Gesture Control and Situation Awareness in Underwater Human-Robot Teams

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***Abstract*— Humans working with robots have been studied extensively, but the problem of human-robot collaboration in underwater settings has not been given much attention. Humans working underwater are exposed to a variety of risks and stressors including complex tasks, inefficiencies arising from time limitations, and task overloading. Robots can help improve the safety and efficiency of underwater operations by performing hazardous tasks in place of a human, assisting humans with complex tasks, or performing tasks in parallel with human team members to increase efficiency. However, introducing an autonomous robot into a team of humans can introduce new types of risk arising from robot performance, human-robot communication, and other factors. In this abstract, we present a case study in human-robot teaming consisting of two SCUBA divers and a robot and discuss observed issues in the scenario arising from the robot's communication abilities and situation awareness. We also discuss initial work on a gesture-based communication system for an underwater robot, as well as an omnidirectional camera system for diver tracking. This initial work outlines operational considerations for human-robot teaming in dynamic underwater environments and builds a framework for future field experiments in this area.**

I. INTRODUCTION

In many scientific domains, humans are tasked with performing underwater work such as equipment installation, surveys, inspection, or sample collection. Underwater work has inherent risks and inefficiencies due to limited air supply and bottom times, and frequently the particular tasks at hand introduce additional risk, for example when collecting samples of hazardous biological specimens. Collaborative robots working as part of underwater operational teams have the potential to increase the safety and efficiency of underwater work, whether by collaboratively performing hazardous parts of tasks, or by offloading menial tasks to the robot to increase efficiency. However, introducing a robot into a team of humans adds a layer of complexity and thus new types of risk, arising primarily from the robot's task performance, limited communication abilities and potential for poor situation awareness. Task performance is of greatest interest, but before a robot's task performance can be safely studied as a fully-autonomous member of an underwater human-robot team, the robot must first have sufficient communication abilities and appropriate sensors for situation awareness.

The underwater environment is communication-restricted, meaning that many of the typical modes of communication employed either in human communication (*e.g.* speaking) or robot communication (*e.g.* wi-fi) are unavailable as a communication mode. Additionally, the reduced field of view created by the air-water interface of optical imaging systems results in worse situation awareness than on land. In SCUBA diving, situation awareness is a key skill for diver safety, and many of the issues that affect situation awareness in divers, such as attention tunneling and data overload [2] also affect underwater robots. Robust communication techniques and ensuring robots have good situation awareness are key to safely introducing robots to an underwater team to facilitate further research in robot task performance.

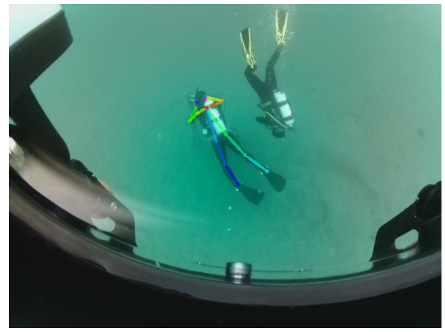

Fig. 1. Underwater human-robot teaming scenario.

We present a case study of a human-robot team consisting of two SCUBA divers and a robot working in a coastal environment to install an array of cameras. From observations made in this case study, we discuss key factors related to both situation awareness and communication, and present initial work addressing these factors with an omnidirectional camera for situation awareness and a gesture-based communication system.

A. Related Work

Due to the complexity of working in ocean environments, there are few examples in the literature of true underwater human-robot collaboration. One example is the OceanOne robot [4] which is a hybrid between a humanoid robot and a Remotely Operated Vehicle (ROV), which can communicate with divers underwater by making gestures with its limbs and hands, and is controlled by a topside human operator. Another example is a diver-controlled soft-robotic fish [3], where a diver operates a wireless acoustic controller to drive a robotic fish underwater.

II. UNDERWATER HUMAN-ROBOT TEAMING

We conducted a case study of underwater human-robot teaming in the ocean off the Scripps Institution of Oceanog-

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