2009

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Petros J. Katsioloudis
Old Dominion University, pkatsiol@odu.edu

Original Publication Citation
Katsioloudis, P. J. (2009). Discovery of the depths. *Technology and Engineering Teacher*, *68*(8), 12-16.

Discovery of the Depths

By Petros J. Katsioloudis

The world's oceans have been almost impenetrable to human exploration because of obstacles associated with underwater exploration—until the very recent development of remote underwater vehicles.

More than 70 percent of earth's surface is liquid water, most of it sparkling blue oceans that cover nearly 140 million square miles of Earth, a greater area than all continents combined (McMillan & Musick, 2007). Despite the large amount of earth that oceans cover, the world's oceans have been almost impenetrable to human exploration because of obstacles associated with underwater exploration—until the very recent development of remote underwater vehicles (Ramaswamy, 2002). Factors such as the high cost of employing commercial divers for underwater exploration and inspection of pipelines, platforms, and other marine installations led to the development of remotely operated underwater vehicles (ROVs). Generally divers reach depths close to 1500 feet, whereas the ROVs descend to anywhere between 6000 to 20,000 feet, depending on the degree of sophistication of the vehicle to perform complex operations (MacFarlane & Petters, 1986). Remotely operated vehicles have been used for various tasks including inspection, recovery, and construction.

Credit: National Oceanic and Atmospheric Administration (NOAA)

Autonomous Underwater Vehicle ABE (Autonomous Benthic Explorer) is launched over the side of a research vessel. ABE will be used to collect high-resolution multibeam bathymetry at Explorer Ridge, as well as a CTD and magnetometer.

According to Narayan (2002), there are different systems available for underwater exploration. The major systems include: (a) wet diving such as scuba, bounce, and saturation diving; (b) one-atmosphere manned vehicles with manipulators and cameras, either tethered or autonomous; and (c) remotely operated vehicles (ROVs) with manipulators and cameras, either tethered or untethered. Tethered ROVs are attached to a support ship by an umbilical cable that relays control signals and power down to the vehicle and returns images and sensor data to the main computer on the mother ship. The ROV is controlled by an operator on the surface, and a tether is used as a link between the ROV and the operator. The tether is used to both transmit power to the thrusters, lights, cameras, and any other onboard device and receive video signals. The tether allows the operator to enjoy real-time control, and it also simplifies the design; however, there are inherent drawbacks associated with its use such as the significant amount of draft that hinders the performance and mobility of the ROV (Ramaswamy, 2002). Tethers are also prone to snagging on obstacles or the vehicle itself.

Underwater Vehicles

There are different types of underwater vehicles, and one way to categorize them is to identify them by category: manned or unmanned systems. Underwater Robotic Vehicles (URVs) refer to all unmanned underwater vehicles (UUVs). Based on the implementation, manned underwater vehicles are broadly classified as Remotely Operated Vehicles and Autonomously Operated Vehicles.

Autonomous Underwater Vehicles (AUVs) have been in development since the 1960s. Vehicles like the Rebikoff's SEA SPOOK developed in the early 1960s were large, inefficient, expensive, or a combination of all three (Michel, 2002). Institutions such as the Massachusetts Institute of Technology (MIT) have been leaders in the design and development of AUVs since the 1960s (MIT, 2006).

According again to MIT (2006), during 1991 and 1992 a revolutionary new autonomous underwater vehicle (AUV) was developed, called Odyssey, designed to provide marine scientists with economical access to the ocean with great outcomes.

Additionally, underwater vehicles are classified based on their size, depth capability, and onboard horsepower and on whether they are all electrical or electro-hydraulic. The different classes of ROVs include: (a) Small ROV, (b) Medium size ROV, (c) High-capacity electric ROV, and (d) Large work-class ROV.

Small ROV

Small ROVs are capable of operating at depths less than 300 meters and are limited in system power to 5 HP. Costs range from $10,000 to $100,000. (Michel, 2002). These vehicles are used for inspection and observation of leakage in pipes and oil rigs. The operator uses a tether to communicate with the vehicle, and they are electrically powered by batteries.

