

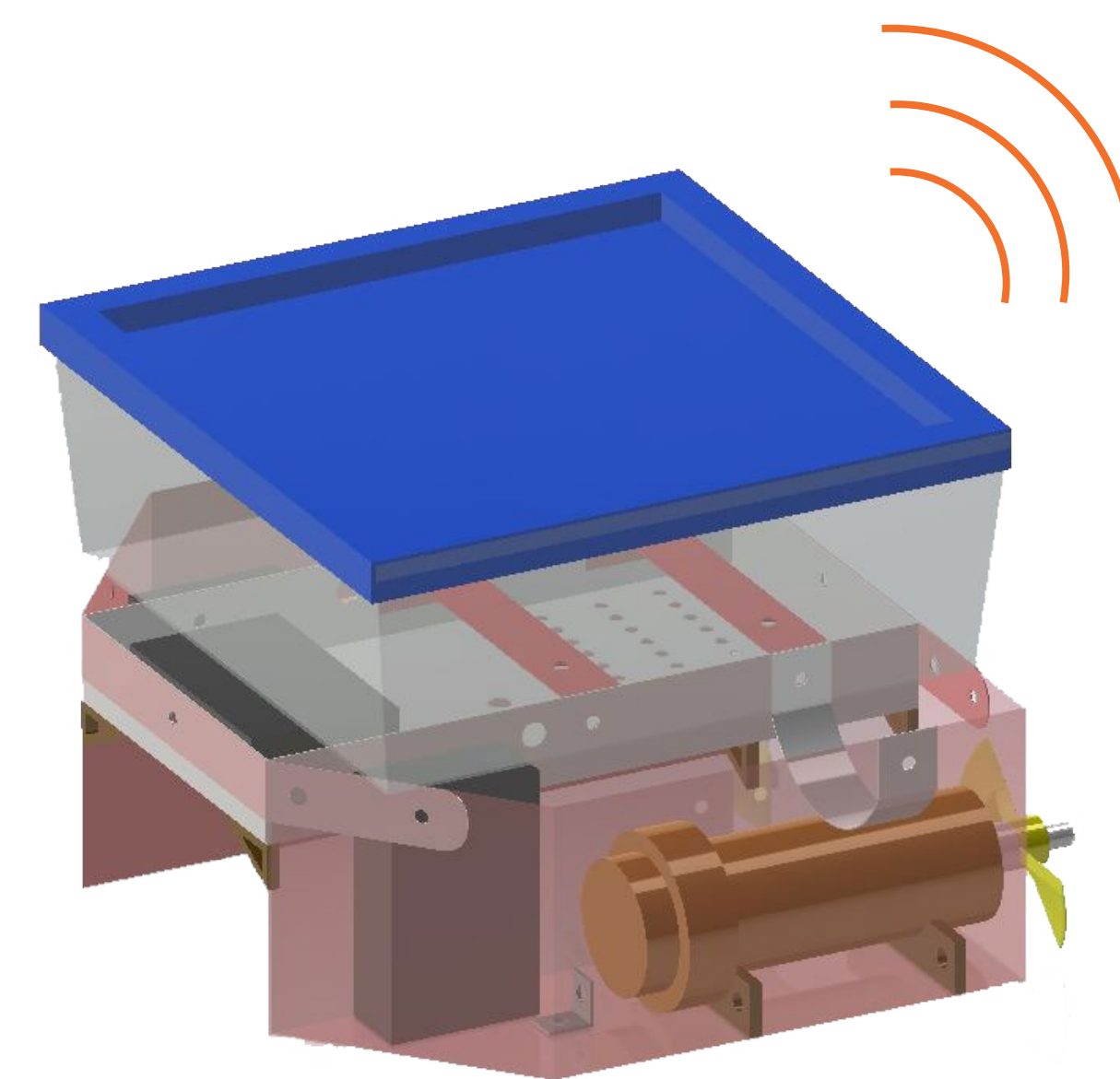
Energy Efficient Propulsion of Autonomous Boats in Ocean Flows

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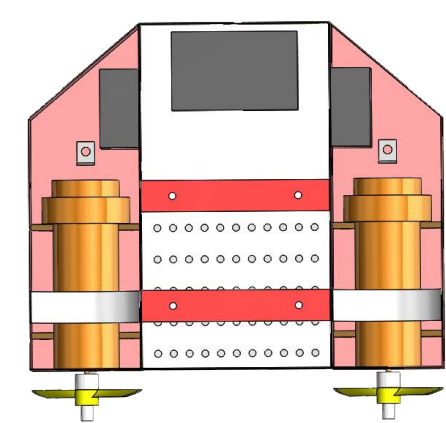
Motivation: When studying the ocean, scientists often need to collect data such as flow speed, temperature, and salinity. However, their current options to collect this data are problematic. For instance, buoys are easy to deploy, but are not mobile enough to react to urgent events. Other options like research boats are expensive and time consuming. Finding a good balance between mobility, cost, and time is a challenge.



