UNH
Aquacats
Underwater
Remotely Operated Vehicle

University of New Hampshire

Durham, New Hampshire

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Abstract

An underwater Remotely Operated Vehicle (ROV) was designed, built, and tested for 2013's UNH ROV team. UNH ROV is an interdisciplinary senior design project team that focuses on building a ROV for competition and research based aspects. This year's ROV team has built a ROV that will compete in the Marine Advanced Technology Education (MATE) competition that will be held in Seattle, Washington on June, 20 2013. The ROV will also be used in a graduate research project where two ROVs will be controlled in a leader-follower type fashion to perform tasks underwater.

Photo of Completed ROV

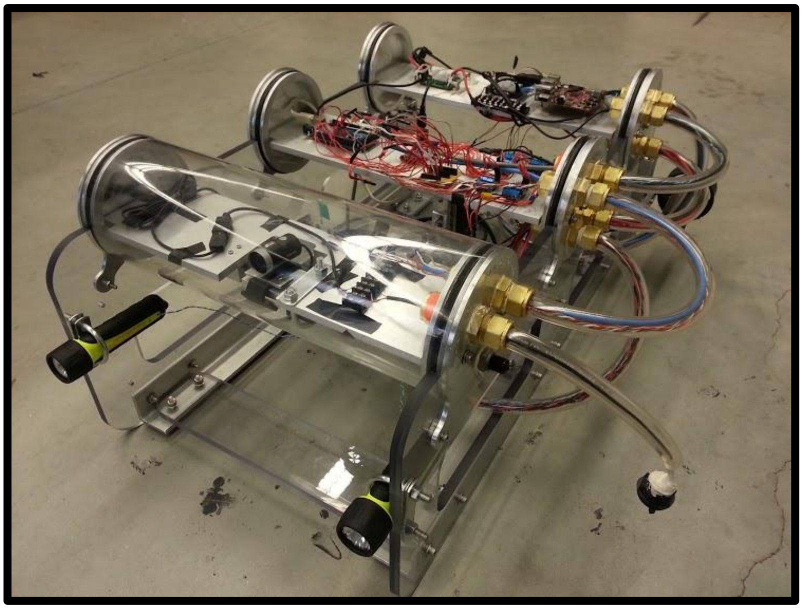

Figure 1: Completed ROV with middle and rear electronics tubes removed.

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Budget/Expense Sheet

System	Expense [USD]
Propulsion System (Purchased Thrusters and additional thruster building material)	$3,500.00
Chassis (polycarbonate plates, aluminum stock, polycarbonate tubes, aluminum plates, O-rings,)	$5,300.00
Chassis (cont.) (Transmissometer materials, bolts, nuts, epoxy, camera)	$300.00
Electronics and Controls (Beagle Board, Arduinos, IMU, and motor drivers)	$1,100.00
Electronics and Controls continued (Switches, LEDs, pressure and temperature sensors)	$200.00
Tether Materials (Braided Sleeve, Wires, USB boosters)	$400.00
Mission Task Mock Up Course Materials (PVC, Hardware, etc)	$300.00
Miscellaneous (Waterproofing, Mission Task Equipment, Fundraising Supplies, Team Shirts, Presentation Poster, Computers, MATE Competition Entry Fee)	$2,000.00
Estimated Total Expenses as of 4/27/12	**$13,100**

Donations	Amount
Brazonics (Chassis Material and Labor)	5,300.00
OE Department	2,000.00
CEPS Dean's Office	3,000.00
ME Department	1,050.00
ECE Department (Controls Material)	1,100.00
Professor Thein	1,000.00
Portsmouth Naval Shipyard	500
Hitchiner Manufacturing	100
Todd Gross	200
Jay S. Smith	500
Raymond Dow	100
Ray and Ann Dow	100
Kelly Dupuis	50
Tom and Alex	80
Total	**13,980**

