Computer Vision in Ocean Trash Clean-Up

Abstract

Trash contamination and patches in oceans have gotten so big that an area of floating waste twice the size of Texas has formed and is called the “Great Pacific Garbage Patch” and contains 1.8 trillion pieces of plastics. Around 90% of the fisheries activities have been oppressed due to this, and the ratio of fish to plastic waste is estimated to be 1:1 by 2050; as compared to the 1:5 in 2014. If we continue, we risk the entire fate of humanity and our survival. That is why we need to manage the trash and being clean up as efficiently and as green as possible to avoid more pollution. An effective way for removing debris and trash off the surface of water bodies with the use of “Autonomous Underwater Vehicles” or AUVs for short. Identifying and detecting debris through just the visual means is a big issue. And lastly, there are a large variety of objects and waste that can be considered as ocean waste thereby requiring a huge data model to train the AI and what it needs to remove and what it does not. In this paper we discuss, about the AUV, datasets to train the model, and related research for ocean trash clean-up.

Keywords: Computer Vision, Ocean Trash, Pollution, AUV, Datasets, Autonomous, Machine Learning

Introduction

[1]Throughout the world, millions of tons of garbage, primarily plastic, are discarded each year, contaminating our lands, rivers, and oceans. This is harmful to both the environment and the economy. In impoverished countries, 90% of sewage and 70% of industrial waste are thrown untreated into local water channels thereby polluting water and adding toxins to our food chain. According to the United Nations' world water development report, almost 3.5 million people (about twice the population of Nebraska), consisting of children, die each year from water-related diseases. While there are many issues which cater to this problem, the foremost issue is contamination and trash in water bodies. Trash dumped into water bodies may be of two types, namely, Soluble, and insoluble. They may include paper, food remnants plastics and more. If this water is then further used for agricultural purposes or for drinking, it may not only harm crops but also damage and cause harm to people. [2]These days, everything we use has some form of plastic in it; right from bottles of water to smart devices, from packaging to clothing and apparel, everything we use has some form of plastic in it or with it. Regarding marine life, Plastics harm and kill over 300,000 sea life every year which in turn will be the biggest threat to humanity as we all depend on water. Additionally, it also poses a threat not only to the marine ecosystem, but also to the small-scale economic activities such as fisheries and more which are related to the marine ecosystem. There is credible evidence that have proven that there are many harmful wastes in the water bodies which has an unfavorable effect to the marine ecosystem. [3]Governments in many different countries have taken preventive steps for example, In Columbia, the local government had initiated the Floating Debris Removal Program. Similarly, in Jakarta, the government had issued a legislation that

prohibits businesses from operating on the floating markets. Many studies are underway to find out easier ways of restoring water bodies and eliminating trash and debris from its' surfaces. Even if we improve and develop our recycling and sorting facilities with better technology and advancement, it will still not solve the waste problem as the waste will still be dumped in the environment instead of it being collected properly, which is a timely process and costly with the current technology. [4]Additionally, the COVID-19 pandemic has made waste management painstaking due to the curfews and lockdowns thereby increase waste generated in households. There is no place on earth that is not polluted or has no form of trash remnants. Methods such as recycling and reducing the use of plastics and waste dumping has had a drastic effect in minimizing the amount of pollution in the ocean, but the trash/debris still in the water bodies needs to be removed. [5]An effective way for removing debris and trash off the surface of water bodies with the use of "Autonomous Underwater Vehicles" or AUVs for short. Although this is a viable alternative there are a couple of technical issues such minor changes in the environment as lighting or appearance of an item. Also, the lighting of the environment may allow the debris to blend with the color/shade of the water body. Ocean debris and trash are rarely in good condition and degrade over time, hence the image processing must be able to identify the debris despite its condition. To ensure optimal and efficient clean up, the algorithms and detection must take place autonomously in real-time on the vehicle itself.

