Danger 'Zona^2 Design Overview

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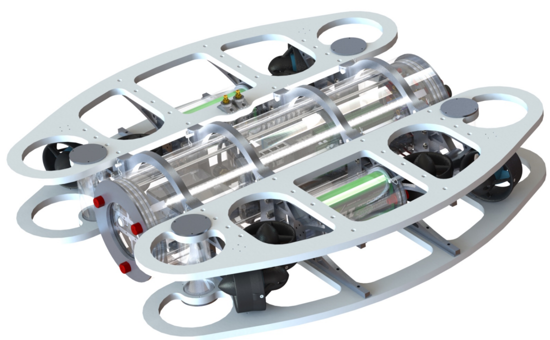
***Abstract*—Our autonomous underwater vehicle maintained several of the practical systems of our previous years robot making improvements where necessary. The main electrical housing compartment was modified to allow easier access to implement adjustments as well as quicker maintenance of parts. Removing the housing for the doppler velocity log permitted reduction of the weight and height profile to the vehicle.**



I. Introduction

For the 2016 RoboSub challenge, *A Pirate's Life for Thee*, the Autonomous Underwater Vehicle team at the University of Arizona (AUVUA) presents Danger 'Zona 2 (DZ2), an upgrade from its 2015 predecessor, Danger 'Zona (DZ). The new vehicle contains similar electronics, but with a redesigned frame, updated primary hull, and a software overhaul. The vehicle has been designed for easier access to the electronics by allowing the primary hull to be detached from the frame via four quick-release clamps. The system voltage has been increased for higher thrust while reusing DZ's BlueRobotics T100 and T200 thrusters. The software has migrated from a custom Java solution to Robot Operating System, which abtracts away complex interprocess communication and provides a variety of open-source packages for stereo vision, mapping, logging, simulation, and more. The overhaul of DZ will provide the team a robust testbed for research over the upcoming year.

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II. Mechanical Design

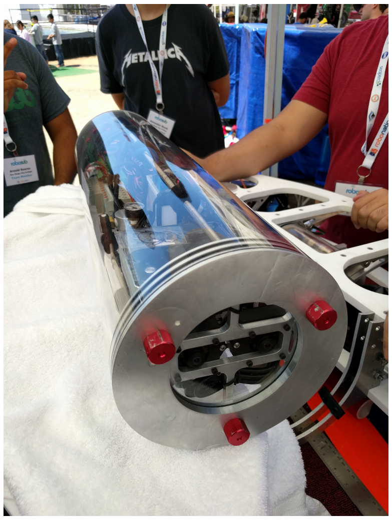
The goal this year was to redesign the frame with the intention of foregoing the Doppler Velocity Log for a slimmer vehicle. Additionally, the team learned from the last vehicle that HDPE is easily machined, neutrally buoyant, and cheap. However, it tends to warp when thin and long, so the team took material thickness and geometry into heavier consideration when creating the design. The two main issues with the primary hull were visibility (from frequent removals) and inner diameter (hard to maintain), which were solved with a cast acrylic tube.

A. Frame

The biggest drawback of the previous frame was accessibility. Though material choice greatly simplified design and machining time, the interlocking design precluded the ability to easily access the main hull. This made adjustments to electronics difficult in both competition and regular maintenance. The new frame design focuses on accessibility; eight cotterpins and three bolts are the only barrier to entry of the electronics, which can be accessed away from the frame.

The frame is constructed with two materials: HDPE for the horizontal 'wings' and aluminum 6061 for the vertical supports, clamps, and endcaps. HDPE (a slippery plastic used in cutting boards) was relied upon heavily for DZ and simplifies the design by having a neutrally buoyant density and being easily machinable. Aluminum is used for the vertical supports and clamps to minimize the footprint of the vehicle while maintaining rigidity along joints.

B. Housings



Electrical Housing

1) Primary Hull: The main hull is composed of a 0.25" wall, 7" OD cast acrylic tube housing three connecting rods for mounting electronics and pneumatics. The tube is mounted to the vehicle with four removable top clamps for easy access, each with a strip of neoprene to constrain the tube when in use. Felt attachments on the connecting rods ensure a smooth positioning of the tube, a feature sorely lacking in the previous vehicle that caused excessive amounts of scratching and impeding vision. Both endcaps use double o-ring bore seals.

The hull is secured with three sealed bolts at the front endcap. The bolts thread into a plate which is rigidly attached to the back endcap via three threaded connecting rods. This allows the hull to be closed without external rods or clamps.