Electrical Schematic

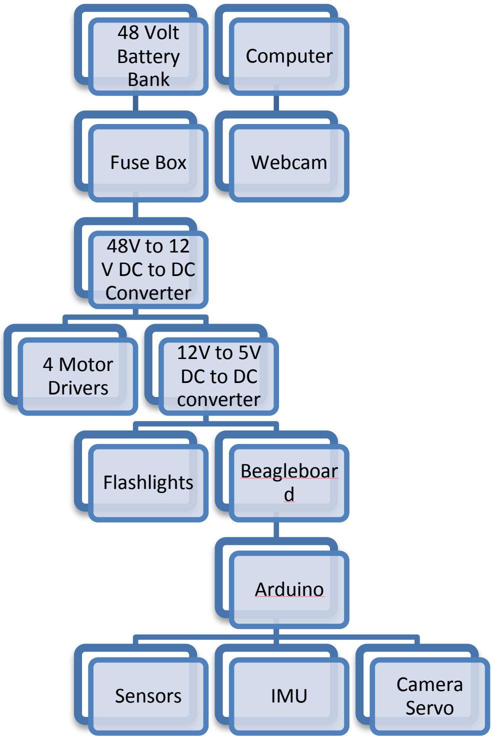


Figure 2: Power Flow Chart

Flow-Chart of Software in ROV

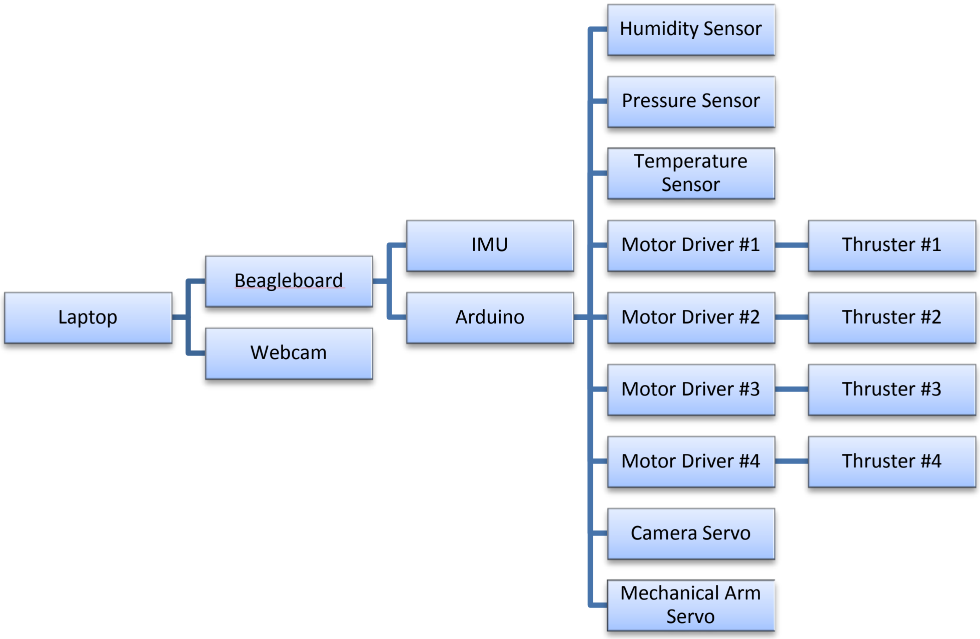


Figure 3: Controls Flow Chart

Design Rationale

Chassis

The most important rule when designing the chassis of an ROV is to ensure that the center of gravity of the submersible is below the center of buoyancy. This will prevent the ROV from rolling or pitching, which would make control of the ROV more complicated. The frame structure of the ROV needs to be relatively light-weight, but robust enough to travel and support the necessary hardware. Polycarbonate was chosen because it has a density very close to water, but is still strong and easily machined.

The electrical components need to be inside of a waterproof container, but still be able to communicate with the thrusters. Acrylic tubes were chosen to house the electronics because the circular ends of tubes are easier to waterproof than containers with corners. The first design that was considered was a single electronics tube with a dome on one end to house the camera. Due to the high cost associated with custom ordering such a large tube with a dome and machining limitations at UNH, this design was revised to have two slightly smaller tubes. However, a two tube design would require a box in the middle to house the Inertial Measurement Unit (IMU) which must be placed between the center of boyuancy and center of mass. Boxes are much more difficult to waterproof so they were avoided.

The final design that was decided upon has three electronics tubes placed laterally across the submersible so that the ends of the tubes are on the sides of ROV. Each of the three tubes is sealed on both ends by an aluminum end-cap with large Viton Fluoroelastomer O-rings to allow for easy removal and to ensure a water tight seal. The 3 tube design allows for the center tube to house the IMU, Arduino and motor drivers, the back tube to house the beagle board and DC to DC converters, and the front tube to house the camera. Temperature and humidity sensors will also be placed in the tubes to monitor water leaks and overheating of the electronics. The tether will be connected to the back tube, where the components that need to be accessed first are located, so the 3 tube design integrates well into the electronics flow.

