Underwater Sensors for Autonomous Vehicles

Introduction

Sensors are devices that are used for the detection (and sometimes response) of signals such as electrical, optical, or acoustic. They can be used to detect changes in temperature, blood pressure, humidity, speed, etc. However, many researchers and engineers use sensors underwater to monitor oceanic changes by relaying back information about the quality, temperature, and pressure of the ocean. They do this by attaching sensors to underwater autonomous vehicles that will monitor the area, record information, and send it back to the main hub. This paper reviews sensors in underwater autonomous vehicles including how they work on a high level, what the widely accepted type of sensor to use is, and how other organizations are utilizing their sensors.

How Do Sensors Work

Sensors gather information from around the unit it's attached to. This information is collected in the form of signals such as acoustic, wireless, or optical signals.

Acoustic

Acoustic sensors take in signals in the form of sound waves. This is particularly effective in underwater exploration since sound waves propagate for long distances in open water. However, in shallow areas, sound waves are prone to bouncing off debris such as shells, plants, rocks, or actual debris such as bottles, plastic bags, or other garbage that may end up in the ocean from human exposure. This causes excessive propagation delay and a very low bandwidth [1].

Wireless

In an underwater area, wireless sensors are utilized in a network called wireless sensor networks (WSN). In underwater wireless sensor networks, the sensor nodes, either stationary or mobile, are connected wirelessly via communication modules that transfer various events that it may pick up. These signals are sent back to a buoyant gateway node which then sends the data to a coastline station [2].

Optical

Optical links rely on low-cost LEDs and photodiodes. They are much cheaper than acoustic sensors. For example, Honeywell's SEP8705-002 infrared emitter diode [3] starts at a base price of \$1.86 for a single emitter whereas a Maxbotix Ultrasonic Rangefinder – LV-EZ4 [4] starts at a price of \$24.95. Even though these are two different products with different purposes, they are still components that may be needed and for a base price for a basic component the price range is vast.

Preferred Sensor for Underwater Autonomous Vehicles

While each form of communication has its positives and negatives, acoustic wireless communication is the most widely used form of communication. Despite the requirements of a large antennae and high transmission power, acoustic wireless communication is preferred over other forms like optical which are affected by scattering and require high precision in the beam used [5].

There are also a few more disadvantages to using underwater acoustic networks. These include, but are not limited to, limited battery power, limited bandwidth, multipath and fading problems [6]. The batteries used for the autonomous vehicles usually cannot be recharged. Furthermore, solar energy cannot be utilized for any underwater expeditions that exceeds 200m in depth. It is possible to use solar power to a depth of 1000m but there is a significant decrease in sunlight past 200m [7]. Bandwidth also poses a problem as the usable range for networks is from 30 - 300Hz (radio waves) which is the range of frequencies that propagate for long distances in water [6]. Lastly, multipath and fading problems occur when there is debris in the ocean that may interfere with the direct line of sight. Signals could be lost in shallower water where there are more surfaces for signal reflection. This would increase the number of paths created and would also attenuate the signal overall.

Despite the disadvantages, sonar is still preferred over other forms of sensing for its long-range capability, lack of a necessary high precision, and lack of scattering.

Utilization of Underwater Sensors

Organizations used underwater sensors for a vast area of purposes. These include public health and research.

Public Health

Libelium launched a wireless sensor that would monitor water quality. The Waspmote is a wireless sensor that may use cellular and long-range connectivity to send information to the Cloud. The Waspmote can also accommodate solar panels to charge the battery to keep the sensor's autonomy [8]. Some application of Libelium's sensor include potable water monitoring, chemical leakage detection in rivers, and pollution levels in the sea. For these applications, the Waspmote detects chemical changes in the water such as pH levels, O₂ levels, nitrate and saline levels. Unfortunately, like most acoustic sensor components, the Waspmote kit can run anywhere from \$198 for a sensor board from the MicroControllerShop [9] to \$648 for the entire Waspmote Starter Kit also from the MicroControllerShop [10].

Research

Organizations use underwater sensors to monitor changes in ocean temperatures and composition ie. pH levels and salinity. For example, Libelium's Waspmote is capable of measuring water conditions of hatcheries such as the level of dissolved oxygen (DO) and ammonia levels (NH_4) [8]. There is also research on ocean levels to predict future conditions as shown at the Monterey Bay Aquarium Research Institute [11].

- [1] F. E. e. al., "Underwater Sensor Network Applications: A Comprehensive Survey," *International Journal of Distributed Sensor Networks*, p. 14, 2015.
- [2] A. a. H. J. Reza, "Robust Grid-based Deployment Schemes for Underwater Optical Sensor Networks," in *IEEE 34th Conference on Local Computer Networks*, Zurich, Switzerland, 2009.
- [3] Honeywell, 'AlGaAs Infrared Emiiting Diode" SEP8705 datasheet.
- [4] Maxbotix, ""High Performance Sonar Range Finder" LV-EZ Series". Patent 7,679,996, 2005-2015.
- [5] Y. Xiao, Ed., "Research Challenges in Communication Protocol Design for Underwater Sensor Networks," in *Underwater Acoustic Sensor Networks*, Boca Raton, FL: Auerbach Publications, 2010, pp. 4-6.
- [6] "Underwater Acoustic Sensor Networks (UW-ASN)," [Online]. Available: http://bwn.ece.gatech.edu/UWASN/index.html. [Accessed 23 Oct 2017].
- [7] "How far does light travel in the ocean?," [Online]. Available: https://oceanservice.noaa.gov/facts/light_travel.html. [Accessed 23 Oct 2017].
- [8] "Smart Water Sensors to monitor water quality in rivers, lakes and the sea," 24 Feb 2014. [Online]. Available: http://www.libelium.com/smart-water-sensors-to-monitor-water-quality-in-rivers-lakes-and-the-se a/. [Accessed 23 Oct 2017].
- [9] M. Pros, "Waspmote Gases Sensor Board 2.0, Supports 7 Sensors at Once," MicroController Pros , 2 Jul 2014.

[Online]. Available: http://microcontrollershop.com/product_info.php?products_id=6777&gclid=EAIaIQobChMIkO_

Um6OM1wIV2AqBCh0XSgXcEAkYBCABEgJKIPD_BwE. [Accessed 24 Oct 2017].

[10] M. Pros, "Waspmote Starter Kit: 802.14.5 U.FL Board and Gateway, Battery," MicroController Pros, 19 Aug 2014.

[Online]. Available: http://microcontrollershop.com/product_info.php?products_id=6886&gclid=EAIaIQobChMIkO_

Um6OM1wIV2AqBCh0XSgXcEAkYAiABEgLiZvD_BwE. [Accessed 24 Oct 2017].

[11] M. B. A. R. Institute, "Autonomous Ocean Sampling Network," 8 Jan 2016. [Online].Available: http://www3.mbari.org/aosn/. [Accessed 24 Oct 2017].