Design of an ROV for Precision Sea Floor Vehicle Mobility and Entry in the 2009 MATE International ROV Competition

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Abstract- **The main goal of this project was to engineer a Remotely Operated Vehicle (ROV) to compete in the 2009 Marine Advanced Technology Education (MATE) International ROV competition. The vehicle was designed to operate in a submarine rescue fashion, while maintaining the maneuverability and precision actuations of a normal ROV. The vehicle has been designed for the efficient completion of tasks that a rescue ROV may have to perform. These tasks range from surveying the submarine, opening a hatch and inserting emergency supplies, supplying an airline, and providing a transfer skirt for rescue.**

I. Introduction

Each year MATE has an ROV competition for students in which the students must perform specified missions based on real world scenarios [1]. This year the mission is a mock submarine rescue with 4 main tasks (Fig. 1). When working to rescue the crew of a submarine on the sea floor additional care must be taken. Many tasks need to be completed precisely or a major mishap such as death or injury could occur. With that in mind PantheROV-V was a major redesign of its predecessor PantheROV-IV, which competed in the 2008 MATE competition [2]. The main goal was to design a vehicle that was more stable and was able to successfully complete underwater rescue missions [3].

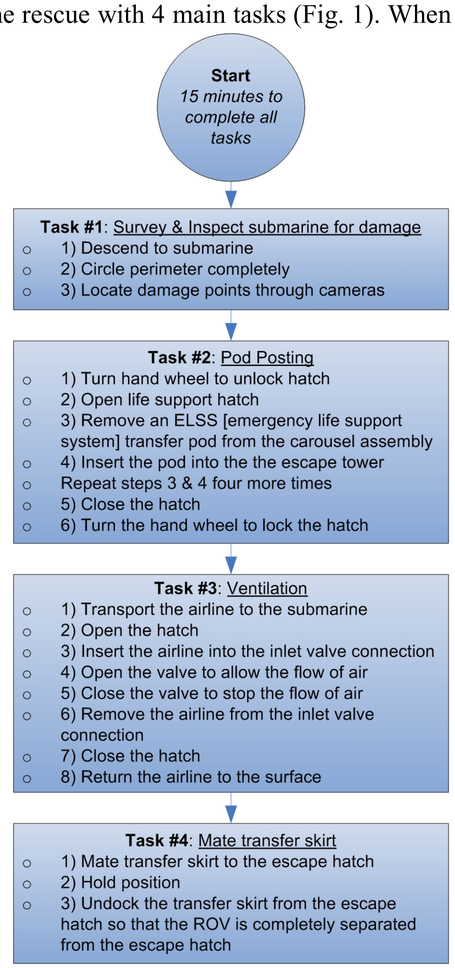

Figure 1 – Competition Task Flow Chart

II. Design Rational & Construction

A. Tracks

PantheROV-V incorporates a versatile track system to crawl on the bottom of the sea floor to complete rescue missions (Fig. 2). These tracks provide a stable platform for the vehicle to execute precision manipulations while drastically reducing positional drift when compared to a free floating vehicle. To further facilitate recovery, the tracks are wide enough so the ROV can crawl over a submarine hatch and accurately position a rescue transfer skirt. Since the rescue ROV is a hybrid crawling robot as well as a swimming robot, neutral buoyancy must be maintained. When in "tank mode" the vertical thrusters are constantly used to keep the ROV on the bottom. When on the bottom, the tracks utilize skid steering to precisely maneuver along the bottom much like a tank would.

The tracks are composed of a rear driven sprocket, which is directly coupled to a geared DC motor. The front sprocket

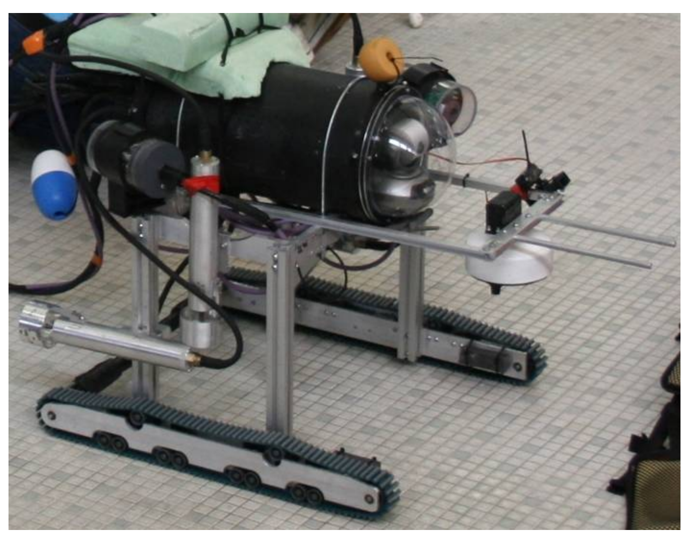

Figure 2 – ROV pool side ready for competition

spins passively with the tracks. There are 4 load bearing idler wheels in between the sprockets to evenly distribute pressure to the ground.