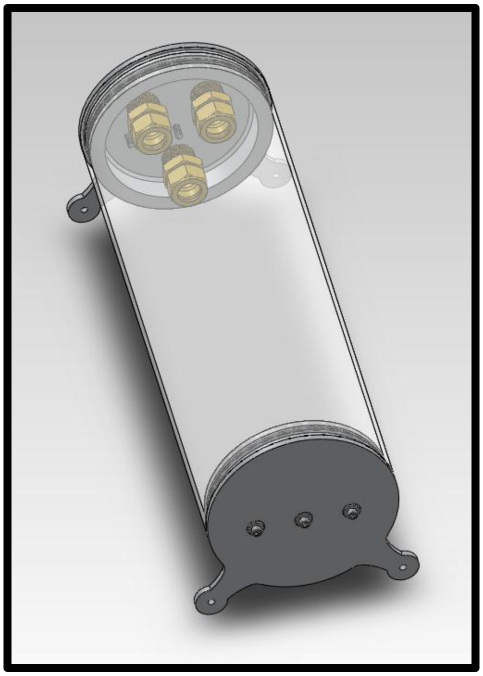


Figure 4: SolidWorks model of electronics tube assembly design.

Wires from the electronics will need to enter and exit the acrylic tubes through the end-caps while maintaining a waterproof seal. This was done through the use of bulkhead fittings with yor-lok compression fittings coupled with flexible plastic tubing which wires will run through.

The ROV was designed to have slight positive buoyancy when fully submerged. In order to achieve this positive buoyancy a MATLAB code was written to calculate the size of the tubes that would best fit our space requirements for electronics while supplying ample buoyancy to keep the ROV from sinking. Each electronics tube supplies about 18lbs of buoyancy force with the entire ROV designed to have a net buoyant force of 15lbs. This 15lbs is key because of the modular design, additional components, such as the mechanical arm, will be added for the MATE competition. The final buoyancy of the ROV will be fine-tuned by adding weights to the bottom frame; this will increase stability and allow for careful balancing of the ROV.

Weight reduction while maintaining frame rigidity was important so key components such as the electronics tubes and thrusters mounts were designed to take the place of frame members. Instead of having large cross members on top and bottom of the frame, the three lateral electronics tubes were built into the frame to act as the cross bracing support members. The vertical thruster mount was used to stiffen the chassis from rotational torques. By using these components as part of the frame, less polycarbonate could be used and a lighter, more open ROV chassis could be designed.

High temperatures in the electronics tubes could damage the electrical components because many components will malfunction at a certain critical temperature. This could be catastrophic if the pilot lost communication with the ROV while underwater. In order to ensure that the heat generated by the electronics in the tubes would not affect the ROV's performance, a thermal analysis was performed using SolidWorks Simulation. A simplified model of the electronics tube was modeled in SolidWorks, along with the electronic components that will be in the middle tube such as motor drivers and the IMU. A low convection boundary condition of 5 W/m2K was used on the outside of the acrylic tube and on the outside surface of the end-caps because the ROV will not be moving at all times. The outside water temperature (the pool temperature) was set at 27 degrees Celsius or about 300 Kelvin. The four motor controllers were each given a heat generation of 15 W/m^2*K based on the power supplied to them. The IMU was given the same heat generation as the motor drivers even though it is expected to produce less heat. Additionally, the Arduino was given a larger heat generation of 50 W/m^2*K. Because of the relatively small size of the electrical components (a motor driver is less than one square inch) compared to the aluminum cold plate that supports them, the temperature distribution that was calculated by SolidWorks had a maximum temperature of a few degrees above the outside water temperature. This high temperature of 28.6 degrees Celsius is well within the operating range of all the electronics.

The maximum temperature is not much higher than the temperature of the pool because the components are small enough that conduction through the cold plate to the end-caps dissipates much of the generated heat. The other two electronics tubes were not analyzed because they contain less electric components and therefor will not produce as much heat.

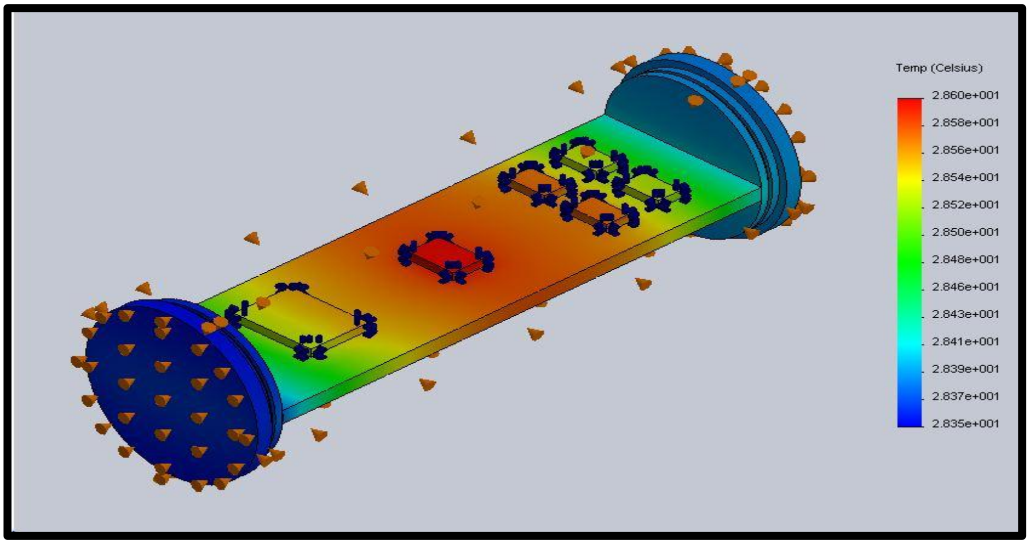


Figure 5: Thermal analysis of simplified tube and end-cap design.

