Journal Paper for California State University, Fullerton: Titan AUV

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***Abstract*— Titan AUV is the first Autonomous Underwater Vehicle designed by five Computer Engineering students from California State University, Fullerton to be used in the 2018 RoboSub Competition.**

I. Competition Strategy

This is the first year that California State University, Fullerton will be competing in the event. The team is composed of undergraduate students of the Computer Engineering department. To accomplish the competition goals, the team approached the competition strategy much like the actual competition, by breaking the whole competition into individual tasks in the same order as the competition itself. The first team objective was to get a working AUV and several decisions had to be made with regards to parts and AUV design.

The AUV frame design was based on the number of thrusters being used. The Titan AUV has a total of six T-100 thrusters with forward and reverse capabilities. Budget constraints limited the number of thrusters that the team could use, after careful research and considerations, the team concluded that six thrusters would be the ideal number of thrusters to provide the needed AUV mobility. As far as mobility, Titan AUV has a full range of maneuverability which allows for forward, reverse, upward, and downward movement as well turning and lateral movement. Multiple thrusters would be on while performing these maneuvers which meant that the thrusters would not be under heavy stress during operation. Thruster positioning determined the frame design, the team opted to use a PVC frame because it is lightweight, easy to work with and durable.

The Jetson TX2 controls the vehicle using Robotic Operating System (ROS) to communicate with different components of the vehicle. The Jetson TX2 is a budget alternative as NVIDIA provides students with a 50% discount. Aside from being inexpensive, the Jetson TX2 compatibility with ROS allowed the team to understand the basic concepts at a faster rate. The Jetson TX2 acts as the brain of the vehicle which communicates to two different Arduino Mega 2560 and receives information from the camera. Also, to stabilize the vehicle underwater, the team went with an inexpensive IMU, the SparkFun 9DoF Razor IMU. Elevated at the center of the vehicle, this IMU communicates with the Jetson through a library provided by ROS.

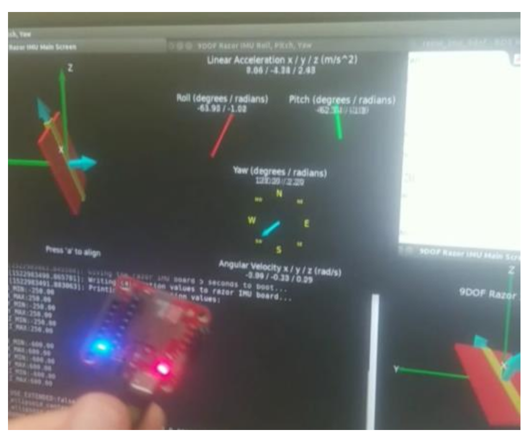

Figure 1. Test of the IMU with the Jetson TX2

With limited budget, the team opted to not use hydrophones on the AUV and instead focus only on image recognition to find the tasks. Although the team will be primarily focus on completing the tasks that do not require hydrophones, an attempt to locate the hydrophone tasks will still be made using only image recognition. The AUV uses 3 cameras. Two Logitech C920 cameras are placed on the front at a 15-degree angle and open BlueRobotics USB Low-Light camera facing directly downwards. The two cameras at the front will be primarily used to locate the next task and determine how far the task is from the AUV. The other camera will only be used for tasks such as the roulette table, cash in, and path markers to help determine where an item needs to be dropped or align the AUV with the direction of the path marker. A TensorFlow model is being used to initially detect where the tasks are. To train the TensorFlow model, the task objects were built for the AUV to take pictures of them underwater. After the AUV recognizes a task it uses a combination of color and distance detection using the OpenCV library to determine how complete the task.

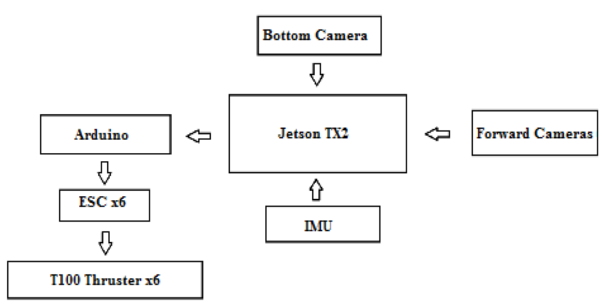

Figure 2. Block Diagram of the Connections for the Jetson Tx2

Without the use of hydrophones, the team has decided to focus on the slot machine and the shoot craps tasks. After passing under the gate and following the path marker, the first task the team AUV will complete is the shoot craps tasks, in which the cameras have been trained to recognize the number six and five to obtain the most points.

