PropaGator
Autonomous Surface Vehicle

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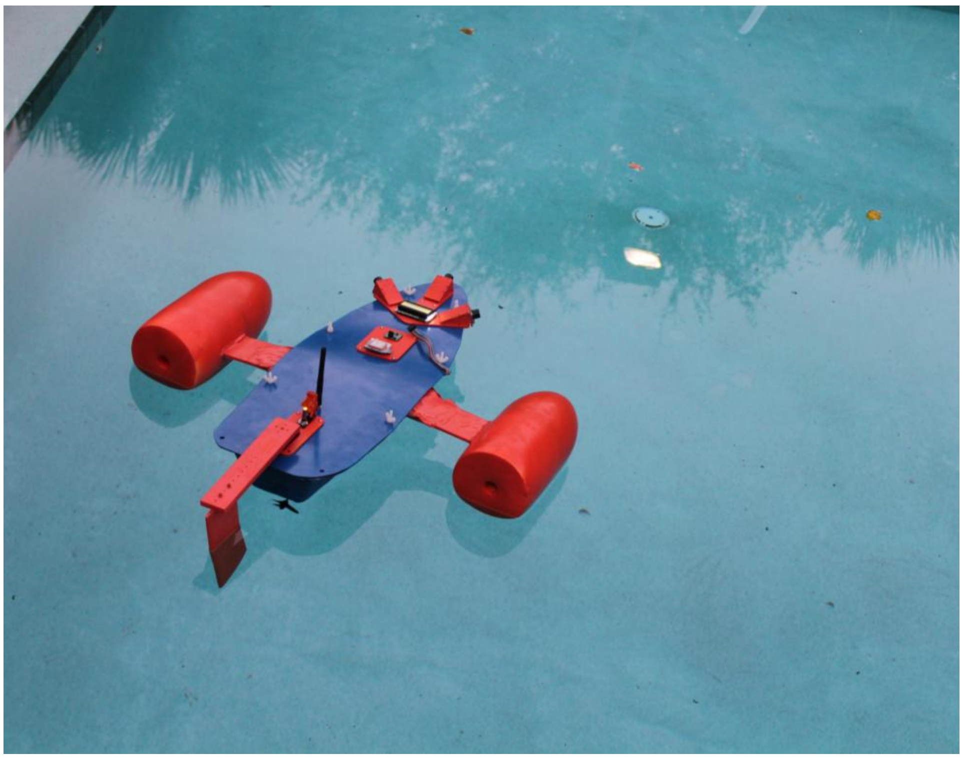

University of Florida

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EEL 5666C – IMDL – Final Report

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A. Abstract

PropaGator is an intelligent autonomous surface vehicle (ASV) designed to clean up the pollution in our oceans. Pollution is an ongoing threat to the oceans and if it is not reduced or stopped the ocean's resources will eventually disappear. If vital resources to the Earth's environment are depleted from the oceans Earth could be headed for disaster. PropaGator is designed to avoid this unpleasant situation and its main goal is to collect floating waste, i.e. plastics, aluminum cans, etc. PropaGator accomplishes this task through navigating through water with nets to capture the waste attached to its sides, and PropaGator navigates by GPS waypoints that are known to have lots of pollution between them.

B. Executive Summary

Pollution is an ever growing issue in today's society. The more the Earth's population grows the more and more pollutants are created and therefore more efficient and faster solutions to prevent, manage, and eliminate pollution need to be developed. One resource pollution affects majorly is water sources. Whether they are contaminated by chemical pollutants, thermal pollution, or even litter on the surface, water quality is impacted extremely based on pollution.

PropaGator is made to help aid in the fight against water pollution. PropaGator is an autonomous surface vehicle (ASV) with the capabilities to fight pollution. Robots can greatly reduce the amount of human labor required to fight these pollution problems. PropaGator uses GPS to navigate to GPS waypoints and sonar to avoid obstacles. These tools to help this ASV navigate paired with netting to collect surface waste make it an ideal tool in pollution management. Multiples of these robots can be deployed and within hours a large area water can be completely cleaned at the surface. If PropaGator-like robots were deployed after the BP Oil Spill, the amount of human labor would have been reduced dramatically allowing those people to work on other problems the spill created.