Hardware and Software

[6]Non-biodegradable and improper disposal of trash is causing the problem of growing trash patches in our oceans. One sustainable solution is the use of Autonomous Underwater Vehicles or AUV for short. These will be powered by A.I and Computer Vision to identify trash and debris on the water surface and retrieve it.
Following are the Hardware that can be used, although these can be used, more powerful and efficient alternatives are welcomed.

Arduino Mega 2560 microcontroller:
The Arduino Mega 2560 is a microcontroller board based on the AT mega 2560. There are 54 digital input/output pins, 15 PWM output pins, 16 analog inputs, 4 UARTs, a USB connection, a 16MHz crystal oscillator, a reset button, a power socket, and an ICSP header on this board. The code is stored in 256 KB of flash memory on the 2560. The analog pins have a resolution of 10 bits. Simply connect the Arduino to your computer through USB to program it or power it with a battery to get started. 5 volts is the operating voltage.

Ultrasonic Sensor:
When the sensor encounters an item or a barrier, it releases a 40,000 Hz ultrasonic signal that travels through the air and back to the module. The distance is computed by considering the travel time and sound speed. Ground, VCC, Trig, and Echo are the four pins of the module. The module's Ground and VCC pins should be connected to the Arduino Board's Ground and 5 volts pins, respectively, and the trig and echo pins to any Digital I/O pin. The Trig must be set on High

State for 10 seconds while doing the ultrasound. This will send an 8-cycle sonic explosion to the Echo pin at the speed of sound.

Motor Driver and Motor:
At the same time, dual motor drivers control the speed and direction of two DC motors. The module can power DC motors with voltages ranging from 5 to 35V and peak currents of up to 2A. The drive module is powered by a 12V rechargeable battery. It is a high-current motor driver integrated circuit. With little power saturation, this twin H-bridge can control up to two motors at the same time. The motors are attached to the driver modules' out pins. To power the motor, the enable and input pins are linked to the Arduino pins.
Any of a group of electrical devices that transform direct current electrical power into mechanical power is known as a DC motor. The most popular varieties rely on magnetic fields to create forces. Here it is used for spinning the turbine of the AUV so that it can move forward or backwards.
A servomotor is a rotary or linear actuator that can regulate angular or linear position, velocity, and acceleration with precision. It is made comprised of an appropriate motor and a position feedback sensor. It has a torque of 5kgcm. This motor will be used for the rudder to steer the AUV left or right.

Camera:
The Camera Module should capture both still photos and high-definition video. It has video capabilities of 1080p30, 720p60, and VGA90, as well as still capture. It will be connected to the Raspberry Pi's CSI port via a ribbon wire.

Raspberry Pi computer or similar:
The Raspberry Pi is a credit card-sized low-cost computer that can connect to a computer monitor or television and use a standard keyboard and mouse. It is a quad-core, 64-bit CPU with a 1.4GHz clock speed. It is a little yet useful device that supports the Scratch and Python programming languages.

Power Source:
A 3300mah Lithium Polymer (Li-po) battery is utilized to power the Arduino, servo motors, ultrasonic sensor, and DC motors. A 10000mah power bank is used to power the Raspberry Pi and the camera.

Physical Structure of the AUV:
The AUV will be made with hardened and waterproof plastic body. This will ensure the body does not degrade due to environmental changes and other natural causes. The AUV will also have a conveyor belt with sieves so that trash can be collected and dropped into the trash storage bins on board without collecting the water and sinking the AUV.

Solar panels (If possible):

The solar panels, if possible, will be mounted on top of the AUV and will charge the power banks and Li-po battery which powers the AUV. This will help to ensure that the AUV emits 0% carbon as the energy on board will be generated through renewable sources.

The software that will be used for training and developing the AUV and its detection methods are as follows.

Python:
Python is a high-level general-purpose programming language. It helps programmers write logical, easy-to-understand code for small and large-scale projects. Python is preinstalled on Raspbian, allowing you to get started straight away. Python programming is available on the Raspberry Pi in a variety of ways.