B. Thrusters

The thrusters are designed to be compact and lightweight so they can be mounted just about anywhere on the ROV. The motor used is a brushless DC motor with attached reducing gearbox, both contained in a watertight pressure canister. A propeller is placed within the throat of a converging diverging nozzle to minimize thrust losses off the tips of the propeller by directing thrust backwards. The nozzle also increases the thrust by using principals of conservation of mass with respect to flow rate. As water passes through the nozzle, the cross section gets smaller until it hits the propeller. Since water density remains the same the water is forced to speed up just before it hits the propeller, increasing the amount of thrust produced [4]. This works at slow speeds because the extra thrust produced is greater than the extra drag produced by the nozzle.

C. Manipulator

The manipulator for PantheROV-V is a completely new design from previous years. It uses a linear actuator and a servo motor to function both as a translator and a rotator (Fig. 3). The manipulator arm will be used to grab the pods (small objects) and place them into the simulated hatch. To do this we made two slender rods to skewer the pods much like a fork would be used (Fig. 4). The skewers will be lined up with the hooks on the pods by using our tracks to carefully maneuver the vehicle into position. Once everything is lined up, the ROV will crawl forward, impale the pods, and then the linear actuator will raise the skewers to hold the pods on the vehicle. From here, it will drive to the hatch and deposit the pods by reversing the procedure.

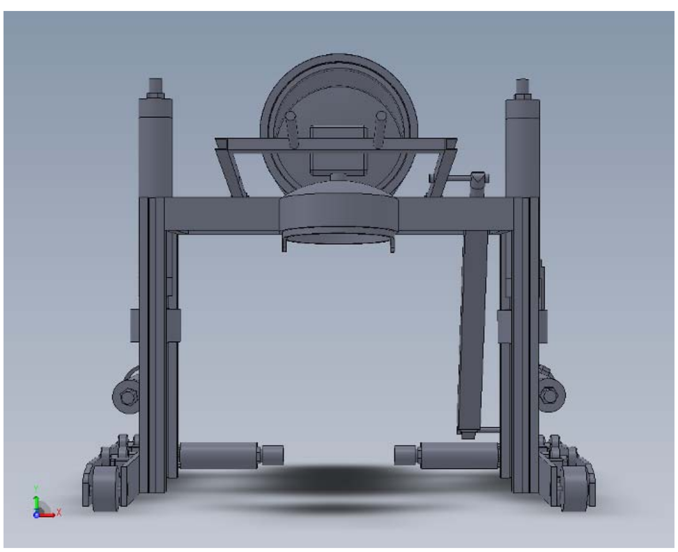

Figure 3 – Front View

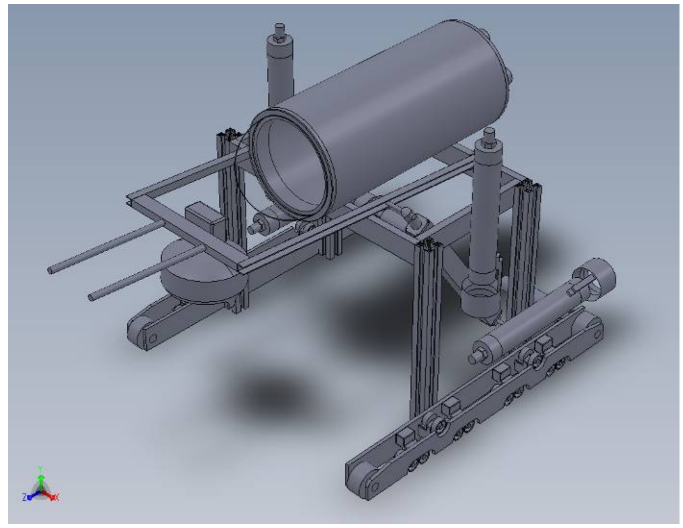

Figure 4 – Isometric View

D. Video

The vision system of the PantheROV-V consists of Ethernet-enabled web cameras, which allow all video from the vehicle to be transferred to topside using a single Category-5 cable. In contrast analog cameras require a separate coaxial cable for each camera, our design connects all of the cameras to a single Ethernet switch with patch Cat-5 cabling and a single shielded Cat-5 cable is sent to the surface (Fig. 5). This system greatly reduces the size of the tether permitting greater maneuverability of the vehicle.