Medium Size ROV

Medium size ROVs are electro-hydraulic work-class vehicles and are the most widely used. Horsepower in this type of vehicle ranges between 20 and 100 hp and weight from 1,000 to 2,200 kg, with typical payload capacities in the 100 to 200 kg range (Michel, 2002). Vehicles from this

Credit: National Oceanic and Atmospheric Administration (NOAA)

The Hercules ROV was specially designed to conduct underwater archaeological surveys at dive sites in the Black Sea. Photo courtesy of J. Weirich.

class were developed to perform work carrying one or two manipulators in high-current conditions, and to work at depths in the range of 1,000 meters.

High-Capacity Electric ROV

These types of vehicles are electric, using batteries, and unlike the small vehicles that are low in cost, vehicles in this category reach the $500,000 mark. Even though high-capacity vehicles are capable of working to greater depths—up to 6,000 meters—they are not capable of doing heavy work due to their lack of electro-hydraulic manipulators. The operator uses a tether to communicate with the vehicle that is usually interfaced with computers using sophisticated communication and imaging systems for deep-dive inspection.

Large Work ROV

Specifically designed to perform heavy work over prolonged periods of time without diver intervention, there are few vehicles in this category due to lower demand. Compared to the medium-size vehicles, this class can operate in deep water (2,500 meters) with a system ranging from 100 to 250 hp (Michel, 2002). They range in weight from 1000 to 2,200 kg, with typical payload capacities in the 100 to 200 kg range. Equipped with both electric and hydraulic components, these vehicles were developed to perform work in high-current conditions at depths of 1000 meters. Such work includes drilling support, construction support, and pipeline inspection.

AUV Technology

Over the years, the technology of AUVs has developed, and as new ideas surface, several technological problems were created (Blidberg, 2006). Even though some of the problems have been solved, others remain. Some of those problems include: (a) Autonomy, (b) Energy, (c) Navigation, (d) Sensors, and (e) Communications (Blidberg, 2006).

Autonomy

Considerable effort was expended to understand how to give an AUV a level of intelligence necessary to accomplish assigned tasks. Issues such as intelligent systems architecture design, mission planning, perception, and situation were investigated. As the capabilities required by first generation AUVs became clear, the tasks performed seemed not to demand a high level of intelligent behavior; therefore, there has not been a significant level of recent development focused on AUV autonomy (Blidberg, 2006).

Energy Systems

Endurance of AUVs has increased from a few hours to dozens of hours (Mahdi, 2000). This extended endurance, however, is at the expense of sensing capability, as well as very limited transmit speeds. According to Blidberg (2006), the majority of early AUV systems used Lead Acid batteries and later Silver Zinc and Lithium. Recent advances in the NiMH batteries have provided new opportunities for AUVs, and this technology is being used in many systems today since it is more efficient and durable.

Navigation

Control systems in current subsea AUVs are immature compared to on-land systems. Several controllers are needed, and the process becomes more complex as the number increases. Separate controllers—one for the vehicle and another for the manipulator—during the working mode can be a challenge for anyone trying to operate the manipulator for a given task, such as gripping an object and keeping the vehicle stationary by using the vehicle controller (Mahesh & Yuh, 1991). Without some type of coordination between the two systems, operator fatigue is common—therefore operating time and performance are limited. Controllers that can coordinate several tasks are under design, and research efforts are being directed towards solving this problem.

Sensors

The manufacturers of AUVs were more concerned with basic technologies required for reliable vehicle operation. Once that task was achieved, sensors were added to the vehicle system to acquire data from the ocean environment. Most of the sensors used on AUVs were existing sensors that have undergone modification to operate in different environments. Recently however, it has been recognized that we must develop entirely new sensors based on the constraints imposed by an AUV (Blidberg, 2006).

