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Development of an Inexpensive Remote Operating Vehicle (ROV), Mountain Lake Virginia

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Abstract: This workshop details the physical description and use of a small ROV submarine, built in 2004 to explore and video bottom features at Mountain Lake, Giles County, Virginia. This project represents an ongoing co-operative effort between the Wilderness Conservancy at Mountain Lake, Roanoke College and Virginia Polytechnic Institute as academic partners. Mountain Lake is the only natural lake in the southern Appalachian Highlands. It is a low nutrient, high altitude, sub-alpine lake and associated ecosystem. In many ways the lake may be considered to be an environmental "early warning" system for much of the Southern Appalachians. It is of particular interest because of its unusual geologic structure (a fault and crevice in the deepest portion of the lake). It is also a cyclic lake on the scale of decade to century, and has recently gone through the low portion of its cycle. The ROV is constructed of PVC, with direct umbilical to the surface. It is controlled by use of 6 (12-volt) electrical mini bilge pumps, and is outfitted with an infrared/visible light underwater video camera, as well as dive lights. The ROV has been used to determine bottom textures across the lake, particularly in the deepest portion of the lake, at more than 95 feet of depth. The ROV is also designed for educational use of visiting groups by the Wilderness Conservancy at Mountain Lake.

Keywords: remote-operated vehicle (ROV), video camera

Introduction

In Winter 2004, senior environmental students at Roanoke College designed and built a small Remote Operated Vehicle (ROV) "Submarine" for class research use at Mountain Lake, Virginia. As outlined below, environmental and biological research at Mountain Lake had continued for several decades. One goal of the previous research had been the use of divers and cameras to explore the underwater lake bottom—this had met with limited success. Our small ROV, adapted from Bohm, H. and V. Jensen. (1997). *Build Your Own Underwater Robot,* published by Westcoast Words, Vancouver, B.C. Canada, was designed and built in the classroom by student novices. The Project was funded and supported by The Wilderness Conservancy at Mountain Lake, for use in Mountain Lake. A tethered ROV design, whereby the ROV power supply, navigation, and video signal cables are remote to the submerged vehicle, was chosen as least expensive and optimal. The main limitation to the Bohm and Jensen tethered design was that it obviously was intended for very shallow underwater use. In response, we developed our own robotic device for use in these deeper lake conditions. Because the target of interest for us included portions of Mountain Lake at approximately 100 feet (33 meters) depth, this necessitated a series of initial design upgrades, which were in turn adapted and improved by the student researchers as the project progressed.

For our ROV, we used an inexpensive PVC "milk-crate" tube frame, upon which is mounted a waterproof video camera (at approximately $300.00, the decent quality underwater camera SUBCAM-CL 1/3" DSP CCD Camera, watertight to 100 feet, was actually the single formidable expense). Power to the camera was cabled from the surface, and the video signal feed was also cabled. The video signal was fed to a portable television screen and videotape, which was in turn attached by power inverter to a marine-rated 12 volt battery. In this way, live video feed was presented on the television screen in real time from the bottom. Propulsion for the ROV consisted of six tethered bilge pumps, used as "jets" and placed geometrically on the frame (forward, back, up down, left, right). Combinations of jets are controlled from a switchbox at the surface. In this way, the student operator can maneuver the ROV in real time from the surface in conjunction with the image on the video screen.

Once initially designed, the classroom construction phase of the ROV project took approximately one week of class time (approximately 6 hours total) for the class group. Technologically, the most challenging part of the construction included physically wiring the switch box (wire leads for switches tended to become reversed), and soldering of wires. Waterproofing of components was thought to be a concern, but proved not to be a significant issue. The design adaptations were created, built and troubleshot by the students involved, and constituted a significant depth to the teaching/learning experience.

Once in operation, halogen dive lamps were added for deep-water exploration well below the photic zone, and a flotation ring (inner tube air bladder) was designed and added by Adam Vittum. These adaptations were particular to the conditions of Mountain Lake itself.

The project was entirely applicable for a college level environmental group, but could be as easily accomplished by a fairly advanced high school age biology group, with a modicum of guidance from the teacher.

The particulars of the device are reported here as being potentially useful in other lakes and in both shallow and deep exploration situations. This project included recovery of sediment and videotape footage from the lake. Video was taken from a transect near the north-south center line of the lake, and the ROV was used by the authors throughout the summer of 2004. Video excerpts will be shown during the workshop, and conditions permitting, the participants will be able to operate the machine itself within the lake.

Stated Objectives and Major Goals of the Project

1. This project was designed to create and operate an inexpensive ROV for research of the lake bottom, particularly the "hole" at the deepest part of Mountain Lake.
2. Summer research involved constructing the ROV, followed by the mapping of the lake bottom.
3. The project has resulted in the production of a professional conference workshop. A print copy of all materials will be made available to the Wilderness Conservancy at Mountain Lake.
4. Supervised use of the ROV has been made available to guests of the Mountain Lake Hotel.
5. Roanoke College Environment Program has allowed the ROV to remain at Mountain Lake for use during the peak seasons of Hotel operation.