PropaGator's system is centered around a custom designed controller board that uses an Atmega128 microcontroller to control the boat. The ASV is communicated to through wireless serial links and the boat displays debug messages on the LCD screen. PropaGator is propelled by a waterproof motor removed from a bilge pump and is steered by rudder mounted onto a servo. Propagator uses an EM-408 GPS unit to read the current GPS point and based on selected points a desired heading is selected then. Then a Micromag3 magnetometer and the desired heading are inputs to a PD controller which controls the orientation of the rudder during waypoint navigation. Sonar sensors are used to avoid any objects that might impede PropaGator.

C. Introduction

PropaGator was designed to be small, modular, and easy to use robotic boat. This boat is the main objective of a project for the Intelligence Machine Design Lab (IMDL). The idea is to be able place PropaGator into the water, input your desired destination, and let the ASV do all the work. PropaGator is designed around a trimaran design for stability. PropaGator will use a GPS receiver for navigation to waypoints and a magnetometer to adjust heading. PropaGator will navigate to her desired destination cleaning up pollution along the way using nets attached to the sides. To avoid obstacles PropaGator is equipped with sonar on her bow, port, and starboard side. For returning data to the user and inputting data into the robot, PropaGator will use wireless serial links to transmit data.

D. Integrated System

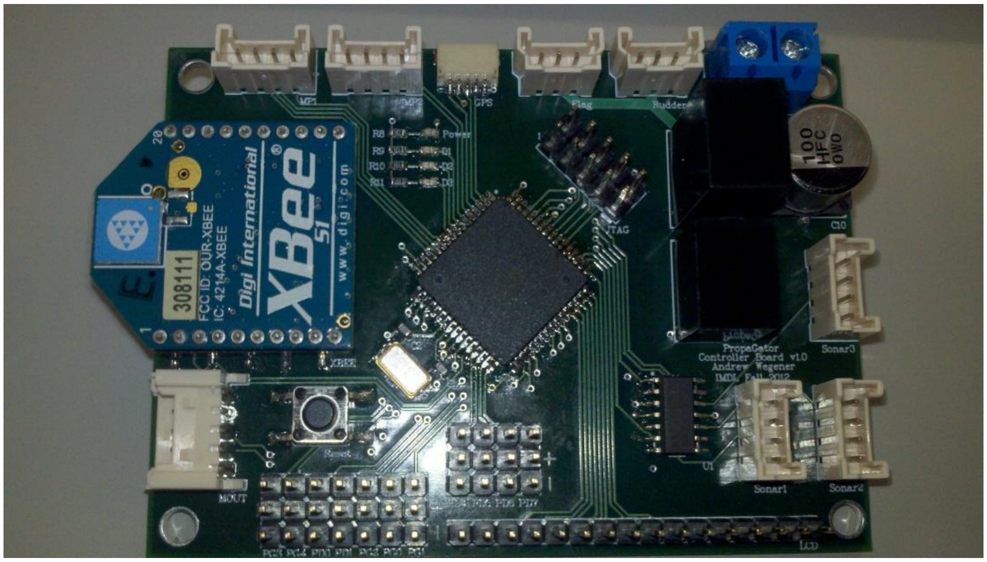

Figure 1: Custom Controller Board

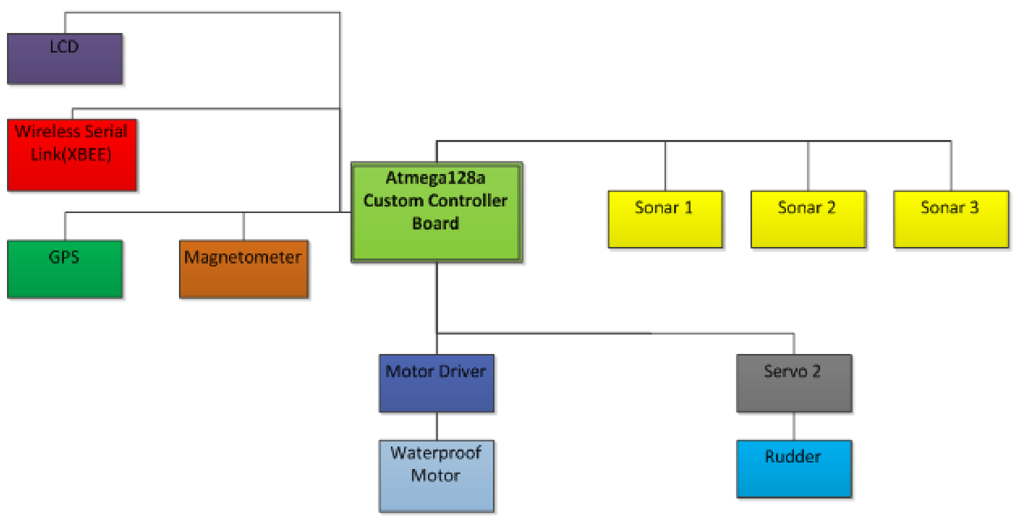

Figure 2: PropaGator Block Diagram

E. Mobile Platform

PropaGator's mechanical system is designed around a trimaran design as seen in Figure 3. Trimaran's have a main center hull and two hulls attached to the side of the main hull. The center hull is constructed out of a sturdy lightweight custom fiberglass hull. Fiberglass makes the hull modifiable/expandable. This means that sensors can be easily mounted to the main hull and one can easily expand the main hull by just adding more fiberglass material. The center hull holds all of the electronics and actuators for PropaGator to function. The two side hulls are attached using pieces of plastic and fiberglass. The side hulls are repurposed crab pot buoys and hold no sensors or actuators for PropaGator. The whole purpose for the buoys is to provide stabilization for the boat. Having a stable platform simplifies controls and eliminates the chance of the boat tipping over. PropaGator cleans the oceans by having nets on each side of her to clean the ocean. The nets are easily removable and mounted onto the each of the pontoons.