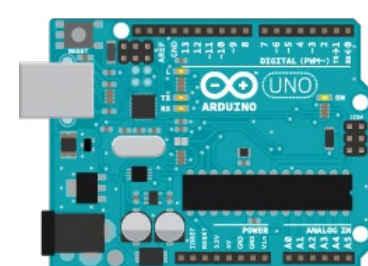
Goal [Energy Efficient Propulsion]: Our solution is a system of autonomous boats carrying sensors to measure local currents. The measurements are used to find favorable currents, and control algorithms then direct the boats along these currents, saving energy. This approach allows the boats to stay out on the water for long periods of time while remaining highly mobile and relatively inexpensive.



Autonomous Boat



BOAT HULL: The autonomous boat is designed as a **catamaran** to ensure its stability. The boat is made out of folded steel sheet for ease of manufacturing and coated with waterproofing to prevent leaks. Finally, a Tupperware container is mounted on top of the boat to contain the electronics to a waterproof area.

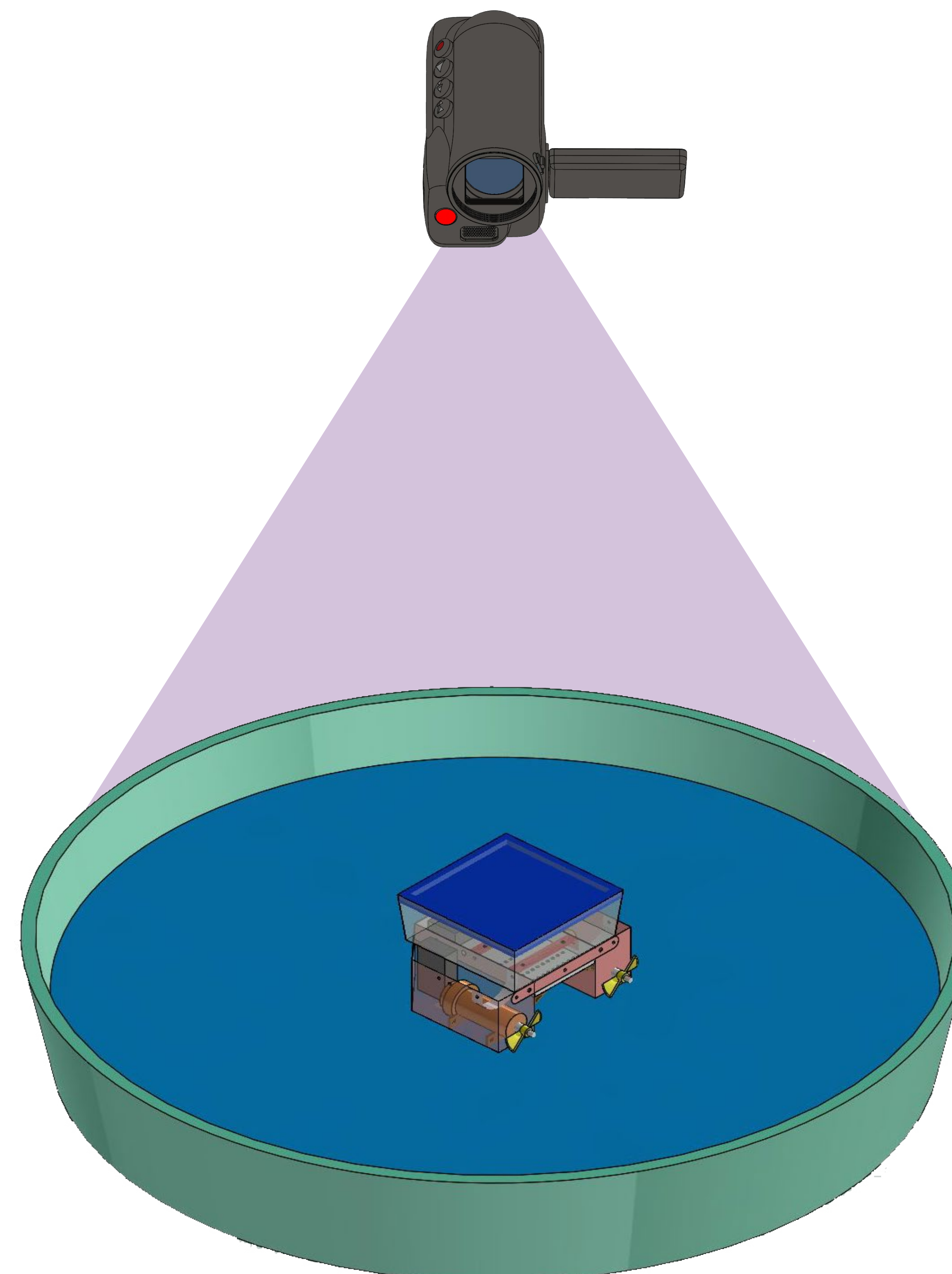


BOAT ELECTRONICS: The boat is driven by two DC motors (**differential drive**). These DC motors are mounted in pillboxes filled with grease to prevent water from leaking into the boat. These motors receive PWM signals from an Arduino Fio, which **receives commands from a computer** over a serial connection via an Xbee chip.