The next design consideration the team focused on was on the buying the gold chip task and the play slots task. For these tasks, the team decided to use a stationary arm that is responsible for pressing the plate in the buying the gold chip and pulling the lever during the play slots task. Due to budget, and time constraints, the team decided to implement the stationary arm over a servo-controlled arm. A substantial amount of emphasis had been placed on navigation, so the team decided to use the AUV navigation to control the stationary arm.

The team designed a tray in which the golf balls would fall after the plate is pressed. The tray was designed so it would not matter if the dispenser is inline with the push plate or it is at 90^{o} to the push plate. The tray allows the golf balls to flow into a two-inch PVC pipe that leads to the bottom camera and it is set ready to be released at a later task using a servo. The team designed a spring powered system to be used during the play slots task. The system the releases a set of two torpedoes via a single servo. To accomplish this task the AUV navigates itself to press the lever down, repositions itself to find the slots, and finally the torpedoes are launched.

II. Design Creativity

As a team composed of only Computer Engineers, building the frame and making the hull waterproof proved to be a challenge. After researching different types of materials to use for the frame, different ways of placing thrusters on the frame, and with some help from the school's machine shop to get the flanges milled out of aluminum, the team was able to overcome this challenge and build the external and internal frame. Waterproofing the connections for the cameras and servos took a couple of attempts; each time learning from any mistakes made previously. This experience allowed the team to challenge themselves and learn more about other areas of engineering.

Figure 3. The Frame of the vehicle

Distributing power throughout the entire vehicle became a challenging task when the team first decided to use the Jetson TX2 because it requires an AC connection while the batteries the team had were DC batteries. That became an easy solution when the team decided to use an Energizer XP 18000A Power Pack with a custom-made connection for the Jetson that was provided by the Institute of Navigation at CSUF. That same organization lent the team two Gens Ace 5000mAh 11.1V 40C LiPo batteries, which reduced the cost of the budget quite significantly. Each one of these batteries is connected in parallel to provide 11.1 V to three of the T!00 thrusters. The Jetson is used to power the three cameras, the IMU, and two Arduinos via USB.

III. Experimental Results

The hardest challenge the team faced was estimating the amount of time left for testing. When the team first began working on this project, most of the time was dedicated towards research on building an underwater vehicle. This was tougher than expected as the team only consists of five undergrads in the field of Computer Engineering and had to knowledge of designing a vehicle. Once the team had a basic understanding, the purchase and testing began; but with limited budget, this had to be done perfectly.

To make sure the thrusters functioned and did not arrived damaged, each one was tested by placing them in a container filled with water. Once the end caps were milled out, the hull and the front facing camera enclosures were also tested with the container of water to make sure the enclosure did not leak. The hull did not leak, but there was an issue with weather-strip of one of the camera creating a tight seal. After replacing the weather strip, it did not leak anymore. Although this was a simple test, it was necessary to make sure no expensive components would end up water damaged.

The first underwater test using object detection had some issues. The TensorFlow model would return too many false positives. The model was trained with very few images under only one type of light condition, this ultimately caused this issue. The second TensorFlow model is still being developed with more images per task object and different light conditions to return a more accurate result. In the first test, the distance detection was also tested and had more promising results then the TensorFlow model. It was returning accurate distances to an object when the model was able to recognize a task. The color detection part of the program also had an issue with light condition. The settings had to be changed to get the correct color to be recognized. This is an issue that is also currently being addressed since the lighting varies depending on the time of day and weather.

The second underwater test will be three weeks before the competition. The test will involve testing the latest implementation of the program focusing on getting the AUV to complete the qualifying maneuver. The issues with the TensorFlow model and different lighting conditions when using color detection will be checked to make sure they have been fixed or improved upon. A couple updates have also been made to the thruster control which will be test as well. The updates should help keep the AUV more balanced when moving.

IV. Acknowledgment

The Titan AUV team would like to thank the Institute of Navigation at CSUF and CSUF’s Computer Engineering and Mechanical Engineering departments for supplying materials, lab space, tools and funding.

V. Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Cost (if new)
Frame		PVC Tubing		$75
Waterproof Housing	Schorr Metals	Aluminum		$55
Waterproof Connectors	BlueRobotics			
Thrusters	BlueRobotics	T100		$864
Motor Controller	Arduino	Mega 2560		$60
Battery	Gens Ace	LiPo Battery	5000 mAh	
Convertor	Energizer	Power Pack	18000: A	$90
Computer	NVIDIA	Jetson TX2		$350
Programming Language 1		C++		
Programming Language 2		Python		
Inertial Measurement Unit	SparkFun	Razor 9DoF		$80
Camera(s)	Logitech	C920	USB	
Camera	BlueRobotics	Low Light HD	USB	$90
Team Size	5 members			
Testing Time: in water	3 weeks			