Manipulator Hook

The ROV will be equipped with a hook to allow it to interact with the environment. This hook will be composed of an arm bar that extends out the front of the ROV. That bar will have a short peg on the end and a slightly larger peg 2 inches behind to stop components from slipping down the arm. This will allow the ROV to hook objects and have them rest in between the pegs and then release objects by lowering the arm and sliding them over the front peg.

Camera

In order for the pilot to be able to see where the ROV is going and observe the surrounding environment, a camera was placed in the front electronics tube. The camera needed high resolution to ensure that the camera feed is still clear even with varying water quality;, it needed to be small so that it could fit in the 5 3/4 inch inner diameter of the tube, and it also needed to be able to send its video feed through 60ft of tether up to the surface. 3 different video transmission options were researched, the first being a small security camera attached to a coaxial cable. There were plenty of small security cameras with 60 ft cables that could transmit video but the resolution of these cameras was low. In order to find a security camera with acceptable resolution the camera became too expensive. The second option was to use a high resolution webcam that uses USB to transmit its video feed, the problem with that is USB can only transmit video at lengths of 15 ft or less. To solve this problem a USB to Ethernet converter was used to see if a 100 ft Ethernet cord would be able to transmit the video from the camera to the surface. This USB to Ethernet system could only increase the cable range to around 30 ft which was only half of what was needed. The last option was to use the USB webcam with signal boosters along the USB cable that would increase the range to 60 ft. With the Ethernet option a failure and the security cameras at such a high cost the last option of USB boosters was chosen as the solution. Once the cable solution was determined all that was needed was to find a small camera that would be easy to mount in the tube, which was found to be the Microsoft LifeCam Cinema. It's a 720p resolution camera that is a 1 inch diameter cylinder that is 1.81 inches long.

Once the camera was chosen the camera mount was the next step in the design process. The camera needed to be mounted in the front electronics tube and in the center of the width of the ROV. The mount also needed to be able to tilt 180 degrees up and down to give the pilot the option of looking down at the mechanical arm or up at the surface or anything else in the surroundings. To accomplish this, the cold plate in the front tube needed to be milled out to fit the camera and a servo needed to be added to rotate the camera up and down. A mounting system to attach the camera to the servo, as well as stabilize the camera during operation needed to be designed and machined. The design for that mount was a square mounting plate, a motor shaft, stabilization rod, and a stabilization cube. The camera directly connects to the mounting plate, the motor shaft inserts into the side of that plate and connects the plate to the servo motor, and the stabilization rod connects the stabilization cube into the other side of the mounting plate to support the mounting plate from each side.

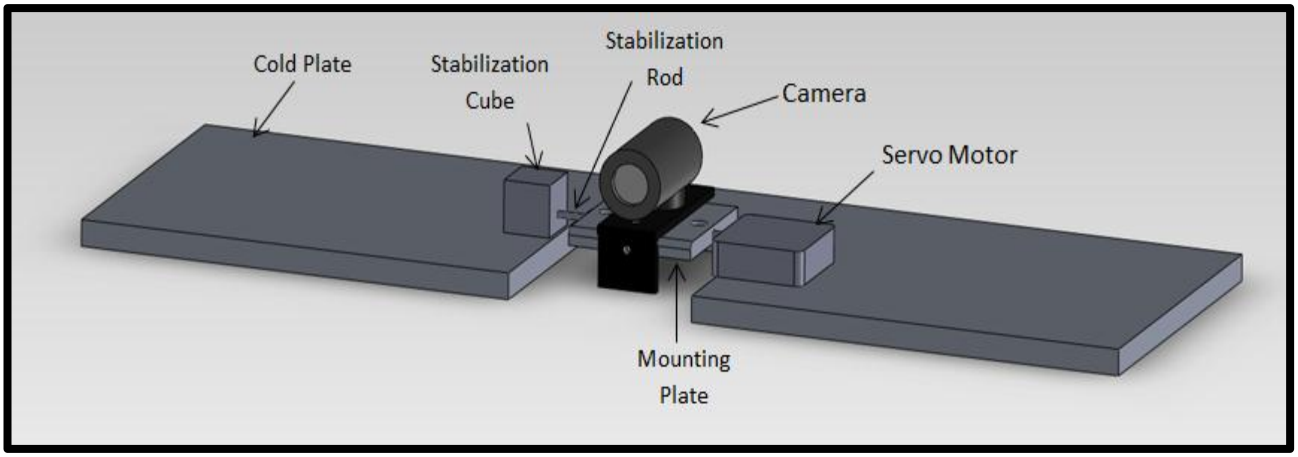


Figure 6: SolidWorks model of camera and camera mount design.