The rear endcap contains all bulkhead connections for the primary hull, including eight cable penetrators for thrusters, six auxiliary penetrators, eight push-to-connect fittings for pneumatics, two large SubConn connectors for the ethernet tether and hydrophone assembly, and charging and venting ports for the pneumatic system. A bracket spacing the connecting rods is mounted on the end and fastens into the endcap, allowing the main electronics to disconnect easily from the frame and its fixed electronics.

The front endcap contains a thin polycarbonate window with an o-ring face seal. A retaining plate ensures a robust connection. The camera mount performs the same function for the front endcap as the rear spacing bracket, while also providing threaded connections for the sealing bolts.

A thick polycarbonate sheet is used to support all electronics and pneumatics in the hull, with the exception of the LEDs. Mounting of the electronics is accomplished with 3D printed brackets specially designed for each component. This allows for easy positioning of tightly integrated parts, and the rapid prototyping means adjustments to the design are less cumbersome. The LEDs are mounted along rails attached to 3D-printed rings.

2) Battery Hulls: The battery housings are mounted on the sides of the vehicle. Cutouts on the longer aluminum stabilizers are used to captivate the tube while clevis pins retain their position, making for quick re-installation. Each compartment houses one battery, and a cable penetrator supplies power through the main bulkhead.

C. Actuation

This year the team made a push to include actuation beyond movement for the first time. Pneumatics are fully plumbed, and the torpedoes and markers were designed pragmatically to allow for greater margins of error leading up to the competition.

1) Thrusters: DZ2 uses four Blue Robotics T100s and four T200 thrusters for vertical and translational movements, respectively. The T200 thrusters are mounted in a vectored arrangement at 30 degrees from forward for a simplified and symmetrical thrust scheme. Frame components such as the vertical supports are designed to allow unobstructed water flow through the vehicle. The thrusters are all mounted in the same plane to minimize vehicle height. This lowers the stability of the vehicle, removing control of the robot from gravity and bringing it into the realm of the software. The thrusters are also placed on the outer corners of the vehicle. These two design choices provide the opportunity to ambiguously orient the vehicle with little cost on energy to maintain the position.

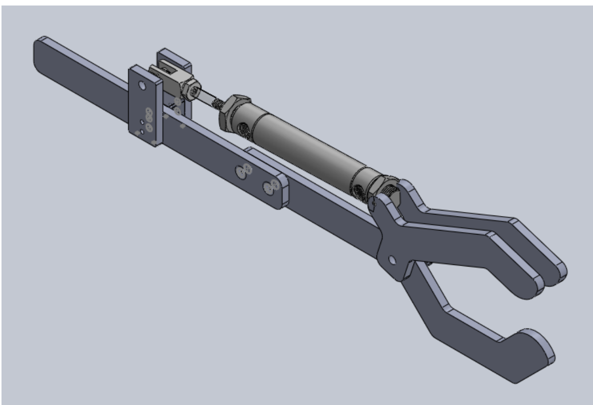
2) Torpedoes and Markers: The vehicle features pneumatically actuated torpedoes and markers for the Set Course and Weigh Anchor tasks. Pneumatics are used because the footprint, cost, and design time are low relative to alternate methods.

The torpedos are constructed from HDPE rods. Much like the frame, HDPE is chosen for its neutral buoyancy, which has a greater impact in the case of torpedoes. The slightly positive buoyancy allows the torpedoes to be easily retrieved after use. Both torpedoes are housed in a single polycarbonate tube and are retained using neodymium magnets in the nose and tail. Air is pumped into the cavity between torpedoes to launch the first and from the back to launch the second.

The markers are housed in two smaller tubes to the side of the main hull and close to the bottom-facing camera. Each is retained with magnets and released in the same fashion as the torpedoes.

Torpedoes Housing

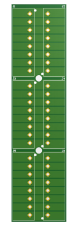
3) Claw: The design and fabrication's process for DZ2 will be upgraded for the following year's competition. The system will include three main components: main arm, arm extension and gripper. The claw will be designed to operate with the support of two pneumatics, one located at the main arm allowing for a 90 degree vertical movement. The second pneumatic being attached to the gripper will allow it to extend in a pivoting distance with a minimum radius of one inch to a maximum radius of approximately 4.0 inches. The incorporation of these pneumatics will allow the claw to grasp objects in front of DZ2's forward facing cameras as well as directly below the robot. Implementing the arm extension will provide a better view of the gripper in order to allow better accuracy.