NumPy:
A high-level mathematical operation that may be performed on a multidimensional matrix array. NumPy can perform mathematical operations on arrays, such as algebraic, statistical, and trigonometric patterns. A matrix is created from the picture. The Convolutional Neural Network is used to decipher and analyze the matrix form of the image. During the pre-processing processes of an image, it is upgraded to 224x224 pixels.

Matplotlib:
This will be used to draw the enclosing boxes around the image name and score range that will be shown. The item detection name, as well as the image's score range, are displayed in the bounding box.

TensorFlow:
A Google-developed technology called TensorFlow is utilized to do rapid mathematical computations. Using the most recent Python library, deep learning models may be simply generated. This is a type of math library that may be utilized in neural networks and other artificial intelligence and machine learning applications. Many different types of deep learning models may be employed with the TensorFlow pip program. TensorFlow may aid with data augmentation before the model is trained. It is also utilized to improve the algorithm's efficiency before downloading the image net's pre-trained weights. However, in this scenario, TensorFlow is used to classify and identify debris from a Real-time video footage.

OpenCV:
OpenCV is used to perform a variety of tasks on pictures and videos, including facial identification, object detection, image editing, sophisticated robotic vision, optical character recognition, and more. OpenCV is used to process the images. It is mostly concerned with real-time computer vision. Python scripts will be built to test the newly trained waste detection classifier on any webcam stream, pictures, or videos, using the OpenCV python library.

Literature Review

Computer Vision and its use in AUVs: [7]Computer vision was employed by those who used cameras as sensors to assist them detect items within pictures. Computer vision is a notion in computer science that allows a computer to recognize objects on its own. Many firms, like Tesla, are using this technology to develop self-driving cars, which must be able to recognize people and objects while on the road. Similarly, this methodology will be implied here as well, by which the AUV can identify trash debris on the water surface and maneuver towards. Image processing methods are used in a subset of computer vision to modify the image. [8]Image processing is necessary for extracting characteristics from an image since it aids computers in distinguishing between objects and noise. Grayscale and thresholding are two common image processing techniques. Feature extraction is a computer vision approach that extracts features from a picture and compares them to similar features in other pictures. Because feature comparison is a key reason one item in an image is categorized as its classification, these techniques are essential in the object identification process.

Dataset: [9]To evaluate deep learning architectures for ocean trash and debris recognition, we need to create a first-of-its-kind dataset for training and evaluation, design our data model, and annotate photographs for training. The videos and images in the collection vary in terms of quality, depth, items in settings, and cameras used. They include photos of a variety of marine rubbish collected in real-world locales, allowing us to observe a variety of things in varying stages of decay, occlusion, and overgrowth. [10]Furthermore, the water cleanliness and light brightness vary significantly from one video to the next. Unlike previous contributions, which have relied heavily on internally developed datasets, this enables us to create a training dataset that closely reflects real-world scenarios. Videos that looked to contain some forms of plastic were chosen. Every video may now be sampled at a rate of three frames per second, resulting in pictures that can be tagged and used in learning models. This sampling may then be converted into a series of photos that can be manually searched for and annotated for good instances of plastic marine trash. [11]The annotating procedure can be accomplished manually by using the publicly accessible LabelImg application or like label objects. We may alternatively source and train our dataset using open-source datasets like TrashNet or TACO.

Humanitarian Impact: [12]Unwise human conduct when it comes to trash disposal is harmful to the ecosystem. This garbage-collecting robot recognizes different forms of rubbish without the need for user intervention. The proposed device will collect rubbish that has been strewn about on the water surface. This would help us clean up our rivers and oceans and the garbage patches in our oceans as well. If responsibly sourced, the materials needed to build the AUVs is quite less and ensures that it stays in service for an extended period. [13]Various contemporary models focus on collecting all waste or everything that comes in its path, regardless of whether it is rubbish or not. Instead, we should focus on establishing a system that only collects items that are classified as "trash." [14]This ensures that any aquatic life that comes into touch with it is safe. In addition, the AUV should be able to discern between trash and non-trash objects with high precision, making it more trustworthy and reducing the chance of mistake and hazard.