Propulsion System

The first step in designing the propulsion system was determining how many degrees of freedom the ROV would require to complete the chosen mission tasks. The chassis' self-stabilization automatically accounts for pitch and roll, and it was determined that left-to-right translational motion would not be required to complete the mission tasks. By removing the requirement of these degrees of freedom, the ROV could function with only 3 thrusters. One additional thruster was added in the up/down direction to help the ROV descend more rapidly.

Once the high-level propulsion system design was determined, the design characteristics of the individual thrusters had to be determined. Ducted propellers driven by an electric motor in a waterproof housing were chosen as the propulsion system thruster design based on their ubiquitous use in industry. The easy to control and competitive cost of brushed DC motors made them the obvious choice for our thrusters. The addition of a cowling reduces the tip losses of the propeller, directs the flow more effectively, and can add additional thrust output by accelerating the water, and creating lift in the direction of the thrust. As is common in industry a MARIN type 37 kort nozzle was selected for the contour shape of the cowling. Lastly a two bladed propeller was chosen for its high thrust-to-electrical power ratio.

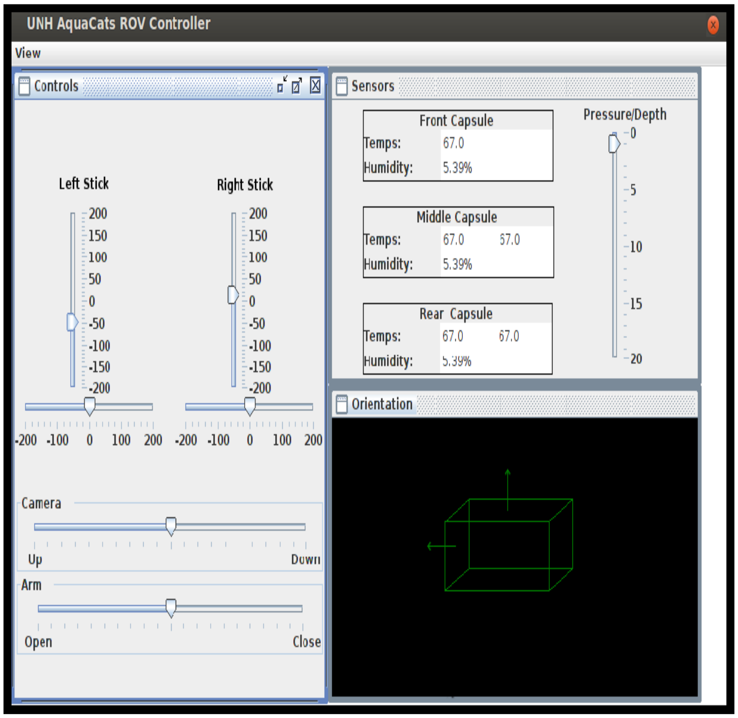
Controls

The Design for the ROV's control system is broken into three main parts. The Graphical User Interface, or GUI located on shore on a laptop, the Beagleboard on board computer (OBC), and the Arduino microcontroller and its sensors.

The OBC's job is to act as a relay agent for all data communication between the GUI and the other on board electronics. The OBC runs three different servers that were written using C++, one for handling motor commands, one for sensors information, and another for receiving data from the inertial measurement unit (IMU). The IMU is a collection of sensors including a gyroscope, an accelerometer and a magnetometer that used together can give accurate orientation values. The IMU outputs roll, pitch, and yaw data in a text string over a serial connection. The OBC reads these using our custom Serial class created using library functions from the C++ boost library. The orientation information is relayed back to the GUI over Ethernet. The sensor server works in much the same way, utilizing our Serial class to read text strings coming from the Arduino, and relaying them back over Ethernet for processing and display on the GUI. The motors server waits for commands to arrive from the GUI over Ethernet. Upon receiving a command, it will relay it over the serial connection with the Arduino, again using our Serial class.

