MANTA RAY
Autonomous Surface Vehicle (ASV)

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Abstract

The purpose of the continued work on the Autonomous Surface Vehicle (ASV) is to improve upon the design from last year's team to allow the robot to fully enact a deployment sequence as well as achieving an autonomous path. With this year's progress, the ASV was able to fully deploy an unpiloted underwater vehicle (UUV) and autonomously navigate to a designated waypoint, along with fully integrating to using the Robotic Operating System (ROS). This progress is crucial to the MANTA RAY team since it furthers the ability of the network of marine robotics to accomplish more complex tasks and paves the way for future development.

Introduction

Team MANTA RAY is an interdisciplinary project dedicated to creating, maintaining, and expanding a network of marine robots for seafloor mapping and underwater perception. The network began as just the Autonomous Surface Vehicle (ASV) and Unpiloted Underwater Vehicle (UUV) but has expanded to include a prototype of the ASV, known as TUPPS, and two kinds of remotely operated vehicles, known as GUPPS and KRILL. With these systems, students work to improve communication between vehicles, develop autonomous behaviors and algorithms, and upgrade existing mechanical systems to improve precision and performance.

The ASV is a catamaran style boat measuring 7'9" in length and 5'6" in beam that was originally built by the 2017-2018 ASV team. It is driven by twin 55lb thrust electric trolling motors powered by two 12V batteries on the stern of the platform. The upper 'penthouse' platform houses the winch motor that drives our tether management system as well as our TTS setup that controls the amount of tether used by the UUV.

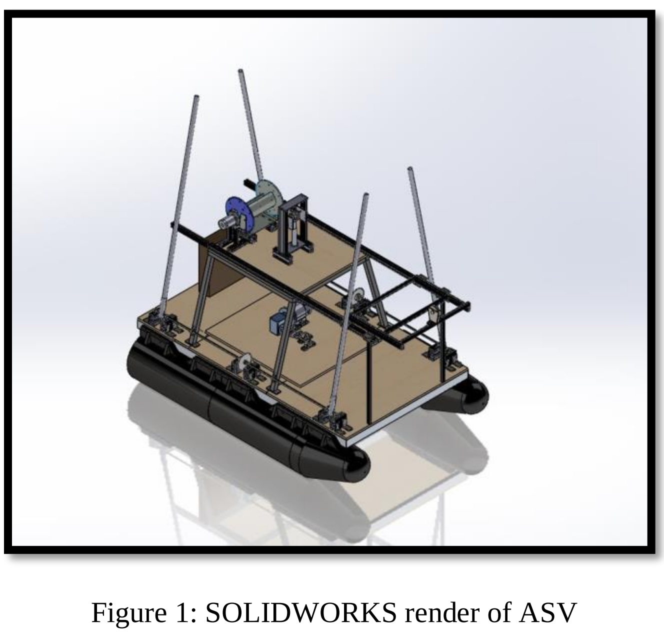

Figure 1: SOLIDWORKS render of ASV

The top of the TTS also houses the Pixhawk 4 that enables mission uploads and performs scripted autonomous navigation between pre-designated waypoints. It also contains a robust sensor suit that includes a compass, internal monitoring unit (IMU) and a GPS.

The importance of the ASV is primarily to deploy a UUV for various missions, and in the future to be able to host more than just one robot. The project was left off last year with a functioning platform for the subsystems as well as a trap-door style deployment system for the UUV and the beginnings of a design for the tether tensioning system (TTS) and underwater GPS system (UGPS). This gave the team a solid base to start out with as well as the intended purposes of the new subsystems. The electrical system was also fully working; however, better organization and optimization of the electronics would be required.

Objectives

The ASV mission for this year was to enact a deployment sequence to launch a UUV from the platform, perform mission functions autonomously, and to follow an autonomous path of pre-determined waypoints. These goals then required the construction or redesign of several subsystems, including the underwater GPS system, the tether tensioning system, and the deployment crane for the UUV.

Along with the construction of these systems, testing in both the Jere A. Chase Ocean Engineering Laboratory engineering tank as well as open water testing were planned to test ASV's functionality in a true water environment. Part of these tests would be deploying the UUV and sending it mission plans remotely via ethernet, as well as recovering it as part of the undeploy sequence.

Methods

One of the subsystems that required a redesign was the UGPS system. The purpose of this is to incorporate ultrasonic nodes that have the capability to triangulate the precise position of the UUV. This system allows for real-time tracking of the robot that is then relayed back to the shore station to provide this information. While this node system was not fully implemented electronically into the ASV, the mechanical system was put in place to house the nodes and wiring to later be implemented.