E. Electronic Overview

The vehicle system is basically an Ethernet network with several subsurface nodes, the onboard microcontroller and the video cameras that communicate with a surface node, a laptop computer, via the Cat-5 cable in the tether. The onboard microcontroller (Rabbit RCM3700) receives user commands, controls the motors, reads the sensors and sends the sensor data back to the user. The RCM3700 communicates with a second microcontroller that generates PWM signals to control the speed and direction of the motors that drive the thrusters, tracks, servo and linear actuator. An integrated sensor module is mounted in the front of the vehicle to provide yaw, pitch, and roll data. This information is critical for determining if the ROV is firmly planted on the bottom. The surface laptop computer acts as the user interface. The pilot views video and sensor data on the computer screen and commands the vehicle via joystick or keyboard input. Power is provided to the vehicle from a topside 48 VDC supply via power lines in the tether. Onboard voltage regulators convert the 48V to 12 V to power the motors and linear actuator and 5V for the servo and vehicle electronics.

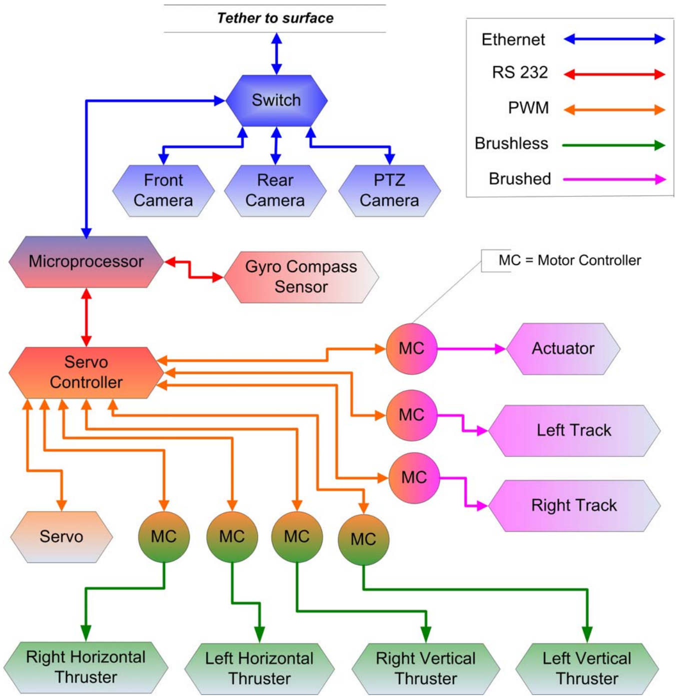

Figure 5 – Internal ROV Signal Diagram

III. TESTING, PERFORMANCE AND CRITIQUE

A. *Dry Test Results*

During the build and upon completion of PantheROV-V various tests were conducted to design and create an optimized vehicle for the competition missions. Control of the new track system, arm actuator and servo were tested on the vehicle. During our initial dry test we discovered unpredicted movements in the actuator and servo for our manipulation. A major troubleshooting technique used on PantheROV-V was to work backwards to isolate the point of "trouble". All connections were verified and an oscilloscope was used to probe the signal from its origination towards the actuator and servo. Viewing the initial waveforms, it was discovered that noise was being generated by the motor controller for the actuator through its line to the arm. The pulsating power signal to the actuator was providing a "ghost" PWM signal through the servo line. We then eliminated the noise with a capacitor, which acted as a low pass filter for the signal. After resolving interference within the communication lines, the vehicle was tested for the specific missions on dry land.

The vehicle successfully maneuvered around the hatch into position with its tracks. Through remote control, the arm successfully actuated the lock and opened the hatch. This test confirmed the designed abilities of the vehicles manipulation and stabilization system.

B. *Qualification Results*

In order to compete at the MATE International ROV Competition the Explorer vehicles must qualify. The Qualification consists of proving the vehicle's ability to ascend, descend, and drive forwards and backwards the length of the tether. Additionally, the vehicle must be able to unlock and open the hatch, which is part of the specified mission.