The Arduino microcontroller is responsible for both relaying motor commands to individual thrusters, and collecting sensor data to send back to the user. The Arduino receives motor commands in a three byte format: (Motor Address, Direction, and Speed). This format allows all the necessary information to be relayed for the Arduino, while cutting down on the size of the data transmitted. The four thrusters installed on our ROV are each connected to their own pin on the Arduino; this pin correlates to the "Motor Address" field of the command. All thrusters are capable of forward and backward thrust at various speeds. We define the speeds for our motors from 0 to 255 (size of an unsigned byte). The second "Direction" field is used to specify forward or backward speed. With regard to sensor information, the temperature, pressure, and humidity sensors all send voltage values to the Arduino pins they are connected to. These voltage values are placed in text strings with character identifiers before the values for easy parsing on the GUI when they arrive. Like many small embedded systems, the Arduino board functions by calling an Init() function, then repeatedly calling a loop() function. On each execution of the loop function, the serial connection is checked for any control commands waiting to be read. The loop also records a system time and checks it against the last instance of a sensor poll. When the difference in time is 1 second, the sensors are polled for their information, and the text strings are sent back over the serial connection to the OBC. All the Arduino code is written in C++ using the Arduino libraries.

The GUI is the pilot's main interaction point with the ROV. Upon starting the GUI, bash scripts connect to, and initialize all necessary servers on the OBC. When the user opens a sub window of the GUI (Controls/Servers/Orientation etc.) the GUI connects to these servers and data transmission begins. The Controls section of the GUI allows the user to send motor commands to the thrusters and the servos running the camera and mechanical arm. Sliders are present on the Control window that can be dragged to send desired values to individual motors, however the primary method of control is through the PlayStation 3 controller. The PlayStation controller provides a much more intuitive interface for the pilot, allowing control of multiple thrusters at the same time. As commands are sent to the ROV from the controller, the sliders on the GUI update to help the pilot determine what speeds they are sending for better feedback and precise control. The design of the control code mimics the design of the chassis in that it is modular and easily edited to add more servos or thrusters as future designs may need. Sensor information is displayed in its own window on the GUI. Visual representations of the three electronics tubes are present. Humidity and temperature values are shown within these tubes. As the temperature or humidity of the tubes increases or decreases, the tube's representations change color. Red is used for temperature and blue for humidity. Pressure data is converted to depth and displayed through the use of a slider showing the operating depths of the ROV, 0-20ft. The data the GUI receives from the IMU is integrated into the Orientation view on the GUI. In the orientation view, a rectangular 3D box representing the ROV is used to show it's orientation under the water. The raw roll, pitch, and yaw information is used to update this 3D display. The Control, Sensors, and Orientation view combine to create an intuitive interface, allowing a relatively unskilled pilot to have all the information they need to safely and effectively control the ROV.



Front Capsule
Temps: 67.0
Humidity: 5.39%

Middle Capsule
Temps: 67.0 67.0
Humidity: 5.39%

Rear Capsule
Temps: 67.0 67.0
Humidity: 5.39%

Figure 7: Graphical User Interface (GUI) displaying sensor info, orientation, and thruster control sliders.

The control system construction consisted mainly of ordering the correct components, mounting those components to the cold plates, and wiring those components together. The beagle board, IMU and Arduino could be ordered as soon as the controls flow was designed because those components don't depend on the parameters of the ROV system. The voltage regulators and motor drivers were dependent on the requirements of the thrusters so the voltage and amperage of the thrusters needed to be finalized before those components could be ordered. It was determined the thrusters would need no more than 10 amps each and would operate at 12 volts, so motor drivers with a 15 amp max and 12 volt supply were purchased . The custom made voltage regulators were ordered from Vicor. Sensors were then chosen that would integrate easily with the Arduino and a camera servo was also chosen that could be controlled directly from the Arduino.

Once all these components were ordered the layout of the electronics was determined with 3 criteria in mind; the heat generated by the electrical components, the spacing for the connectors and wires, and minimal wiring between electronics tubes. The heat generation was only a concern with the motor drivers but a heat transfer analysis was done and it was determined they could all be placed in the same tube. The spacing for the connections between components was a concern for the beagle board as well as the Arduino, they both were placed far enough away from the end caps to allow there power and data cables to be plugged in. Along with the cable spacing the components position was determined by the flow of data and power to try and minimize tube to tube wiring. The tether enters the back tube, where the first components that the power will interact with are located. The power is stepped down and then passed into the beagle board and the data cable from the tether is plugged directly into the beagle board. Then the data and power are sent into the next tube where the Arduino, IMU and motor drivers are located and the flow then continues to the front tube where the Arduino sends commands to the camera servo.

Power

The design for the ROV's power system was governed by two main ideas, MATE competition requirements, and meeting the power specifications of the onboard electronics. The MATE competition specifies that the ROV must be powered by a 48V supply on-shore, which will provide up to 40 amps. Additionally, an onshore fuse must be used to prevent any malfunctions onboard the ROV from damaging MATE supplied components or injuring people. The last MATE competition requirement is that any power management or voltage regulation must be carried out onboard the ROV.