Communications

Acoustic communications are probably the most valuable in the underwater environment. In the past 10 years there has been a significant advance in acoustic communications, such that relatively low-error-rate communication is possible over long ranges (Comms, 1999). Other technologies, such as laser communications at short range and relatively noise-free communications over larger ranges using RF current density techniques, are also being investigated. Along with communication of the vehicle, another aspect of communication is the issue of connecting multiple vehicles and/or mounted instrument platforms via a network-based information structure. This subsea network can then be connected to a surface vehicle that will act as a gateway to a different form of communication such as the Internet (Welsh, 2000).

The JASON Project

The JASON Project was founded in 1989 by Dr. Robert D. Ballard, the oceanographer and explorer who discovered the shipwreck of RMS Titanic (Jason, 2009). Using an ROV called Jason, the oceanographer was able to find the wreck of Titanic and retrieve photos and film. After receiving thousands of letters from middle school students asking to join his next expedition, Dr. Ballard decided to get involved and start a student program. Allowing the students to interact with the scientists and guide the multimillion-dollar ROV created enormous interest.

The program is open to all students who log in at www.jason.org/Public/GetInvolved/GetInvolved.aspx and register at the project's website.

Design Initiative for Students

As a part of this activity, students will fabricate an underwater remotely operated vehicle, according to specifications and under guidance of the instructor. To complete this activity, students need to be able to read technical specifications to determine the type of material to be used to fabricate a UROV design and the materials and tools required in the production of appliances—therefore a week of research on the related topic is suggested.

To begin, students will identify potential designs of already existing Remotely Operated Vehicles. As a second step, students will identify the best design and also provide

Table 1.
Correlation with *Standards for Technological Literacy*

The Nature of Technology	Technology and Society	Design
Standard 1: Students will develop an understanding of the characteristics and scope of technology.	**Standard 4:** Students will develop an understanding of the cultural, social, economic, and political effects of technology.	**Standard 8:** Students will develop an understanding of the attributes of design.
Standard 2: Students will develop an understanding of the core concepts of technology.	**Standard 5:** Students will develop an understanding of the effects of technology on the environment.	**Standard 9:** Students will develop an understanding of engineering design.
Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.	**Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.	**Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
	Standard 7: Students will develop an understanding of the influence of technology on history.	

Note. Adapted from the International Technology Education Association. (2000/2002/2007). *Standards for Technological Literacy: Content for the Study of Technology*. Reston, VA: Author.

justification for the rest of the initial choices that were not selected. Once the best design is identified, students will determine the different components that comprise a UROV and assign each category to smaller groups within the class. Such components include the fabrication of the exoskeleton, propulsion of the vehicle, communication systems, and navigation.

Each group will now work independently, and the instructor will serve as a moderator to ensure that all groups are on the same task. As groups complete their tasks, the instructor will evaluate their work and ensure that components will fit well in order for the vehicle to be functional. During the building process, even though each group works independently, weekly progress reports will be given to the rest of the groups, and a problem-solving session will take place for groups to help each other. Also, a daily journal should be kept by each group. Once the project is complete, the journals can be combined and shared. During construction of the UROV, students will apply physics and math skills that relate to buoyancy and resistance of the vehicle underwater, biology in the way a UROV can affect the environment, engineering concepts by calculating hydrodynamics and material properties, and, of course, technology education principles through the entire vehicle fabrication process.

Activities such as the one described above are easy to correlate with *Standards for Technological Literacy: Content for the Study of Technology*, (ITEA, 2000/2002/2007). See Table 1 for correlations with ITEA's standards.

Summary

Throughout history the oceans have directly or indirectly influenced humans. The importance of knowing how to protect this valuable resource and insure it for future generations is vital. Underwater Vehicles are tools essential for this process, and therefore research and development to perfect these devices is needed. However, the main goal of these devices—to transmit images from places where humans cannot go—remains the same, and their importance to future discoveries remains vital.

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Petros J. Katsioloudis, PhD *is an assistant professor and Ambassador to Cyprus for the International Technology Education Association. He is a member of the Department of Occupational and Technical Studies at Old Dominion University in Norfolk, Virginia.*