Abstract

A cheap, 3D-printed autonomous underwater vehicle (AUV) is designed to collect underwater footage, while a trash detection machine learning model is developed to analyze the footage for underwater litter. The model accurately yields five areas of concentrated ocean debris at depths of 500-800 meters below the surface. **This study highlights how marine debris can be mapped and categorized with the trash detection model.**

Rationale

- 5.25 trillion pieces of plastics are in the ocean.
- Ecosystems are at risk from declining fish populations.
- Ocean litter must be mapped for effective cleanup.
- Ocean litter is primarily tracked with satellites.
- However, satellite imagery is ineffective because of an inability to detect litter in depths > 10 meters.
- More advanced detections systems for deep waters are necessary.

Methods

Control Board Design and AUV Fabrication

- Collects footage of underwater environment
- Fully designed in CAD and 3D-printed
- Control board designed in ECAD and fabricated
- Control board programmed in C++.
- Performed field test in bathtub with 190 liters of water
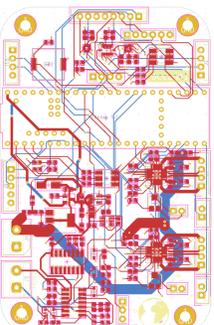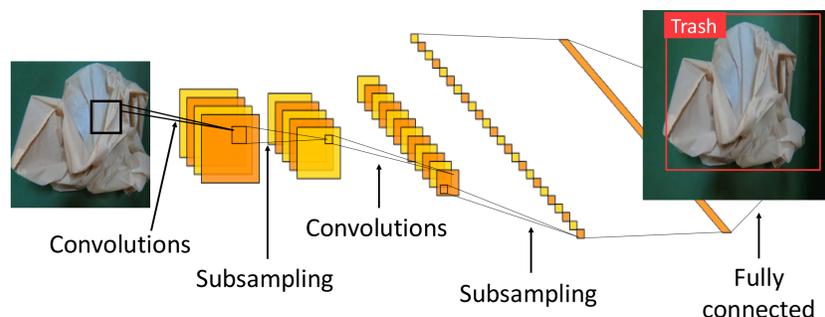
Control board design
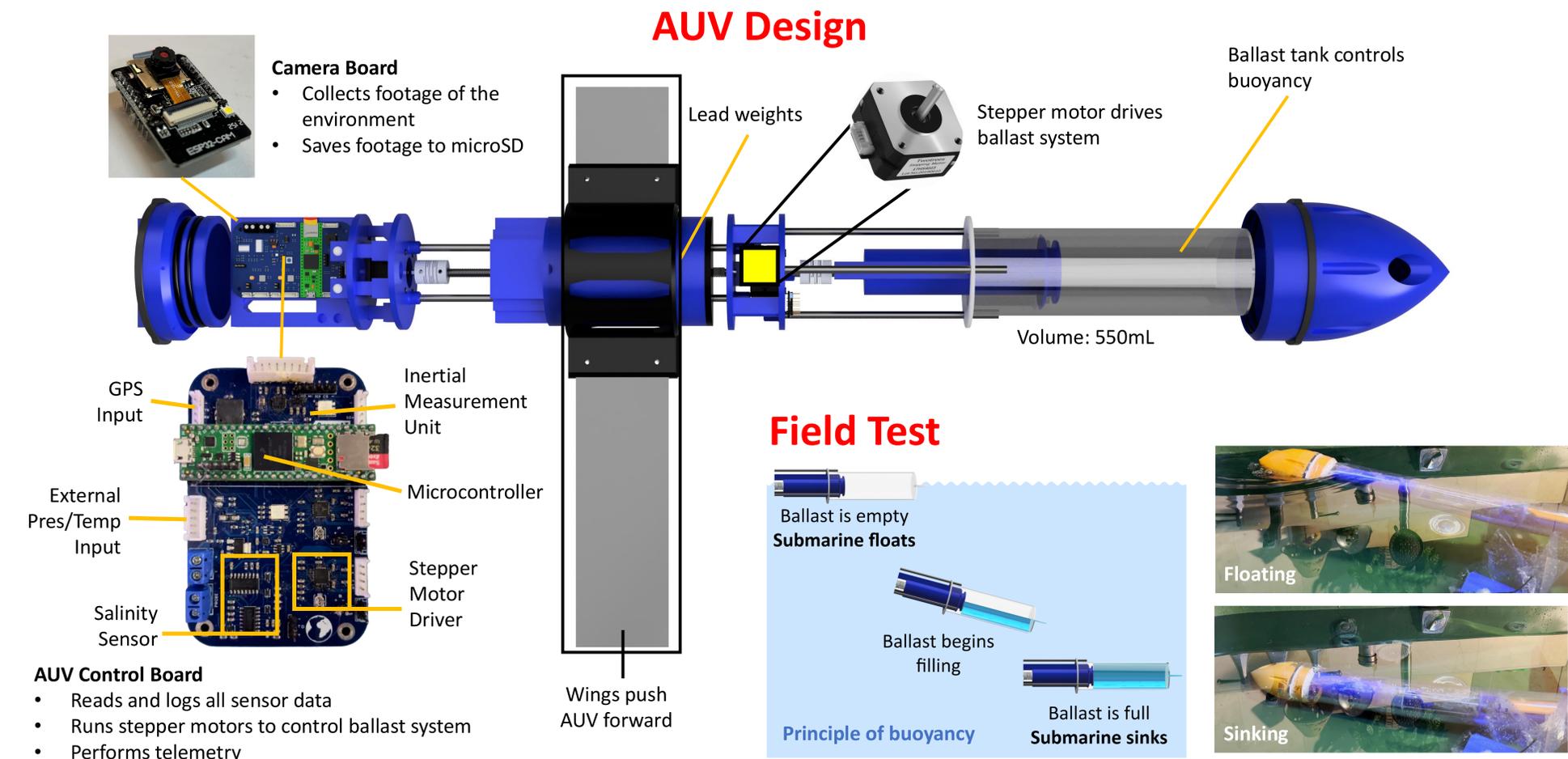
Soldering the control board