Role of Machine Learning: [15]We have used several instruments to make specific tasks simpler since the beginning of time. This has resulted in the development of different gadgets. These devices made people's lives easier by allowing them to meet a variety of demands such as travel, industry, and computing. One of them, for example, is machine learning. [16]Machine learning is a branch of artificial intelligence that aims to train computers to learn without being instructed. Machine learning is a technique for teaching computers how to handle data more effectively. After examining the data, we are occasionally unable to assess the collected information. This situation necessitates the use of machine learning. [17]Machine learning is growing more popular because of the vast number of datasets available. In a variety of industries, machine learning is utilized to retrieve critical data. Machine learning is a method of retrieving data information. Several experiments have been carried out to explore if machines can learn without being directly programmed. [18]Several mathematicians and programmers use a variety of ways to solve this challenge, which involves enormous data sets. Machine Learning uses a range of algorithms to tackle data problems. There is no such thing as a "one-size-fits-all" algorithm for fixing a problem, according to data scientists. The type of method you employ depends on the problem you're trying to solve, the number of variables involved, the best model to utilize, and so on.

Details of Physical Model

[19][20][21]The hull of the AUV can be made with toughened and durable plastic so that it stays buoyant and will not be affected by natural degradation such as rust and more. The AUV will have a camera placed in the front so that it can identify debris. It will also have a sonar to detect and avoid harming nearby marine life by changing course or stopping operation temporarily. As for collecting the trash, it will all be collected by a conveyor belt with sieves that keeps on running. The waste will then go into bins which also have a capacity sensor to detect when it is full. The AUV moves with the help of a motor with blades which helps it move forward and backward. Along with that there is also a motor to steer the rudder left or right depending on the way the AUV wants to turn. All the control of the movement will be controlled by an Arduino microcontroller which will maneuver the AUV depending on the data processed from the Camera and Ultrasonic sensor. The video feed and ultrasonic data will be processed by a raspberry pi device which will analyze the data and thereby give necessary instructions to the Arduino controller. The video feed will be analyzed in real-time by OpenCV which will classify the object as trash or not and depending on the outcome, the AUV steers to it. The ultrasonic sensor detects for marine life nearby and upon detection, either goes away from the marine life or stops operation on the spot and shuts the AUV down until the marine life passes by or moves away to a safe distance.

So how the model works is that, first it identifies the debris and goes closer to it; it steers accordingly depending on whether it needs to go left, right, front or back. After the debris is less than 100m (about the length of a football field) away, the real-time video footage is immediately sent to the Raspberry Pi where the model tries to identify whether it is trash or not based on the dataset. Higher the video resolution and quality, higher the accuracy and identification. If it is not trash, the AUV moves away, steers away from the object on the surface of the water. If it is trash, it sends a message to the DC motor to continue forward and or the servomotor to steer the AUV left or right. At this point the motor on conveyor belt starts thereby moving the belt. After the AUV travels for 20m more than the point of the debris, it shuts the conveyor belt back off and starts looking for more debris. And this keeps on repeating and repeating, until the battery on the AUV is low, if there is a structural breach or if the trash storage bin has filled up. After which the AUV immediately returns to base.