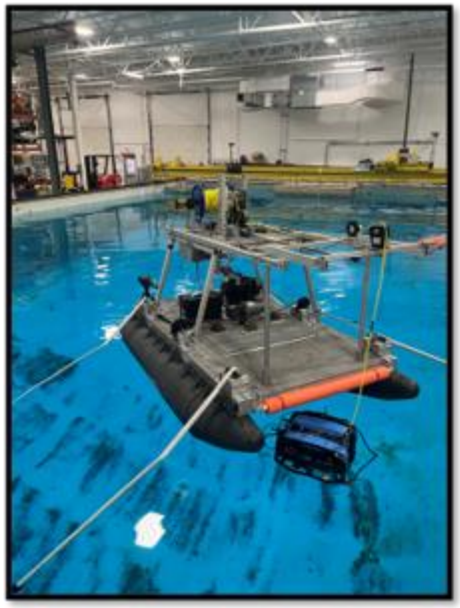

Figure 2: UGPS arms deployed in engineering tank while UUV is deployed

The system itself is four PVC pipes mounted on each corner of the ASV platform that rotate on a shaft to deploy the ends of the nodes housed in the pipes into the water. The pipes rotate downwards and lower into the water until they trigger limit switches that stop the motor and lock the arms downward. Similarly, when the arms retract, they continue to move up out of the water until triggering limit switches mounted at the top of the ASV to halt the sequence. Both of these sequences are part of the fully functioning deployment and un-deployment sequences.

The UUV needs to launch over the front end of the boat to enter the water. One achieves this using the Deployment Crane. The deployment crane is a linear actuator that has one open and one closed magnetic limit switch to turn off the motor upon it reaching its final location. This system is an assembly made of 8020 components and pulleys.

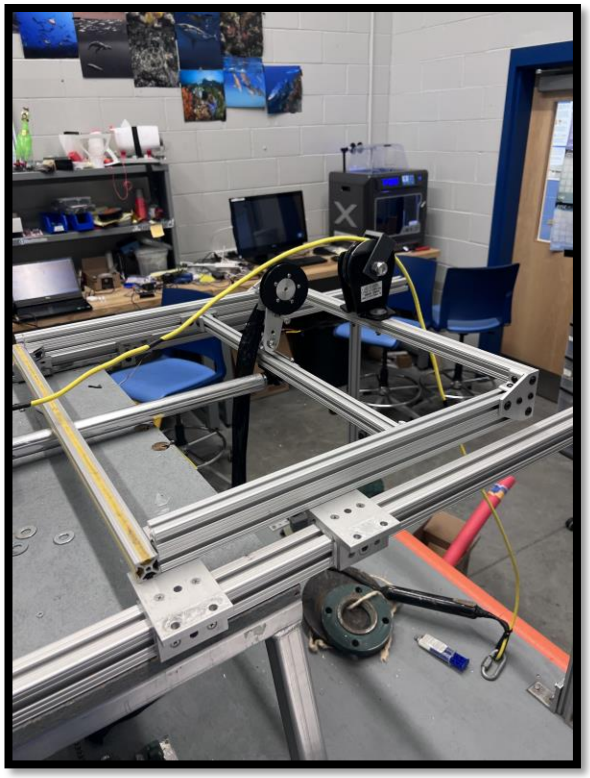

Figure 3: ASV Deployment Crane in the retracted state

When deploying the UUV using the crane the winch needs to be spooled out to maintain proper height of the UUV. In order to attain this a rotary encoder is mounted on the crane such that if the rotary encoder sense movement it spools out the winch to match the amount of rotation on the encoder. This maintains a constant height of the UUV throughout the deployment sequence. The rotary encoder also tracks the amount of line that has been deployed to ensure the system does not spool out too much line and that the system is able to retrieve the UUV to the proper height each time.

Upon deploying the UUV there needs to be a way to manage how much line has been deployed so that the UUV is capable of navigating under water without tangling in its own tether. To maintain a proper tether length the Tether Tensioning System or TTS was created.