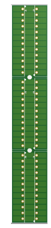
Claw

As of this year's competition the team designed a static claw located at the front of the robot. DZ2's claw is composed of two parts: a hook and an arm. The hook has two inch radius and the threaded rod arm has a length of 12 inches. Using the maneuvaribility of the vehicle and the slenderness of the claw the platform will be able to interact with any and all items required of it.

Static Claw



(a) Connectors Board A



(b) Connectors Board B

III. Electrical Design

The goal this year was to improve the modularity of electrical connections for ease of access and update the existing circuit boards. We started this process by implementing modified, improved and revamped improvements on our existing three custom PCBs and by looking at the overall framework of the electrical design. A flowchart was created in order to clarify and organize the layout of our overhauled system.

A. Custom PCBs

With generous donations from Altium and Advanced Circuits, the team has created five custom boards, some built off prior designs. A power distribution board is used to supply current from lower voltage rails and for sensitive electronics. An actuators board is responsible for controlling ESCs at a low level as well as powering pneumatic solenoids and auxiliary switches. A sensors board, designed as an add-on for a Raspberry Pi 2 or 3, interfaces a 9-axis IMU, depth sensor, pneumatic pressure sensors, and humidity sensor to the rest of the system. While the previous boards all received updates from last year, two additional boards were made for providing quick-disconnect functionality to all electrical interfaces in the main hull. These boards are crucial for maintenance of the electronics, which would otherwise be tethered to the rest of the vehicle.

B. Power

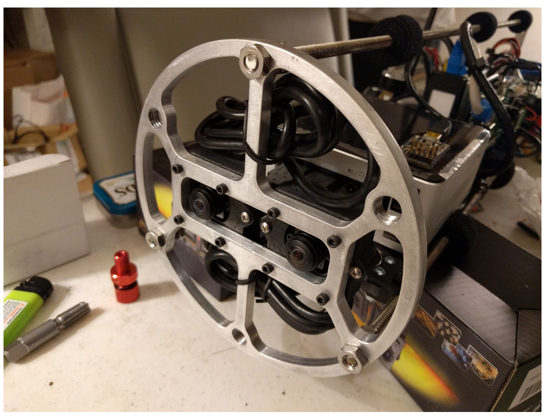
This year, the team switched from 3S lipo batteries to 4S (16 volts). The increase was dictated by a desire for a faster vehicle. Additionally, the batteries were readily available and increased the runtime of the vehicle slightly. All electronics on DZ2 are tolerant of both voltages, so the switch was a low-risk design consideration.

C. Sensors

The vehicle contains all necessary sensors for operating in an underwater environment, including an MPU-9250 9-axis inertial measurement unit and a BlueRobotics depth sensor. Additionally, a humidity sensor is used to detect critical leaks, and current sensors on various boards are used to track battery usage.

Last year, GoPro Hero 3 cameras were used for vision. While this significantly increased performance compared to USB cameras without exceeding the cost of COTS machine cameras, the interface was lacking and required addional HDMI capture cards and dedicated software. This year, the team opted for a simpler camera solution. Three wide-angle USB board cameras, roughly one-fifth the cost of the previous setup, are used for forward stereo vision and downward viewing. The cameras use standard interfaces for Linux, making integration with ROS straightforward.

In order to conserve space, the team opted against using a generously offered DVL from Carl Hayden Robotics. Instead, a camera-based software solution will be developed for current and future years to map the environment and localize the vehicle.



Foward Facing Cameras

IV. Software Design

A. Robot Operating System

At its core, ROS is a collection of libraries, binaries, and build tools for creating processing elements called **nodes** that can communicate via TCP sockets with little forethought. **Topics** are used to pass data in a publish/subscribe relationship between programs. A parameter server allows the architect to modify values between or during rus.

B. Simulation

V. Conclusion

The software on this year's robot was updated from java to ROS for simplicity, a more extensive function library, and improved camera vision. A more modular, accessible, and lightweight frame was designed and manufactured by the team at our machine shop. The electronics systems are heavily based in the same platform as our previous robot with a few new custom made PCB boards. These PCBs allow for rapid integration and removal of the majority of our systems. This years robots sees actual integration of torpedoes and markers into platform. All of these changes coalesce to produce the Autonomous Underwater Vehicle of the University of Arizona for the 2016 RoboSub competition.

Acknowledgment

References

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.