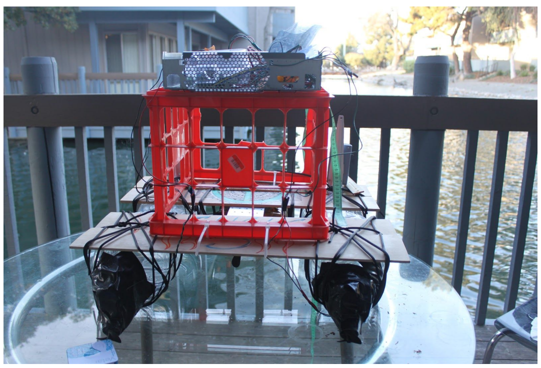
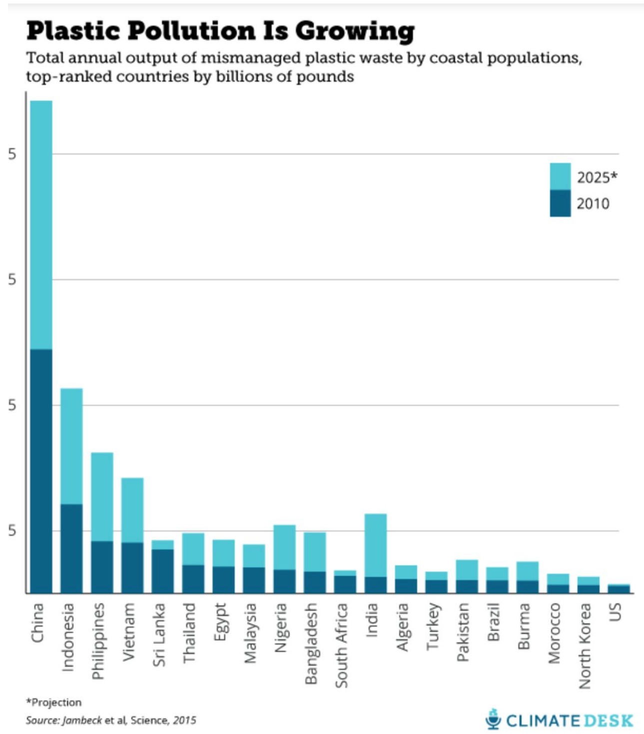
Autonomous Environmentally Beneficial Boat





Abstract

Plastic pollution is a growing threat to our environmental safety. This prototype model, manufactured from recycled materials, is designed to detect floating trash, collect it autonomously, and navigate back to the drop off location when full. ROS pipelines sensor fusion and camera data running on nVidia Jetson TX2. Deep Learning powers it's capabilities to detect trash, wildlife and obstacles on the camera image and distinguish navigable terrain from water area boundaries.

Floatables, Marine Debris, and Nurdles

In the nearly 80 years since the mass production of plastic, it has unfortunately become a large part of the trash on water surfaces throughout the world. Of the 8+ billion metric tons of trash found in Earth's water, an infamous example is the Great Pacific Garbage Patch (NOAA 2017), a large stretch of ocean which traps this marine debris often found in the form of floating islands of plastic.

Marine debris and floatables are defined as the broad range of floating pollutants and trash found on water, which can entangle and injure marine wildlife and damage property (NOAA

2011). These marine debris and floatables are not exclusive to vast stretches of ocean, but are commonly found on ocean and river beach-fronts, and are primarily generated by human activity.

Additionally, pre production pellets of plastic which are often called nurdles, are small, lightweight, and float (California, 2018). These nurdles present an additional danger to earth's ecosystem by being confused for food by fish and entering the food chain.

Call to Action

"Boat skimmers, and other concentration and removal technologies" (Coe & Rogers 2011) are an integral part of the a comprehensive future solution to the surface debris removal problem.

In this dire situation with rampant mismanagement of both natural and man made water resources, EBB is targeted at cleaning the surfaces of water. Our boat is a cleaning device, and more particularly a cleaning means that is self-propelled over the top surface of still bodies of water.

Hardware

Diagram and BOM are available here: github.com/rkaus/ebb

Overview

This prototype model is hand manufactured in a home setting using materials that are commonly found. The generic nature of this build makes implementing and/or improving this work straightforward.

Recycled Materials

We use mainly recycled materials on this prototype version of the boat, and found these from dumpster dives, garage sales, and dusty closet corners. We did this to keep prototyping costs to a minimum, and are exploring sustainable materials for future development.

Boat structure

The foundation of the boat platform consists of 6x water bottles, 4x 0.5mm thick birch boards, and 3 motors. 4 bottles are fastened together with the boards using a combination of long rubber bands and a metal plate. Underneath the boards and between the two rows of bottles is an additional set of 2 bottles and a motor located underneath the center of the boat.

The motors are waterproofed using tape and candlewax, then placed inside of film canisters applying some of the techniques from an MIT Sea Perch construction guide (Shroyer, VanCott, Chryssostomidis, & Soroka 2011). These motor assemblies are attached to the stern end of one of two bottles held base to base, using duct tape and polyester string. The third underwater motor is attached to the central bottles in a similar fashion.

Pickup Mesh

The base material of the mesh is made up of screen door material made from polyester, sewn together with rubber weather-stripping found on the top and bottom of the frame of the screen door. Fishing line threads tie two strips of rubber in between mesh material, with lateral strips of rubber as horizontal tread on the mesh mechanism.

The mesh is driven with a Roomba 14v DC motor, attached to a drive shaft made of a steel rod covered in silicone rubber for tread.

nVidia Jetson TX2 Developer Kit

Autonomous deployment and navigation functions, as well as the specific requirements for trash and wildlife recognition are implemented using the nVidia Jetson TX2 embedded AI system. For such a boat to be able to fulfill all the tasks of a human operated skimmer, powerful AI technologies will need to operate in the field, limiting the use of cloud based AI systems.