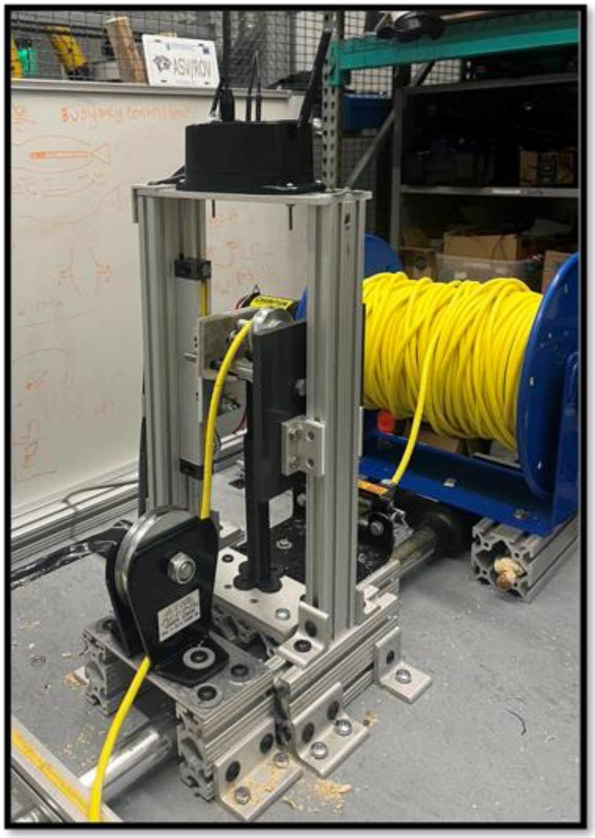

Figure 4: Tether tensioning system

This system measures the amount of tension on the line and spools out or in the tether to maintain a constant tension. This is accomplished using a pully attached to the top of spring with a linear encoder reading how far the spring has compressed under the tension of the UUV pulling. The Tether Tensioning System is not needed during the deployment sequence until the very end and thus there are two main stages of the deployment sequence with the second one being called “Constant Tension Mode”.

$$M\ddot{x} + B\dot{x} + kx = (K_P e + K_I \int e\,dt + K_D e) \cdot cos(\theta_1) + T_2 \cdot cos(\theta_2)$$

$$e = x_{des} - x_{actual}$$

$$M\ddot{x} + B\dot{x} + kx = T_2 \cdot cos(\theta)$$

Figure 5: Series of equations necessary to create the PID function

Constant Tension Mode is utilized after the crane has fully deployed and it enables the system to start responding to the feedback given by the TTS. This system works to maintain a constant and predetermined tension on the line. This Constant Tension Mode can also be activated through the GUI button labeled “Tension”. In order for our UUV to be able to drive seamlessly through the water and not get hung up with slow processing we implemented a PID controller into the system. A PID controller is a type of coding that uses calculus to make predictions as to the response of the system and swiftly and smoothly operate the motor to maintain control of the system.

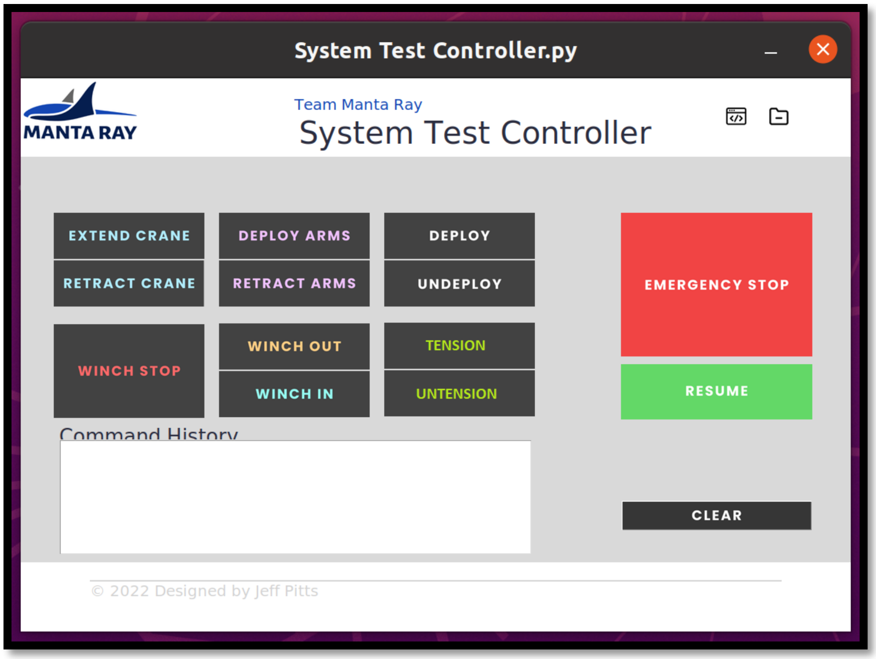

Figure 6: GUI to operate with ASV

In order to have the ability to wirelessly communicate with the vehicle and trigger commands for functionality of various subsystems, we are using an operating system called ROS. ROS or Robot Operating System is a simple protocol for sending ROS messages over a serial network interface allowing commands to be called and trigger functions. For this application, we are using a Raspberry Pi serial connected to an Arduino Mega 2056. Using rossserial which is a client of ROS, creates a series of nodes which are called ROS Topics and allow for serialized commands to be called based from their specific functions on the Arduino.