Tank Flows

Small pumps can be arranged in the tank to **create different flow fields**. Short polyethylene rods painted with black boat primer are used as trackers to visualize the flow. The coating serves both to increase the visual contrast between the particles and the tank, and to reduce the clumping of particles known as the cheerio effect.

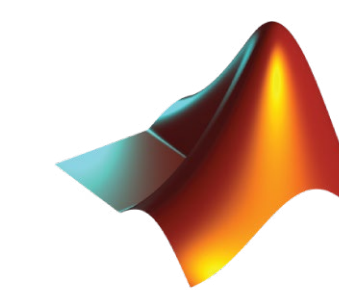
FEEDBACK CONTROL: The control software receives **BOAT TRACKING** data and **FLOW DATA** gathered from the camera. A python script implementation of our control law calculates the necessary motor speeds needed for the boat to follow a specified trajectory, and sends the actuation signals to the **AUTONOMOUS BOAT**.



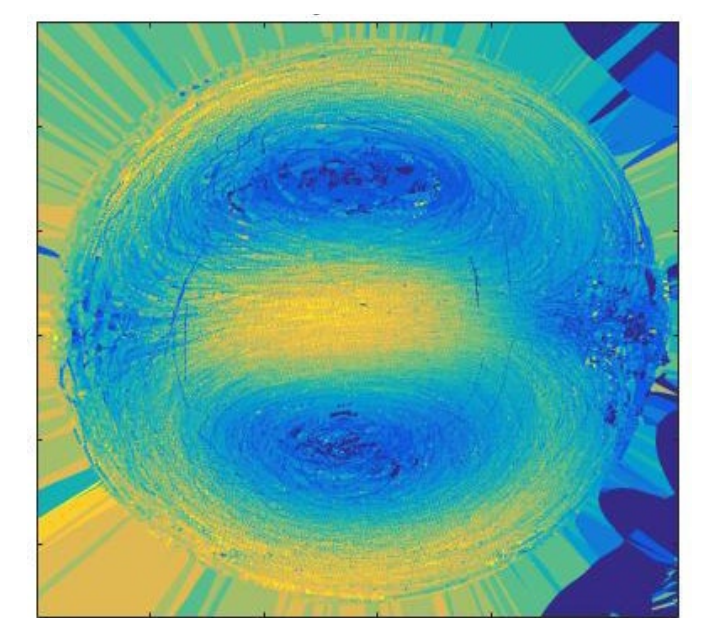
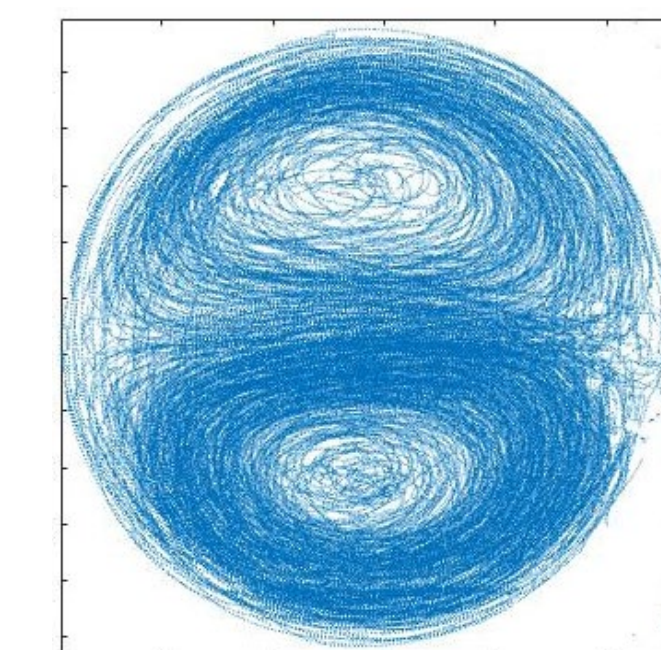
Software



BOAT TRACKING: The boat tracking software uses **ArUco**, a **Python library based on OpenCV**. It can track the boat using marker images that are attached to the boat. It outputs the **boat's position** in x,y coordinates and the **boat's orientation**.



FLOW DATA: The webcam takes a short video of particles moving in the flow and a **MATLAB script analyzes the video**. The script finds moving particles by subtracting out a time averaged background. Predictive tracking is then used to track individual particles. **Pathlines of particles and a contour plot of the velocity in the tank are shown below.**



Left: Particle Pathlines
Right: Velocity contour plot