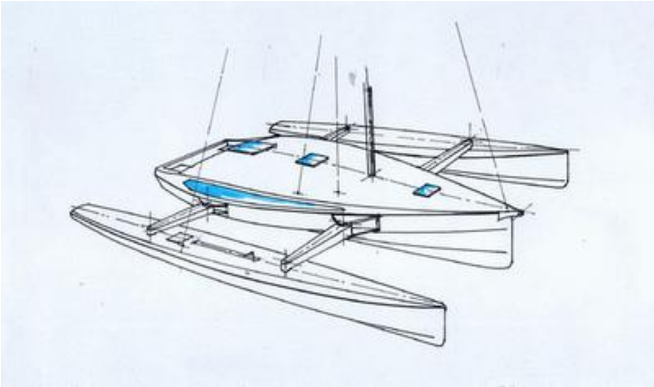

Figure 3: Trimaran Design

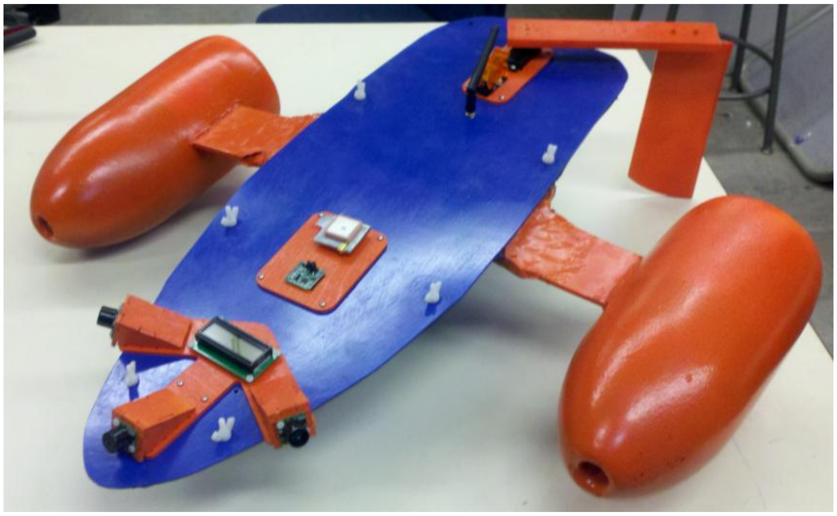

Figure 4: Assembled Platform

F. Actuation

Forward propulsion on PropaGator is accomplished using a single 12V DC waterproof motor. This motor was chosen because of price and ease of integration into the boat's design. The motor was salvaged from a Rule Bilge Pump and is driven by the VNH5019 motor driver breakout board. Turning is accomplished by mounting a rudder in line with the 12V DC motor via a threaded rod and shaft coupling. The rudder is actuated by a 180 degree servo and is constructed from multiple pieces of polycarbonate plastic connected with screws. Figure 6 shows the rudder assembly mounted onto PropaGator and Figure 9 shows the bilge pump assembly attached to PropaGator. The rudder will adjust to make corrections for heading based on the magnetometer readings or avoid obstacles if one is present.

Figure 5: TowerPro SG-5010 Servo used for Rudder Control

Figure 6: Rudder assembly mounted on PropaGator

Figure 7: VNH5019 Motor Driver

Figure 8: Rule Bilge Pump before the motor was removed

Figure 9: Motor to Propeller assembly

G. Sensors

Three Maxbotix Sonars (MB1010) will be used for obstacle detection and avoidance. If an object comes within 25 inches of PropaGator, the boat will execute an avoid maneuver and continue traveling to its desired location. Figure 11 shows the mounted sonars, the sonars were mounted at an angle of 30 degrees to avoid false hits off of the water.

Figure 10: MB1010 Sonar

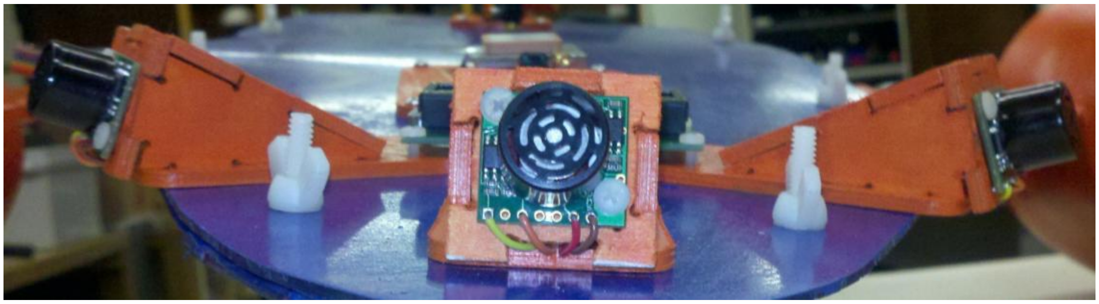

Figure 11: Sonar mounts assembly

An EM-408 GPS Receiver and Antenna will be used for the GPS waypoint navigation. It can achieve up to 5 meters of accuracy at best and transmits data through asynchronous serial. The custom controller board will parse the information output from the GPS and interpret the data. If PropaGator gets within 10 meters of her desired waypoint, PropaGator will then start to navigate towards its next waypoint or if PropaGator reached its last waypoint it stops autonomously navigating and enter remote control mode.