Data Collection

Phase I (spring 2004): While human divers are not optimal for exploring the terrain at the bottom of Mountain Lake, an ROV, piloted from the surface can produce high quality images of the trench and "hole" on the lake bottom. Using an ROV mounted camera and surface recording equipment; such images may be recorded and analyzed for further study. If possible, soil/rock samples will be taken from the surrounding area.

Phase II (summer 2004): Currently there have been several attempts to discover the cause of the lake cycle. This expedition will continue research on the floor of the lake which will include the mapping and analyzing the lake bottom. Several important techniques will be utilized for the mapping of the lake and will be left open to test the water quality and the substrate on the floor of the lake.

Data collection took place by piloting the ROV through the designated areas and recording these images. Field time was the majority of the project. Later analysis was done at the lake and at Roanoke College by viewing and studying the findings recorded on video.

Conclusions

1. The ROV design is initially "off-the-shelf" and inexpensive to build.

2. The students on the project are able to not only build the basic ROV, but also to successfully adapt it to known field conditions.

3. Studies have then successfully recovered samples and video tape footage of the deepest portion of the Lake.

4. The ROV submersible works very well and can dive to a depth of about 106 feet.

5. The ROV concept can be successfully used with a competent, motivated student group as a semester-long (or longer) holistic teaching application, which not only includes data collection and analysis, but also a real-world design and construction element.

6. The ROV is a tangible and tactile product of the project, which then can be used through time to collect ongoing data for analysis. The ROV itself becomes "instrumentational capital."

7. The student skills and application during all phases of the ROV project are able to see and assess how their design, creativity and actions have implications on the resulting portions of the project. The project is self referential, to some extent self-assessing, and is based in critical thinking (and responsibility) by the students.

8. The ROV as created here, by students, is applicable to a wide variety of lake, pond river, stream and wetland conditions. The "Fish-eye" view of the aquatic ecosystem literally adds an additional physical dimension to student understanding.

Mountain Lake Background

Mountain Lake lies near the top of Salt Pond Mountain *(37Y27' 56" N, 80Y31' 39" W)* in Giles County, southwest Virginia at an elevation of 1180 meters (3860 feet). It is the only natural lake in the mountainous southern Appalachian highlands.

The lake has a replenishment time of about 1.6 years, being recharged continuously by groundwater and surface runoff from a mixed conifer and hardwood forest (Thorn and Cooperider, 1964). The lake overlies three different (primarily Silurian-age) rock formations, These are: the Clinch, a white quartz sandstone that underlies the deepest depth of the lake; The Juniata, a red, iron-rich sandstone that underlies the middle portion; and the Martinsburg shale found beneath the shallowest part of the lake.

When full, the lake forms an elongate shape of some 50 acres in size, and is about 33 meters (or 106 feet) deep at its deepest point. This deep spot consists of only a narrow crack or crevice feature in the bottom of the lake. More generally, the deep end of the lake is approximately 24 meters (or 80 feet) deep, shallowing to the south, near the Hotel. The lake is cyclical in nature, and was less than full between 1998 and 2003 (Cawley et. al. 2001). At that time, the lake covered approximately 24 acres, or about half its normal size.

Mountain Lake and the wild-lands surrounding it have always received special attention and description since its first discovery by the British surveyor, Colonel Christopher Gist in 1751 (Johnston 1951).

In the 1930s, Marvin Williams (Williams 1930), the famous geobiologist G.E.Hutchinson (Hutchinson and Pickford 1932) and H.S. Sharp (Sharp 1933) published the first limnological journal papers and theses/dissertations about the lake. The Moody family of Texas constructed the present large stone-hotel in 1936.

In the 1950s, the famous limnologist E.S. Deevy (known for his work on Lindsley Pond in New England) visited the lake and prepared the first bathymetric Mountain Lake map (Deevy unpublished 1957). And in 1964, Thorn and Cooperider published the first enumeration of the terrestrial flora of the county. In more recent decades, the lake has been the focus of nearly continuous research; much of it fostered by UVA, Virginia Tech, and more recently, Roanoke College. A sample of this research includes Marland 1967, Obeng-Asamoa 1971, Parker et al. 1975, Perry 1977, Schultz et al. 1986, Mills 1988, Beaty 1995, Cawley et. al. 1999, 2001. The sediments of the lake were preliminarily cored for paleolimnology in 1967 by Marland, and more recently by Cawley in 1998. Cawley prepared the first SONAR bathymetric map of the lake in 1997 (Cawley et. al. 2001).

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