still cheaper to form new plastics instead of to supply recycled plastics because the process of recycling involves separating different plastic polymers. The government should take initiatives in reducing the usage of new plastics and expand the usage of recycled or reusable materials. For example, the outfits, shoes, gloves used by the front-line workers can be made with recycled materials like recycled plastics instead of traditional fabrics which in turn reduce the cost and also will make awareness among the people for recycled plastic products.

The two main ideas which can be made with the waste plastic which is to be recycled are:

11.1. Sustainable and recycled shoes
Every year almost 25 billion pairs of shoes are made worldwide, sadly most of these aren't made sustainable because of that the textile industry is ranked second in the polluters next to oil and gas. The plastic waste from food packaging and water bottles can be given a second life through cleaning, grinding, and melting which can be made into thread and thus can be woven like a traditional fabric to make comfortable and fancy uppers for the shoes. Each pair of shoes can be made from 3-7 recycled plastic bottles depending on the model and style. The rise in the temperature and the excess chemicals in the ocean creates an easy path for the growth of algae, these harmful algae after processing (drying, crushing, and adding some synthetic materials) can be used as eco-friendly and bio-sourced materials for insoles and outsoles for shoes. This prevents around 20 % less synthetic materials production and also cleans up algae in the ocean.

11.2. Bricks used for construction
High-density polyethylene which is commonly used in milk and shampoo bottles, low-density polyethylene which is used for cereals and sandwiches, and polypropylene used for ropes, buckets, etc. are the good sources for making the bricks. For making the bricks, plastic wastes are to be separated and dried to remove any moisture content. Then, the plastic wastes are crushed into small particles and turned into fine dust. This fine dust is then heated in the furnace till it turns to liquid form. Then, stone dust and sand particles are mixed and melted together and poured into the brick moulds, and are compressed to obtain the form. The bricks made using these plastic wastes are proven to be stronger than the regular concrete bricks and also it is much more cost-effective. The plastic bricks have the
least water absorption capability which in turn won’t let the water leak through the ceiling. Thus, plastic bricks are more useful to the construction industry than regular sand bricks and concrete bricks and also cleans up ocean plastic and make the environment more sustainable.

12. Conclusion

The pollutants that are dumped in the water body can be recovered and recycled for second use, this not only cleans up the water body but also reduces the carbon footprint of producing new materials as the waste can be recycled. The robot aims to clean up the water body by collecting the pollutant and monitor the water quality in the water body. There are large scale methods to clean up pollutants in the middle of ocean, but there are not a lot to clean coastal/rocky water bodies. This robot can be used but not limited to small water bodies like lakes and ponds. About 0.013% of Earth’s water is from lakes, and about 40% of lakes in America are polluted and not fit for human consumption. Though, there are numerous methods to clean the lakes, most of them are based on organic process and it takes a lot of time. The robot would prove efficient to clean those type of water bodies where it is impossible to apply large scale techniques. The information from the robot regarding the pollutants and water quality can be used to draft local laws that would beneficial to the society as a whole.

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