Design Requirements for an ROV for Marine Science Education

Tristan Cowan
Mechanical/Electrical Engineering

Abstract

Commercially available remotely operated vehicles (ROVs) on the market today typically fall into one of two categories: they are sophisticated, expensive instruments designed for research and industrial tasks, or they are smaller, less expensive vehicles with very limited capabilities. Neither option is suitable for university educational use, which requires a full suite of features at an affordable price. A survey was conducted among university marine science departments to determine the optimal characteristics for an ROV for university educational use. Using the results obtained, a basic mechanical design for an ROV of this type was developed. The project will expand on this design with the goal of producing a viable product over the coming year.

Introduction

Remotely operated vehicles (ROVs) have had high profile public exposure as scientific instruments for archeological work, such as the Woods Hole Oceanographic Institution's 1986 survey of the wreck of the *Titanic*.[i] More recently, industrial ROVs were a focus of media coverage as BP's fleet of ROVs attempted to stem the oil spill in the Gulf of Mexico.[ii]

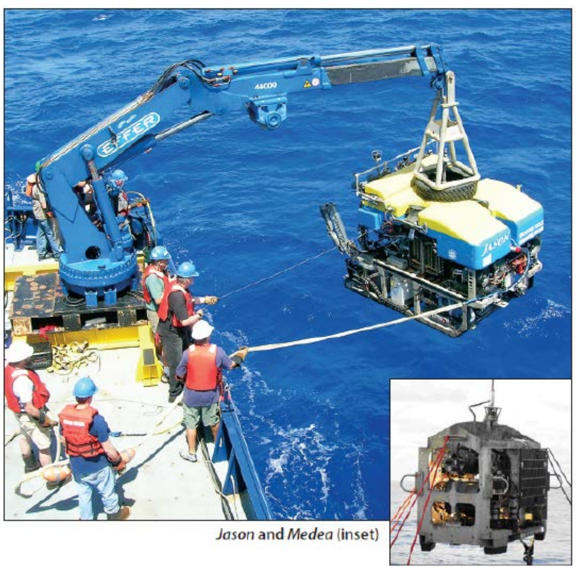

Figure 1
The Woods Hole Oceanographic Institution's *Jason* and *Medea* ROVs[iii]

Besides these very well-known applications, ROVs are also used in military operations, aquaculture, and marine biology and oceanographic research.

ROVs currently on the market largely fall into one of two categories: 1.) Large, very sophisticated, very expensive machines such as those offered by Oceaneering International, Inc., or Seabotix, Inc., which are intended for industrial, commercial, and research applications, and 2.) small, inexpensive kits with very limited capabilities intended primarily for hobbyists and K-12 educators.

Neither of these categories of ROV is a good match for the needs of university-level marine science education, which requires a robust robot with broad capabilities at a lower price-point than those oriented for research and industry tasks.

The goal of this project is to identify specific design criteria for an ROV intended for university-level education and to use these criteria to begin design of a prototype ROV. To assess design requirements, a survey was disseminated to United States universities with marine science programs.

Survey

A short online survey was distributed to 232 university marine science departments. Universities were chosen on the basis of location (i.e. proximity to a coast) and the presence of departments and divisions concerned with marine science or related disciplines. Questions asked included basic information, such as ideal cost and size, as well as more in-depth queries on desirable capabilities.

28 responses were received. Most respondents identified themselves as belonging to biology (8 respondents) or marine science departments (7 respondents), though there were also representatives from environmental science (4), fisheries and aquaculture (4), geology (2), combined environmental and marine science (1), meteorology (1), and university-associated K-12 education (1).

43% of respondents indicated that no ROVs currently on the market could meet their needs, while an additional 21% were unsure. Of the 32% who indicated that an existing ROV served their needs well, the most common ROVs cited were VideoRay models (consisting of a small, lightweight underwater camera), followed by Seabotix and Phantom vehicles (larger, more expensive vehicles common in research and industry applications).

Respondents were clear in their requirements for vehicle size and price (Figures 2 and 3). The majority preferred an ROV measuring less than 2 ft x 2 ft x 2 ft and costing at most $5000, and ideally, $3000 or less.