To simulate the MATE 48 volt supply, the UNH ROV team uses four 12 volt batteries wired in series to achieve a 48V power supply that can supply up to 40 amps. The fuse box used is equipped with a 30 amp fuse, switch, voltmeter, and ammeter as seen in Figure 8. The fuse is designed to cut power to the ROV if the ROV draws more than 30 amps, that is, more current than the thrusters at full power, and all electronics operating normally. To provide the ROV operator with even more information the voltmeter is added to inform the operator of the current supply voltage, and the ammeter is added to let the operator know how much current is being drawn by the ROV. To actually deliver the electricity to the ROV, braided 12 Gage wire is used within the tether.

Figure 8: Fuse Box with switch, ammeter, and voltmeter.

Upon reaching the ROV and passing through the waterproof connectors, the electrical power must now be converted to levels specified by the onboard electronics. The motor drivers require 12 Volts to operate correctly, and the Beagleboard requires 5 volts to operate correctly. 2 Vicor DC to DC voltage converters are used to accomplish these tasks. A 48 to 12 converter is used to power the 4 motor controllers. An additional 12 V to 5 V converter is used to power the Beagleboard as well as the two lights on the front of the ROV. The Arduino microcontroller receives power from the Beagleboard, and in turn powers the on board sensors, IMU, and camera servo motor, the flow chart can be seen in Figure 2.

Tether

A tether was designed in order to transmit electrical power and data from the surface to the ROV. Electrical power needed to be supplied in the form of 48V from the fuse box to the ROV. Communication data from the camera needed a USB connection and communication from the Beagleboard needed an Ethernet connection. Three wires: Power, USB, and Ethernet, would be run through an expandable sleeve, fastened together with zip ties, and then connected to the ROV. The tether needed to be detachable from the ROV to allow for easy transportation and maintenance of the tether and ROV separately. Underwater buccaneer connectors would be installed in the tether a few feet behind the ROV to be able to connect and disconnect the three wires of the tether to the ROV. In order to reduce drag to the ROV the tether was designed to be neutrally buoyant. Foam pieces would be attached along the tether in order to keep it from sinking to the bottom of the pool.

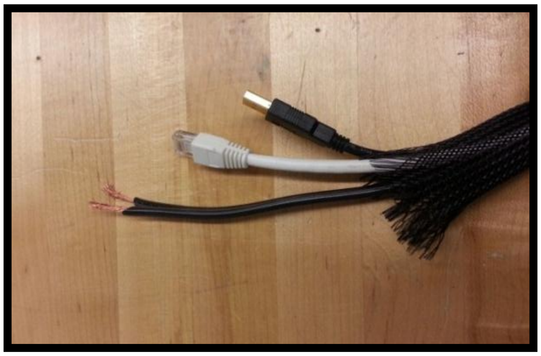


Figure 9: Tether with power, data and video feed cables.

Transmissometer

A transmissometer was designed and constructed in order to complete the mission of “constructing and installing a transmissometer.” A transmissometer is an instrument that measures light attenuation, which can be used to determine the turbidity of water over time. The transmissometer will be installed over a porous disc that rotates about a horizontal axis. The changing porosity of the disc simulates changing water turbidity. The transmissometer needs to be slightly negatively buoyant so that it remains at the bottom of the pool where the ROV deposits it.

For our transmissometer a LED and photodiode configuration was decided on. A photodiode is a semiconductor component that converts photons to current. An OPT101 photodiode was purchased. It is an Integrated Circuit which contains a photodiode and a transimpedance amplifier. The transimpedance amplifier serves the purpose of converting the current through the diode to a proportional output voltage. That output voltage is to be fed into the A/D pin on an Arduino Uno which will read and plot that voltage at 1 Hz frequency. This will allow for real-time signal showing the water turbidity where the transmissometer is located. This photodiode is most sensitive to infrared light wavelengths so 9 infrared LEDs were purchased for a 3X3 array to be soldered on a blank Printed Circuit Board. A separate 12 volt DC lead-acid battery is provided for the competition so the transmissometer will be given its own tether. The tether will consist of power cables to both the LED array and photodiode and a USB for communication with the Arduino. Code was written for the Arduino MCU to graph the real-time output of the photodiode.

Safety

The health and protection of those working on, around and operating the ROV was of upmost concern and key steps were taken ensure safe working conditions. During all machining of ROV components eye protection was worn along with closed toed shoes and pants. Due to potential hazards of chemical fumes, a fan for ventilation was used when epoxy was being applied to the ROV. All wires were wrapped in electrical tape to prevent potential shocks. The fuse box was designed to house and protect all electrical connections that could be dangerous to on shore operators. During the initial electrical testing, rubber gloves were worn to prevent electrical shocks. The thrusters have stickers warning of the propeller as a potential hazard; they are also covered in a plastic protective grate to prevent an object such as a human finger from coming into contact with the propeller blade.