Wing segment of AUV being 3D-printed

Trash Detection Model:

- Analyzes footage from AUV for litter.
- Runs on a convolutional neural network
- Built with YOLOv5 PyTorch API
- Trained and assessed 4 different models
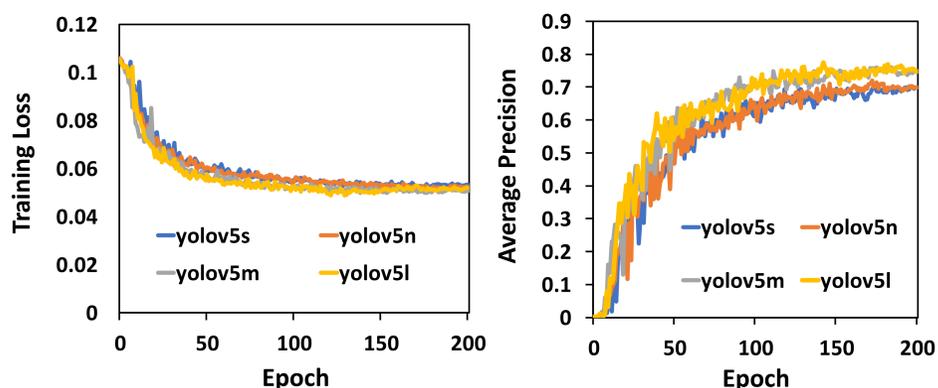- Ran open-source footage through the model to test its capabilities

