Clare Boothe Luce Final Report

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Introduction:

For my research, I set out to create a vision system to enable an aqueous vehicle to autonomously navigate harbors. The application in mind for this system is for robotic (unmanned) research vessels for oceanic research missions. The vessel will contain appropriate sensors to whatever observations need to be made, whether it is testing chemical contents of the water, biomass moving through an area, or tracking various groups of animals. Eventually, my research scope expanded to working some on the architecture level to find ways to integrate two distinct architectures for seamless flow between low-level, small time-scale thinking with long-term analysis and planning.

Vision is more than just the traditional optics of the camera in my mind. Vision comes from any data that creates a physical map of the world both in depth and in color. To navigate, the vision system will include a mobile camera to track buoys and other markers and sensors to track the slope of the floor and the nearby objects above the surface of the water. This will allow the vehicle for fine navigation around and patterns through buoys, shore and depth following, and obstacle avoidance for the safety of the boat and others.

Project endeavors:

Most of my research was dedicated to creating the vision system, although it expanded to working on some system-level architecture within the Sense-Think-Act paradigm of Olin's Robotic brain and figuring out how to blend it with MIT's drastically different MOOS architecture. While the system has been tested in various ways, included some field testing from at dry dock, it was unfortunately not implemented on an autonomous surface vehicle due to various delays yet.

When working on the camera system, I created an algorithm to look for buoys in the water to determine both heading and a rough estimate of distance to the desired buoys. Because the camera is mounted on a pan-tilt unit, it goes through a sweeping search pattern while the boat is directed to move in spirals until the desired buoy is detected and is expected due to rough GPS coordinates. The system is programmed in LabVIEW, a graphical programming language developed by National Instruments. The buoy identification algorithm relies on color, luminance/hue, and position compared to the horizon to extract the size and position of the buoys. Because the system is in a highly dynamic environment for light levels, this vision system should be able to deal with conditions from 100 lux (dark overcast day) to at least 40,000 lux (direct sunlight). On the water, not only could the sun be shining into the camera, but reflection from the water, which could cause the camera to over saturate. In low light, it might not have enough contrast in the image. Analysis of the image determines the control of the mechanical iris of the camera, which controls how much light gets to the photo receptor of the camera. This self-calibrating system was tested by the water on sunny and cloudy days, and consistently spotted the buoys in both environments, but it needs to be exposed to a wider variety of conditions to hone the algorithm and see if more filtering besides the iris is necessary.

With buoys identified, the image is mapped back to the boat's coordinate system with IMU (Inertial Measurement Unit) information and known pan-tilt position. The heading of the buoys can be easily determined; however, determining the distance is more difficult, even if the buoy size is known because it is always partially obscured by the water by inconsistent amounts. The size is used to get a rough distance, but that guess is improved by determining how high the camera is from the water and seeing how much water is between the buoy and the boat. I started to investigate good ways to improve the efficiency of the vision system, since making a more robust algorithm lead to heavy computations that resulted in time delays not ideal for real systems needing reaction times less than a second. Determining selective computations to run instead of having all images go through the whole process improved things. I also worked on a way to thread the processes, which are great for the NI devices, and make use of FPGA's for some computations.

In an effort to create a robotic platform to test they system on the water, I helped make a small boat based on an Arbotix board that wirelessly communicated with the laptop. The boat was small enough to run in the indoor pool in the Large Project Building while waiting for a larger vessel to be up and running. I wrote an alternative hindbrain to communicate with the Arbootix board that used better programming practices for LabVIEW and would be easier to integrate into autonomous code. This was for the mini-boat, which was never made fully functional, but I got a cheap camera system up and running to be used on the mini boat. The image was not consistent (cut out some regardless of distance from sensor and not having things in its path). This could be due to the relative closes proximity of the transmitter to the motor controller and possibly sharing the same power supply. The image quality was also not very good and could not accurately and consistently see small buoys in the pool unless it was relatively close to them, even with large tweaks to the algorithm.

My vision processing base morphed to become a component on another vessel that we worked on with MIT. As a result, I translated the algorithm for python using OpenCV to be compatible with their system, but the rest of the code has yet to be translated. I also helped with the architecture communication to interface our Sense-Think-Act architecture with that of MIT's MOOS architecture. As I've learned, it is very valuable to assess the current system and find a way to make it compatible with others to make used of the strengths of both systems and work with other remote research groups.

As other facets to the vision system, I created a basic system reading SONAR data for tracking the depth contour under the boat so it can track a consistent depth and prevent running aground, damaging sensors and stopping the mission. The sonar side-scan sensor can be mounted under boats or other aqueous vehicles to image the sea floor by emitting sound waves in a flat fan shape and determining the distances to the floor. By analyzing the data from this sensor, it is possible to find how far the vehicle is from the floor at a point to the side and determine the depth of that point. Due to the bobbing and listing of the boat from the waves and wind, it is imperative to use an inertial sensor to adjust the point of reading the data. Based on the read distance, the boat will need to turn away from and towards the shore accordingly. A LIDAR mounted at the front of the boat also does basic obstacle avoidance to for safety reasons and will be expanded to shore following if there is vegetation to sense since it is a relatively short range sensor.

Future work:

Due to major delay issues with getting the research vessels up and running, the next step is to implement the system on a large vehicle on the water. The system needs to be tested for robustness in several environments (lakes, bays, harbors) and in various environmental conditions, specifically ones that test the optical system in various light conditions to ensure that the electrical and software controls systems allow for the highly dynamic light levels. Exploring a polarized filter for the camera could be a good rout if the system is not currently robust enough in that regard. I also will get the small boat fully functional as a good research platform for my project and possible other ones. Now that I've taken a basic controls class, I'd like to incorporate some of that knowledge to create smoother controls for reacting to the information from the sensors.

Reflection:

Coming to college, I planned on graduation and going straight into the work force without much of a thought to grad school since I wasn't sure I wanted to spend even more years in academia and working away in labs on projects that may or may not see the light of day. I wanted to jump into the workforce and start working on projects that would have direct applications to improve people's lives.

After my experience doing dedicated research and becoming more familiar with that field, I realized how great it was to dive into developing something new for the pure sake of exploration and furthering what is possible and allowing practical applications to grow from or be inspired by there. I am now planning on applying to grad school in parallel to a job search to see where I can continue my exploration of sensors in the robotics world. While I am unfortunately not extending my CBL, I am excited to continue to do research alongside my coursework in an effort to do the future work previously described.