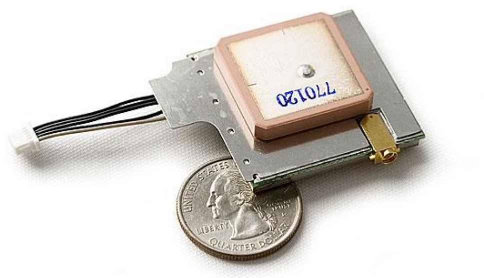

Figure 12: EM-408 GPS Receiver

A MicroMag3 a digital magnetometer will be used to adjust and set headings. The shortest distance between the waypoints will be calculated and heading will be adjusted using the magnetometer outputs. This module operates using the SPI communication protocol. Adjustments in heading will be sent to the rudder which will turn accordingly to set the boat on the right track towards its destination. This heading obtained from this sensor is used as the input to the PD controller which then outputs a servo angle to the rudder.

Figure 13: MicroMag3

Debug information is displayed on the LCD screen mounted to the top of the ASV. In Figure 14, the current GPS point of PropaGator is shown displayed on the LCD screen.

Figure 14: Current GPS coordinates displayed on the LCD screen

Lastly, a XBEE will be integrated into the system. The XBEE operates using asynchronous serial and will be used to share debug data to the user as well as receive the input waypoints from the user and provide useful information back to the user.

Figure 15: XBee Wireless Module

H. Behavior

PropaGator boots up into a menu mode where the user can select different behaviors or see different sensor values. Then the user can update information or turn on autonomous behaviors.

PropaGator's autonomous behavior can be broken into two separate actions obstacle avoidance or GPS waypoint navigation. Obstacle avoidance will interpret the sonar sensor data and if the sonar reading is less than 25 inches the boat will then turn left, turn right, or reverse to avoid the obstacle. Then PropaGator will travel a few feet and the GPS waypoint navigator will resume control.

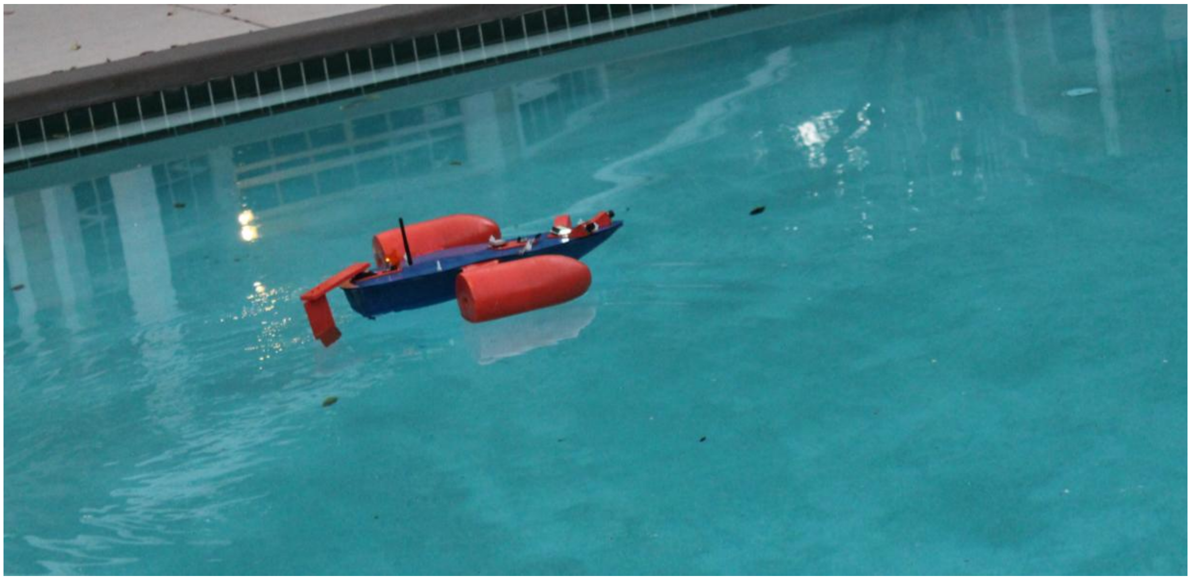

Figure 16: PropaGator traveling towards a waypoint

The waypoint navigation behavior will use the magnetometer, GPS, and motors to get from point A to B travelling the shortest distance possible. The GPS latitude and longitude will be used to calculate desired heading and distance towards the waypoint to efficiently use processor time and there is not much error added to the waypoint navigation when using latitude and longitude instead of other methods like converting the latitude and longitude to UTM points.