Convolutions
Subsampling
Convolutions
Subsampling
Fully connected
Trash

YOLOv5 Architecture

AUV Design

Camera Board
- Collects footage of the environment
- Saves footage to microSD

Lead weights

Ballast tank controls buoyancy

Stepper motor drives ballast system

Volume: 550mL

GPS Input

Inertial Measurement Unit

Microcontroller

External Pres/Temp Input

Salinity Sensor

Stepper Motor Driver

AUV Control Board
- Reads and logs all sensor data
- Runs stepper motors to control ballast system
- Performs telemetry

Wings push AUV forward

Field Test

Ballast is empty
Submarine floats

Ballast begins filling

Ballast is full
Submarine sinks

Principle of buoyancy

Floating

Sinking

Litter Detection Model

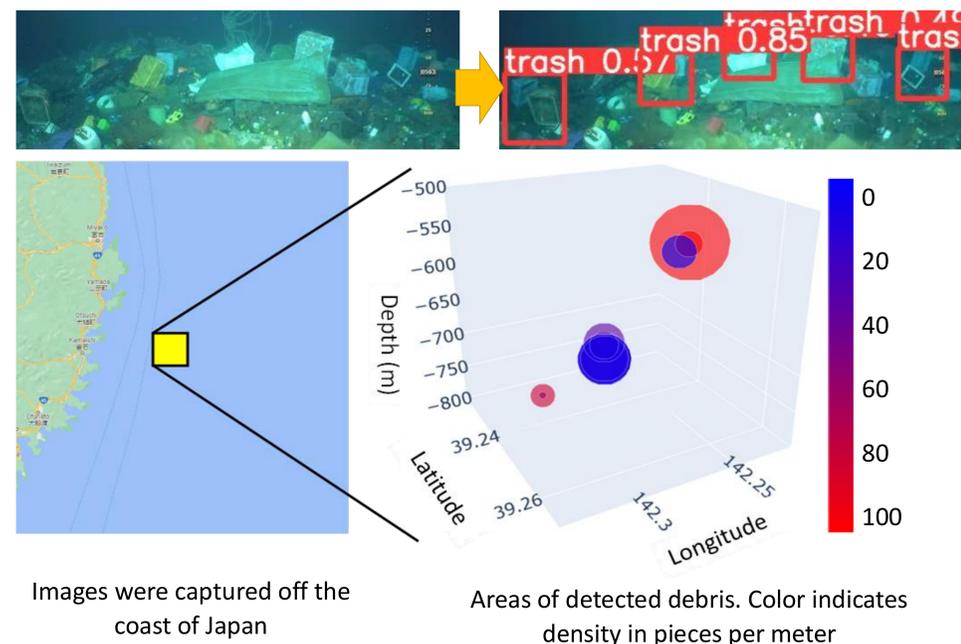**The trash detection model was trained on four different models**

- Validation loss was not larger for any of the models – no overfitting
- YOLOv5l performed with the highest accuracy and the lowest loss
- YOLOv5l was selected for deployment

Open-sourced underwater footage was inferenced with the model

- Detected 174,734 litter objects
- Objects were at depths of 500-800 meters, undetectable by satellites
- GPS & depth data from each detected object used to build a map

Training Loss (yolov5s, yolov5n, yolov5m, yolov5l)

Average Precision (yolov5s, yolov5n, yolov5m, yolov5l)

trash 0.57   trash 0.85   trash   trash

Images were captured off the coast of Japan

Areas of detected debris. Color indicates density in pieces per meter

Model	YOLOv5s	YOLOv5n	YOLOv5m	YOLOv5l
Average precision (best)	0.707	0.721	0.760	0.775
Training loss (best)	0.105	0.106	0.106	0.105
Validation loss (best)	0.105	0.106	0.106	0.105

Conclusions

I successfully:

1. Developed an AUV capable of collecting underwater footage and metrics.
2. Performed a successful field test of the AUV in 190 liters of water
3. Created a detection model to inference footage and map ocean litter.

Future Work

1. The detection model will classify different types of litter (plastic, metal, etc.)
2. The AUV will be tested in bigger bodies of water to further test its abilities.
3. Improve the water sealing method on the AUV to improve its deep-water capabilities.