With our qualification our vehicle was able to successfully unlock and open the hatch underwater; however, we concluded the positioning of the center of buoyancy and mass needed to be adjusted to optimize traction of the vehicle's sub-surface drive system. For the qualification of the vehicle's mobility, drag on the tracks was an issue of concern while using the thrusters. With the slim design of the tracks the drag proved to be minimal and longitudinal movement worked well. One problem was encountered where a thruster obtained a leak due to a faulty o-ring; however, the vehicle was able to successfully prove mobility while driving with one less thruster. This allowed us to create a slightly negatively buoyant vehicle, while still being able to maintain ascend ability, to ensure proper traction on the bottom of the pool.

C. *Pre mission Test Success*

Prior to the first mission at the competition, a pool test of the vehicle was done. Each of the vehicle's control systems were tested and seemed to be working properly. Only minor adjustments were made to the vehicle. Confidence was high at this point and the vehicle appeared to be working properly (Fig. 6).

D. *Mission 1: Thruster Failure*

During the first mission the vehicle descended successfully to the mock submarine. While it was maneuvering around the submarine with its tracks, it appeared to encounter problems with the curvature of the pool floor. Swim mode was then enabled on the vehicle. Within little time the vehicle was unable to move at all.

Through post mission examination it was found that the track's sprocket's coupling was slipping from the drive shaft. Additionally, it was found that the thrusters encountered a leak. The leak was determined to be caused by the minute imperfections around the press-fit seal. The seal was then epoxied to close the leak and the sprockets were additionally secured to the drive shaft. Furthermore, the vehicle's Ethernet switch's power was augmented to ensure a more stable communication.

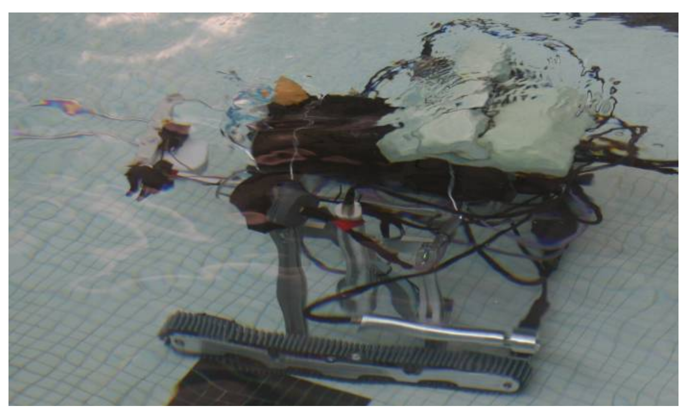

Figure 6 – ROV crawling during pool test

E. *Mission 2: Success and Failure*

The second mission proved to be more elaborate. The vehicle descended well and began to navigate around to inspect the submarine. The tracks were working well, even on the uneven floor of the pool. When the vehicle encountered a steeper incline, swim mode was activated and the vehicle maneuvered effortlessly.

After examining the entire submarine, the vehicle's main pan-tilt camera shut off. It seemed the vehicle had encountered a power issue. Upon power cycling the vehicle, communication was maintained; however, vehicle response was gone.

Upon post mission examination, it was found that there were no leaks; however, a motor controller appeared to be severely fried. After the analysis of the motor controller, it was concluded that the newly replaced controller was a faulty part which failed and created a short on our twelve volt regulator. Since the individual power components were not fused, the thermal fuse of our regulator would not reset. This was a difficult lesson learned but improvements to protect against these faults and others are already being worked on for next year.

IV. Future Use

This hybrid tracked and swimming ROV has many other advantages and applications beyond simulated submarine rescue. Track propulsion makes benthic studies possible including high resolution bottom sensing, bottom sampling and instrument servicing. In the presence of heavy currents or turbulence the ROV can protect itself by sitting on the bottom and resume its mission after the disturbance subsides. Being able to choose whether to use thrusters or tracks allows the advantages of both to be utilized such as precise crawling on the bottom, while being able to swim over obstacles. The buoyancy can be externally adjusted negative for mostly track propulsion or positive for mostly thruster propulsion depending on the mission requirements.

Acknowledgment

Thanks to our advisor Dr. Thomas Consi for all his help and support throughout the history of the ROV team at UW-Milwaukee as well as previous ROV Team Alumni, the M.A.T.E. center, all the people who helped make the ROV Competition possible, Great Lakes WATER Institute: Dr. Val Klump, Robert Paddock, Francisco Schlenker; University of Wisconsin-Milwaukee College of Engineering and Applied Science: Mike Brown and Ron Perez.

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