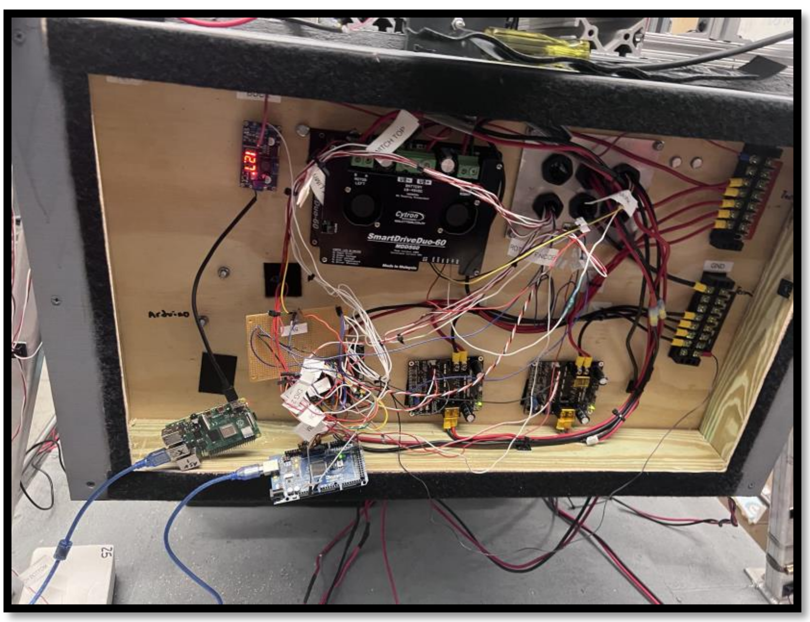

Figure 7: Full electronics box layout created this year by our team

For our application of ROS, we have created a series of eight different topics, each with a very important function for our usage. For starters, it is essential with an autonomous vehicle that we have an Emergency Stop function, which kills any command being run and can only be cleared by sending a resume command to the ROS network. On top of this, we have our Deploy and Undeploy commands which respectfully complete an autonomous sequence of releasing and retracting our unmanned underwater vehicle from the ocean.

For debugging purposes, we have a status update allowing us to ensure that each function completes when required to and can help us to understand if we have any hardware or software issues. This enables us to provide a surface vehicle capable of successfully supporting the UUV in a redundant and reliable environment where we can maintain control of every function the ASV provides.

We have also added the necessary framework to enable us to trigger functions like our Active Tension Mode which runs a PID loop based on readings from our linear encoders using buttons on the GUI. A GUI is short for a graphical user interface, and we have coded in buttons which call ROS commands which saves us a lot of time trying to manually call the commands separately. We have turned the rotary encoder into a publisher which is acting as a listener and actively tracking how much tether has been fed into the water when deploying the UUV and accurately allows us to spool the exact amount of tether that was fed in, out again.

Results

The deployment sequence was a success with the rotary encoders integration with crane deployment working seamlessly. We were able to consistently track the amount of line spooled out which enabled us to retrieve the UUV to the proper height each time.

Constant Tension Mode was a success. We were able to create a system that responds to our increased and decreased tension allowing us to maintain a proper tension at all times. The PID controller worked with us only utilizing proportional and integral control. There is more tuning that can be done with the PID values for the TTS that would improve the functionality of the system.

The ASV was tank tested in the Jere A. Chase Ocean Engineering Laboratory engineering tank to test each of the subsystems, the controls, and to fully deploy the UUV in a safe and controlled environment. The full deployment and unemployment sequences were tested successfully and the UUV was deployed with the ability to communicate via ethernet through the winch tether.

In addition to tank testing on campus, additional testing was done in open water at Swain’s Lake in Barrington, NH. This not only allowed us to fully test the subsystems in a realistic environment, but to also test the range of communication with the ASV from a shore station.

Discussion

Our results have proven that UUV deployment is possible for our ASV system, and a complete autonomous mission would likely be successful. Our ASV has passed the tests that we have put it through, and we are ready to upgrade our craft to better suit higher sea states.

Conclusion

Throughout the two semesters of work on the project, the ASV was able to successfully enact the deployment and undeployment sequence for the ASV to launch the UUV. This deployment sequence included deploying the UGPS arms, extending the crane with the constant tension mode of the TTS, and lowering the UUV safely into the water. These sequences were able to be called through the ROS integrated GUI from a shore station. Furthermore, an autonomous path was achieved through testing at Jackson Estuarine Laboratory in the summer by pre-designated waypoints.

Some of the next steps that are recommended for this project are to change the overall platform that the ASV is on to better organize the subsystems and electronics, as well as to incorporate the deployment of multiple UUVs. To fully encompass the MANTA RAY mission, the ability to deploy multiple robots off the ASV platform, including potentially working with the drone swarm team would be ideal steps for the future.

Figure XXX: Potential test site at UNH Pier located in New Castle, NH

Other changes would include switching to radio communication to the ASV to increase range when conducting open-water tests. While the team has not yet found the limit of the range of communications with the ASV from a shore station, radio would undoubtably increase the range while open water testing. More water tests, both in tank and ocean, are recommended to identify more changes that should be made to the ASV.

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