Intelligent vision is very important for object identification, and additional computing power needs to be drawn for Deep Reinforcement Learning algorithms that optimize navigation and path planning.

The TX2 delivers dual CPU power with 256 cuda cores on a mini-ITX sized board with a low energy footprint, making it perfect for developing such an integrated solution to a complex robotics challenge.

Sensors

Three HC SR-04 ultrasonic/Sonar range sensors are used to detect port, starboard, and stern/rear edges. Encased in a 3d printed cover, these are sensitive to objects and walls between 5cm and 4m away.

The IMU measures accelerometer and gyroscope data which are fused together in the pose estimation extended kalman filter algorithm.

Software

Github with code and for updates: github.com/rkaus/ebb

Motor and Sensor Control

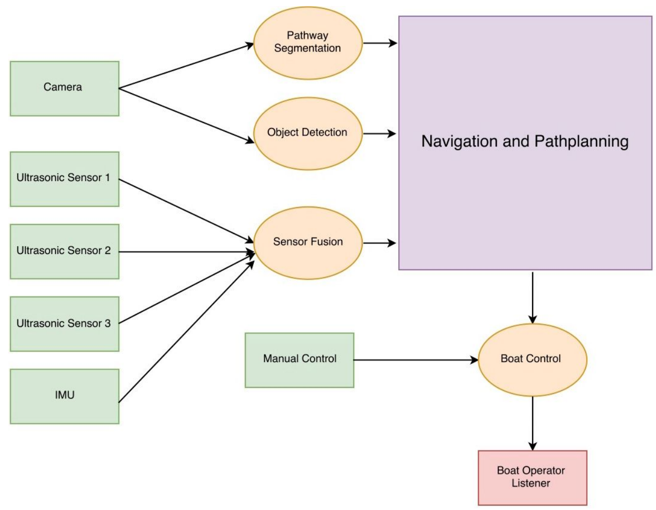
Motors and sensors are controlled using the Adafruit MotorHAT Python library with a modified version of the Adafruit Python GPIO that has default I2C settings specific to the TX2's J21 Pinout Header.

```
def callback(self,data):
 rospy.loginfo(rospy.get_caller_id() + "I heard %s", data.data)
 if data.data == 'Forward':
       self.forward()
 if data.data == 'Backward':
       self.backwards()
 if data.data == 'Left':
       self.left()
 if data.data == 'Right':
       self.right()
 if data.data == 'B':
       self.stop()
 if data.data == 'Done':
       self.cleanup()
```

The ultrasonic range sensors interface with linux native sysfs_gpio using a python library to turn on 'Trigger' and wait for an 'Echo' edge. Distance is calculated based on the amoutn of time travelled by the sound pulses.

The internal measurement unit provides acceleration and gyroscope data via the I2C bus and is used to calculate the boat's orientation in the environment in combination with the ultrasonic sensor data.

ROS - Robot Operating System



The ROS pipeline uses and analyzes sensor input, performing data transformations relevant to the boats position and understanding of its environment. This data is then used to output direct control commands to motors based on the navigation and path planning logic.

Deep Neural Networks

Visual Deep Neural Networks perform navigable pixel segmentation, and wildlife, trash, and object detection. Navigation constants use reinforcement learning to arrive at local minima. While these networks have been trained on low resolution generic data, full feature labeled data is still being actively collected and processed by the Neural Network in an ongoing data collection and learning process. More specific results will be provided in the linked github repository as they are available. The neural networks are deployed using [jetson-inference] guidelines via TensorRT installed through the native TX2 Jetpack installation and are trained by [AWS EC2 Instances].

Scope of use

EBB is well suited to areas with still or slow moving water. It can safely traverse ponds, pools, river-walks, and waterfronts with human activity. As it periodically needs to return collected debris to collection stations, its range of activity will be limited to areas where it can be easily returned for deposits and check-ups.

Private use in still water

Such a cleaning device may be used alongside dredging and chemical systems to create a complete solution to keeping still waters clean. Small private pool surfaces and managed bays, ports, and larger still bodies of water can incorporate EBB into their environmental cleanup strategy.

Global Use

The modularity of this boat's design allows it to be recreated and deployed on cheap and readily available components, including less powerful microcontrollers. Trash collection on coastlines as well as in the ocean should enable recycling of the material gathered and be able to provide additional funding for the project of saving our environment.

Future Improvements

Short Term

In the next three to five weeks, we hope to make several hardware improvements to the boat including; reinforcing the mesh ramp and support structure to better funnel trash into the pickup container, using leftover plastic to make a collapsible and removable pickup container, and adding solar charging.

Additionally the software implemented in the presented prototype is in no way comprehensive, but provides a basis for future work and development. We will be tuning our Neural Network hyperparameters, and integrating additional sensor data including gps and compass.

Long Term

The EBB platform can have even longer life and functionality designed into the FLOW platform. Providing centralized power, trash collection, unit synchronization, and maintenance, FLOW can use multiple EBB

units to perform a wider variety of tasks. It can be used for long range trash collecting mission, and track and report on things like ghost gear, fishing equipment left behind that can fatally ensnare wildlife. Additional modularity built into EBB can enable further scientific and security monitoring functionality.

Lastly, with the influx of smart devices likely to be present and involved in the effort to keep Earth's water clean, we want EBB to combine and cooperate with other devices and initiatives on the water to create a network of solutions to address the multivariate nature of challenges faced in keeping our waters clean.

References

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