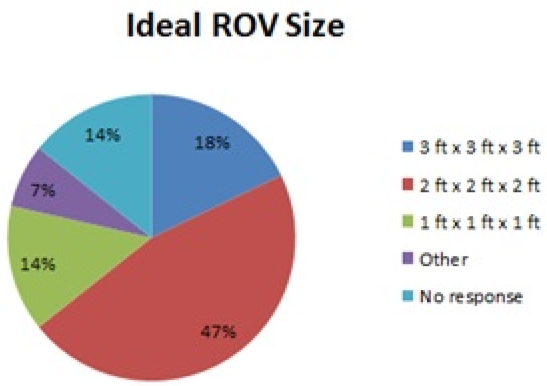

Figure 2
ROV size responses

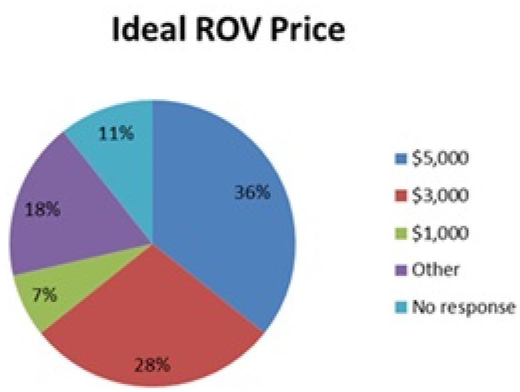

Figure 3
ROV price responses

Respondents also had clear preferences with regard to the ROV's desired sampling capabilities (Figure 4). 71% of respondents indicated a need for water sampling capabilities, followed by sediment (54%), biological (43%), video (36%), still images (18%), and manipulation capabilities (11%). In addition to these major categories, 29% of respondents cited other, more specialized sampling needs.

A similar pattern emerged with respect to desired passive environmental monitoring capabilities (Figure 5). The most prominent needs are for temperature data (89%), salinity data (82%), and dissolved oxygen data (71%). However, there is wide demand for other capabilities, and a significant portion of respondents (21%) identified highly specialized needs specific to their applications.

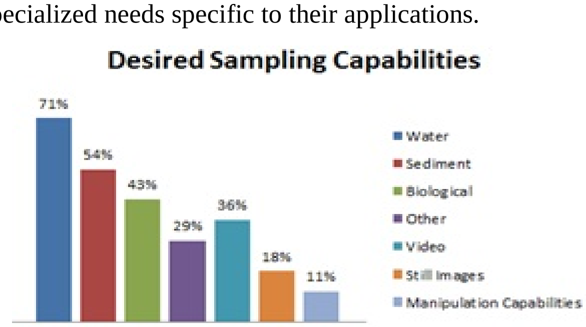

Figure 4
ROV sampling capabilities responses

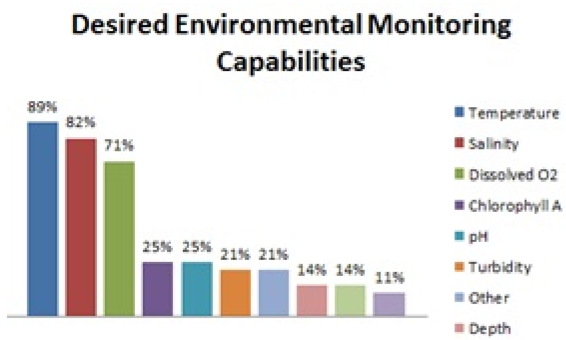

Figure 5
ROV environmental monitoring responses

Respondents were asked to comment on desired audio/video capabilities for an ROV. Half of all respondents required only video, while an additional 25% indicated a need for audio as well. 11% of respondents worked frequently in low-visibility environments, which would make audio capability advantageous. Many respondents (21%) indicated a specific need for HD video.

Most respondents were uninterested in an autonomously operating vehicle. 50% explicitly preferred an operator-controlled ROV, while approximately 29% indicated that autonomous operation was either unimportant, or best implemented as a flexible feature.

Respondents were also asked to comment on the desired navigational capability of the ROV. Many respondents (39%) stressed the importance of accurate positional data to their work without mentioning other requirements. A further 18% requested GPS capability specifically. 18% were unsure as to the specific navigational capabilities they required, and 4% of respondents requested acoustic navigation. Only 4% of respondents believed navigational capability to be unimportant. 7% emphasized a need for easy and intuitive operator control of the robot.

Respondents were also given the opportunity to request additional features not specifically touched on in the other survey questions. Although some specific features were mentioned (e.g. a pan/tilt-capable camera, multiple manipulators), the single most-requested item was modularity. Users are extremely interested in an ROV that can be configured and programmed to suit their specific needs. This bears out the trend seen in the questions on sampling and environmental monitoring. Although there are some core needs that an educational ROV must be able to meet, it is critical that the users be able to modify it to better suit their particular situations.

Design

Using the data gathered from the survey, work was begun on the design of the ROV. Due to the time constraints of the Summer Undergraduate Research Program, a decision was made to focus on the vehicle's basic mechanical design for the present.

As per the size and price constraints indicated by the survey, efforts were made to limit the footprint and cost of the ROV. Because the first users of the ROV will be local to the University of New Haven, it was also decided to limit the ROV to a maximum depth of 320 feet (the maximum depth of Long Island Sound). A solid model of the prototype design is shown in Figure 6.

