Session Overview Underwater Robotics

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It is an auspicious time for this first-ever ISRR special session on the topic of underwater robotics. Underwater robots are now performing high-resolution acoustic, optical, and physical oceanographic surveys in the deep ocean that previously were considered impractical or infeasible. For example: in 2001 the Argo II underwater robotic vehicle, [1], was employed to discover the first off-axis hydrothermal vent field located 15 km from the Mid-Atlantic Ridge at 30° North Latitude [5]. The dynamics of this important hydrothermal vent site have since been mapped, sampled, and probed extensively with human-occupied submersibles, tethered remotely controlled underwater robots, and untethered autonomous underwater robots [6, 4, 7].

The technical obstacles arising in underwater robotic missions differ from those in land, air, and space missions in several fundamental respects: First, the rapid attenuation of acoustic and electromagnetic radiation in seawater severely restricts the range (and field of view) of high resolution acoustic and optical sensors. In consequence, high-resolution underwater survey sensors must be submerged to the immediate vicinity of a survey site — in sharp contrast to airborne and space-based survey sensors systems. Moreover, radio navigation techniques commonly employed in land, air, and space operations do not function undersea. Second, the high ambient pressure of the underwater environment poses formidable design challenges both for (inhabited) submarines and (uninhabited) robots. At present, only a handful of the world's submarines are capable of diving beyond 1000 meters in depth. Only one present-day operational research submarines can dive to 6500 meters; none can dive to the ocean's deepest depths of 11,000 meters. In contrast, numerous underwater robots operate to 6500 meters, and at least one vehicle presently under construction will be capable of 11,000 meters operation [2, 3]. Finally, in the case of untethered vehicles, underwater missions are limited not only by on-board energy storage capacity, but also by the severely limited bandwidth and delay inherent in underwater acoustic communication, the intelligence of on board control system, and payload capacity.

The three papers in this session represent accomplishments in the engineering science problems arising in the problem domain of underwater robotics. Moreover, the are exemplars of engineering science which is motivated by and directly advance the natural sciences by enabling new methods of oceanographic research.

Plotnik and Rock report a computer vision tracking system to enable a remotely controlled underwater vehicle to track autonomously a class of gelatinous animals (e.g. free-swimming Coelenterates or "jellyfish") in the water column. The problem addressed is that, due to the irregular natural motion of these animals in the water column and the limited field of view of underwater camera systems, it has proven difficult or impossible for an underwater vehicle to observe these creatures for any significant length of time, thus limiting scientific observations thereof. The paper reports a model based approach which seeks to classify statistically the observed motion of the animals into the distinct phases of motion which characterize their natural swimming behavior. This system, which is evaluated on field data obtained with an actual oceanographic robotic vehicle, holds promise of significantly enhancing our ability to observe these animals and, in consequence, enable advances in mid-water Pelagic Biology.

Yoerger, Jakuba, Bradley, and Bingham report the algorithms developed and refined with the Autonomous Benthic Explorer (ABE) autonomous underwater vehicle over a decade of field work performing autonomous scientific surveys in the deep sea. At the time of this paper's writing, ABE had successfully performed a total of over 150 science dives, traveling survey paths totaling over 2,500 Km and over 1,300 hours of bottom-time at an average of over 2,000 meters depth. The paper articulates the need for precisely navigated co-registered AUV surveys in order to combine datasets obtained with a variety of disparate scientific sensors, vehicles, and deployments. The paper reports robust and accurate methods for autonomous navigation of underwater vehicles with long baseline acoustic navigation, bottom following and obstacle avoidance, and automated nested survey methodologies for locating hydrothermal vents on the mid-ocean ridges. These methods have resulted directly in numerous scientific discoveries, for example [7].

Singh, Roman, Pizarro, and Eustice report advances in high resolution acoustic and optical imaging from underwater vehicles. The authors report advances in methodologies to exploit consistency and redundancy of local sensor measurements of the environment to construct large scale high-resolution optical and acoustic maps that are a self-consistent quantitative representation of the environment. Their approach extends techniques from simultaneous localization and mapping (SLAM), photogrammetry, and computer vision to address directly the structure-from-motion problem as it arises in large scale underwater surveys with sensors possessing limited range. The authors report an overview of their research in large-scale structure from motion, self consistent bathymetric mapping, and visually aided navigation. The utility of these methods is demonstrated on several large scale deep-ocean data sets including a survey of the shipwreck *RMS Titanic* and the Trans-Atlantic Geotraverse (TAG) Hydrothermal Vent site at 26°N 44°W on the Mid-Atlantic Ridge.

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