Logical Model

[22]The model will utilize A.I and machine learning using CNN (Convolutional Neural Networks). CNN is a well-known image categorization and analysis method. These neural networks model the human brain to replicate the learning process. These networks are an important part of computer vision and a good technique to give machines the ability to identify objects. Convolutional layers distinguish CNNs from traditional neural networks. Pattern recognition is possible thanks to these convolutional layers. [23]In the CNN, it will run the Resnet34 which is a pre-trained CNN. This implies that it has been previously trained. The algorithm utilized will be the KNN (K Nearest Neighbors) Algorithm for image classification. This algorithm is the most suitable as it is simple, and the performance and the computational requirements are low. [24]The dataset which will be used for initial training of the dataset will by TrashNet which was created by Gary Thung. This dataset contains 2527 images of 6 distinct categories in total. The category is trash. While this category is not used currently for segregating the trash based on material collected from the ocean, it can be used for future development and as a new feature. This dataset is then spilt into 3 separate sections, which are training dataset, validation dataset and test dataset. 70% of the dataset will be used to train the A.I model, then 20% will be used to validate the dataset where it will be decided if the A.I model needs further training or if the training needs to be stopped. And lastly, 10% will be used to test the dataset and see how accurate the image detection and classification is. [25]If any errors occur in the last stage, the whole A.I Model needs to be further trained. The creation of a convolutional neural network precludes the identification of non-existent classes. If the mother class is Trash, for example, we can be assured that the child class will be trash as well. The image is used as an input, and the bounding box and mother-class are created by the CNN as outputs. The genuine image is cropped using that data, which is one of CNN's inputs related to the mother-class. The child class was developed after that, and it united with the mother class to form the final class. The bounding box is used to predict the outcome before the model is identified.

Alternative Logical Models & their Comparison

While we've identified the best algorithm to use, here are other alternatives and the reason as to why we didn't use those algorithms for the AUV. [26][27]SVM is a classification and identification technique that categorizes and identifies objects using machine learning. For multi-dimensional data, it accomplishes this by dividing items on hyperplanes. The working concept of support vector machines is clear. Make a hyperplane that divides the data into groups. We must determine which places are most convenient for both classes. Support vectors are the names given to these points. The distance between our dividing plane and the support vectors must then be calculated. The goal of an SVM algorithm is to extend this margin as much as possible. The hyperplane becomes the best option when the margin reaches its maximum. But the downside to this algorithm is that it's not very accurate as compared to KNN. To add to that, it also uses more computation power. [28][29]Another algorithm can be the R-CNN model or Region-Based Convolutional Neural Network. When used for object detection, R-CNN is a deep convolutional network that appears to the user as a single, end-to-end, unified network. The network can precisely and quickly predict the placement of diverse items. R-key CNN's contribution is the use of a convolutional neural network to extract features (CNN). The rest of the system works in the same way as a normal object detection system. But the drawbacks of R-CNN include its reliance on the selective search algorithm for generating the exact region of the image which take a lot of computation and time. Additionally, the algorithm cannot be customized, thereby it poses the issue of detection. Alongside that, each region is fed independently to the CNN, which takes more time for feature extraction. This rids the model of real-time capability.

New Learning and Challenges

The main challenge of the dataset is that if the dataset is not trained enough or fails in certain cases, it may misidentify or not identify the trash debris. This may arise due to not enough data models in the data set which does not let the AI classify and identify if it is trash or marine life. Then arises the issue of image processing and capture; the farther the image capture, the less clear and more pixelated the image thereby reducing the efficiency and accuracy of object detection. There is a lot more features and fine tuning that can be done to develop and improve the model. For example, we can further train the dataset and create more categories and then also maybe introduce the option of recycling. In the future, we can implement faster algorithms and image processing and object detection methods with lower computational power and GPUs. While we have learnt of new algorithms, software, and datasets; there are many more better features and methods with better computation and less latency. All these methods and algorithms were what was the best at the time of writing of this paper. Also, there might be many more challenges in terms of Computer Vision and object detection along with image processing and all, we cannot identify all of them unless we physically create and deploy the model.

Conclusion

In this paper, we applied and evaluated the Hardware and software needed for the AUV, the need for AUVs or similar smart vehicles and devices for ocean trash clean-up or management. We also identified the best algorithm to used amongst others which provided the best speed, accuracy, and computational needs. We also identified how to train the dataset and the way to train it. We also brought to light, the impact this will have on our oceans. We also highlighted the humanitarian outcomes and reasons for why the Ocean Trash clean-up is necessary. These techniques may be used to design an AUV and remove trash and similar debris from the surface of our water bodies, which in turn, will save marine life and contamination in our oceans. Although the technology available is not limited to just these, there may be many better algorithms and datasets which may provide faster computation and image processing. This will be a critical tool for us in the current time and future to save our oceans and get rid of pollution.

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