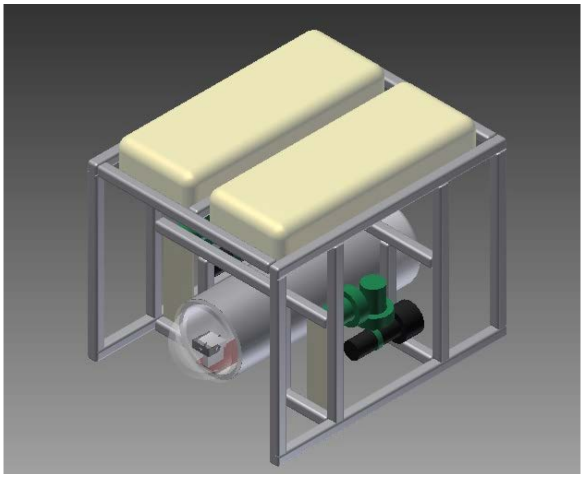

Figure 6
Prototype ROV solid model

Frame

In designing the frame, the use of metal was avoided, where possible, to minimize weight and cost. This was also considered to be advantageous due to the corrosive properties of seawater. PVC was originally considered as a possible frame material, as it is highly corrosion resistant and will easily withstand the pressure at this depth. However, it lacks rigidity, and it was expected that a PVC frame might experience twisting when the vehicle was lowered into or lifted out of the water. In light of this, fiberglass was selected as an alternative. Although it is more expensive than PVC, it is still economical, and its rigidity, corrosion-resistance, and workability are attractive. The frame is designed to have a small footprint (2 ft x 1.5 ft x 1.5 ft) and to provide numerous attachment points for instrumentation.

Buoyancy

The ROV was designed to be slightly positively buoyant. Although this means that the ROV will require power to sink, it also ensures that the ROV will float to the surface in case of malfunction. Foam floats coated with a marine paint are located on the top of the vehicle to provide positive buoyancy. Trymer 2000 insulation is selected as the float material, as it is readily available on the University of New Haven premises and exhibits good density and water absorption characteristics. The floats are countered by a ballast that the user can adjust according to the amount of instrumentation equipped on the ROV to provide the desired buoyancy.

Pressure Vessel

A pressure vessel is installed in the ROV to house the onboard electronics and camera. A length of 6 inch Schedule 80 PVC is selected for the pressure vessel body, with an acrylic dome capping one end to provide a window for the camera.

Camera

The camera selected is an HD 720p wing camera, originally designed to be mounted on a remote control airplane or glider. This device offers up to three hours of high quality video which can be easily streamed to a computer in real time. It is mounted on a LynxMotion micro pan/tilt system, which allows the user to orient the camera precisely.

Propulsion

A thruster specifically designed for ROV use, the CrustCrawler High-Flow 400HFS-L, was selected to provide propulsion. Although these are quite expensive, they grant significant benefits to the ROV in terms of thrust, maintenance, and reliability. To reduce the cost, it was decided to minimize the number of thrusters used on the vehicle. The ROV is required to move forward and aft, and upward and downward, as well as, being able to strafe side to side. Upwards locomotion is taken care of by the overall positive buoyancy of the ROV. To provide the other directions while minimizing the number of thrusters, a system is required to orient the thrusters at will. This is accomplished with small DC motors, magnetically coupled to prevent the intrusion of seawater in the motor workings. This design permits the ROV to use three thrusters to move agilely in all three axes.

Sensors

Although work was concentrated on mechanical design, some preliminary investigation was conducted on possible sensors. It was required that sensors be small, and able to interface with a microcontroller, and also withstand a seawater environment at 300 feet of depth. Temperature and conductivity (salinity) sensors from AtlasScientific are selected as rugged, low cost solutions designed for integration in embedded systems.

In the survey, the most commonly used ROVs among respondents were various VideoRay models. VideoRay's least expensive vehicle, the Scout, starts at approximately $6,000, and allows the user to take underwater video.[iv] VideoRay ROVs with more extensive capabilities (e.g. sampling, water quality monitoring) are considerably more expensive.

The design proposed here offers many of the capabilities of higher-end VideoRay models at an economical price, and furthermore allows the users to easily modify the vehicle as necessary for their work.

Future Work

Work will continue on this project over the course of the school year. The mechanical design will be finalized, and efforts will focus on the electrical, electronic, and controls systems. By the end of the year an early stage prototype will be constructed. Throughout the process, there will be a concentration on modular design to enable future revision, modification, and expansion. It is hoped that this work will eventually produce a valuable teaching aid for marine science departments.

References

[i] *RMS Titanic*. (n.d.). Retrieved September 7, 2013, from Woods Hole Oceanographic Institution: http://www.whoi.edu/main/topic/titanic

[ii] Yarett, I. (2010, May 18). Our Eyes Underwater. *Newsweek*.

[iii] National Deep Submergence Facility. (2009, December). *Jason ROV Fact Sheet.* Retrieved September 7, 2013, from Woods Hole Oceanographic Institution: http://www.whoi.edu/ndsfVehicles/Jason/

[iv] VideoRay LLC. (n.d.). *VideoRay Corporate Brochure.* Retrieved September 27, 2013, from VideoRay: http://wwv.videoray.com/CB_Online/VideoRay_CBonline.pdf

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Biography

Tristan Cowan will graduate in May 2014 with B.S. degrees in mechanical and electrical engineering. He intends to work in the field of robotics and mechatronics.