Once a GPS coordinate has been selected PropaGator will turn on the propulsion motor and then adjust the rudder in accordance with the PD controller. The PD controller receives information from the magnetometer and then outputs to the rudder the desired heading. Figure 17 shows a diagram of a PD controller. Once in range of a GPS point PropaGator will then begin navigation to the next waypoint and the above behaviors will execute for amount of GPS waypoints entered into PropaGator. The GPS waypoint and obstacle avoidance behaviors are all executed within update functions that are called 10 times a second.

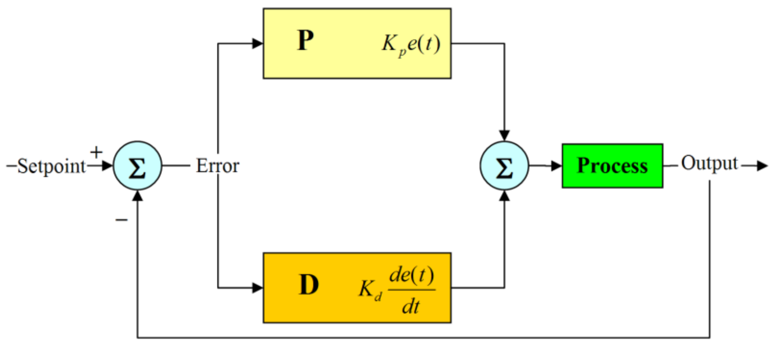

Figure 17: PD Controller

I. Experimental Layout and Results

PropaGator's hull design was thought through over and over again until the trimaran was decided upon because of its stability. A mono-hull design was thought of because it would be able to move more hydro-dynamically, but was decided against because the trimaran design simplifies the controls and eliminates the risk of the ASV tipping over.

When the custom fiberglass hull was initially manufactured and the propulsion motor was mounted, a leak was found where the propulsion motor was mounted. The leak was repaired by surrounding the area with waterproof silicon. Once the silicon dried, the robot was tested again and the leak was eliminated.

The rudder control was created using a PD controller based on PropaGator's current heading and desired heading and then based on these inputs to the PD controller an output to the rudder is produced. This controller was tested and tuned in a pool and originally an error in the controller created a wavy motion in the rudder as it travelled towards its waypoint.

When obstacle avoidance was tested, it was determined that crosstalk between the Maxbotix sonars caused error in the central sonar. To fix this, the sonars were daisy chained and the obstacle avoidance worked much better after that. Also, the sonars were mounted at an angle to avoid false hits off of the water.

J. Conclusion

In the future, sensors to monitor water quality will be added and PropaGator this will upgrade PropaGator's ability to fight and monitor pollution. PropaGator will be able to travel to different locations around the world and report data back to users remotely about the status of the water pollution. In the future, swarms of PropaGator will be made to keep the oceans clean and the oceans status monitored.

K. Documentation

Atmega128a-http://www.atmel.com/devices/ATMEGA128A.aspx?tab=documents

MicroMag3-http://www.sparkfun.com/datasheets/Sensors/MicroMag3%20Data%20Sheet.pdf

EM-408-http://www.usglobalsat.com/store/download/47/em408_ug.pdf

Maxbotix Sonar EZ1-http://maxbotix.com/documents/MB1010_Datasheet.pdf

Appendices

The software developed for PropaGator can be found here-

https://sites.google.com/site/thepropagatorasv/source-code