Challenges Faced

One of the biggest challenges that the Aquacats faced was to attempt to manufacture our own thrusters. In the earlier stages of the project, funding sources were low, so machining thrusters based on last year's UNH team's design was discussed. After a cost comparison, the decision was made to begin machining them, however many unanticipated challenges resulted from that decision.

The thruster design has several components that require concentric relationships, press-fit tolerances, and a dynamic watertight seal. Six copies of the thruster design were machined, so that extra components could be swapped if issues arose in the assembly process. All of the component copies had slight dimensional variances, and therefore made even lining up screw holes a difficult process. When 4 thrusters were finally assembled, they all had large variances with shaft RPMs which would certainly be problematic since they operate a single system, and 3 of the 4 were not waterproof.

By the time it was determined that 3 of the thrusters needed to be re-assembled, time was more of a concern than money. The Aquacats had received more financial support, and the ROV had to be ready for testing in less than two weeks. Four BTD-150 thrusters from Seabotix were then ordered online. The thruster mounting solution was then altered to accommodate the newly purchased thrusters, and luckily the thrusters easily integrated into the electrical system.

Lesson Learned

A major lesson that each member of the Aquacats learned was the importance of interdisciplinary communication. Some fairly basic things like bulkhead fittings sized correctly to fit all wires through, and laying out the electronics based on physical dimensions were overlooked until it was another problem created. When the Aquacats became a team the members were split into three teams: chassis, propulsion, and controls. The three teams worked individually, and a weekly meeting was held with the captains of each subgroup. Often times at those meetings, someone would bring up an issue, such as the size of the bulkhead fittings and how big they need to be to accommodate the amount of wires going through to connect each electronics capsule. When this would occur the controls design was not at the point where anyone knew how many wires would be going from capsule to capsule, or what size the wires would be. Since the electronics capsule design needed to be submitted for machining, the chassis team picked an arbitrary hole size, and when it came time to assemble the ROV, there were issues with the sizes of the bulkhead fittings. So one thing that every member of the Aquacats learned was the importance of communication, especially with members that come from different technical backgrounds.

Future Improvements

Looking back on this year, some aspects of the design process could have been improved. The thrusters should have been designed to the electrical specifications similar to backup thrusters to be ordered, so that other electrical components didn't need to be ordered to adapt. To avoid numerous modifications to the electronics capsule end caps, each acrylic tube should have been measured so that the caps would be machined for specific tube sizes.

The thrusters that were designed and manufactured by the ROV team used motors that operated at 12V. Once the decision to purchase thrusters was made, an attempt to find thrusters that operated at 12V was unsuccessful. The Seabotix BTD150 thrusters can operate at 12V, but for optimal performance 19V was necessary. In order to supply 19V to the thrusters, an additional power converter is required. Had the original thrusters been designed with 19V motors, then this transition would have been much easier.

The acrylic electronics capsules that were used came from two separate stock orders. Because of this, the loose tolerances on the inner diameter of the tubes caused complications when the machined end caps could not fit into the tubes. The end caps were then sent back to Brazonics to be machined to the inner diameter of a sample piece of tube, however one of the three tubes were of a different size than the other tubes, and so two caps needed to be sent back to fit correctly in the other tube. This delayed assembly by about two weeks. Had all three tubes been accurately measured before machining of the end caps begun, then this issue would have been avoided.

Reflections

This year’s team encountered many challenges throughout the design, construction and testing of our ROV. Some of these challenges included presentations, finance, communication, and report writing. Looking back to the first presentations we did there is a marked improvement from everyone on the team as far as knowledge of the subject matter, comfort and overall delivery in our presentations. This is in part to our improved preparation techniques as well as getting used to speaking in front of other people. In the world of finances, the team definitely underestimated how important they were. Fund raising is a full year full time job that always needed to be on our minds in order to have the money to build the ROV and travel our to Seattle. Communication was another thing that our team improved on greatly throughout the year. Communicating and organizing a large team like the UNH ROV team is a difficult task and at the end of the year it was done quite well. This is something that our team will take with us as we move into other endeavors in our careers. Part of that was being flexible and adaptable to different people and how they work as well as adjusting to other people schedules and those are valuable things to be able to do in the professional world. Lastly the team had all written reports before but none as large or engineering intensive as the final reports for this project. It was a great learning experience for everyone to have to work with 12 other people and many different disciplines in order to make one cohesive engineering report that could be easily understood by the reader. This will apply directly to other projects in the future just like these other challenges they will make our team better in the future. In future work the team will be able to look back at the mistakes and experiences we have had in this project and know how to do the next project better.

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