

Towards a Human Factors Model for Underwater Robotics

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ABSTRACT

The goal of this study is to understand the factors between a human and semi-Autonomous Underwater Vehicles (sAUVs) from a HRI perspective. A SME interview approach was used to analyze video data of operators interacting with sAUVs. The results suggest considerations for the capabilities and limitations of the human and robot, in relation to the dynamic demands of the task and environment. We propose a preliminary human factors model to depict these components and discuss how they interact.

Categories and Subject Descriptors

H.1.2 [User/Machine Systems]: Human factors

General Terms

Performance, Design, Reliability, Human Factors

Keywords

Underwater robotics

1. INTRODUCTION

Semi-Autonomous Underwater Vehicles (sAUVs) are robots that travel underwater with limited input from the operator. sAUVs are used for "environmental monitoring and damage assessment, security applications, oil and gas installation monitoring and repair, and pipeline inspection" [1].

How humans provide commands to the sAUV is a critical component of HRI, and warrants further study. Our goal is to take a human factors approach to understand system components (human, robot, task, and environment) that impact the success of the human-robot team. Thus, we propose a qualitative model to depict these factors and discuss how they may interact.

2. RELATED WORK

Due to the vastness of marine life ecosystems, many unique challenges are presented when conducting research. sAUVs have the possibility to help overcome some of these challenges. Underwater exploration is a difficult and potentially life threatening operation for researchers [2]. Thus, some sAUVs have been developed by researchers to have the capability to help monitor marine environment health. In this application, the onsite operator uses a specific gesture/visual language called "RoboChat" to control the underwater robot to achieve a specific task [4], e.g. to move straightforward or to drive a square path. The onsite operator uses visual cues: tags with QR codes [4, 5].

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Within the context of underwater environments, the interaction between human and robot is highly constrained. In this scenario, there are many factors that may influence the quality or even the success of the interaction. A human factors perspective is a beneficial approach to understanding sAUV human-robot interaction. Such an approach emphasizes the interaction between the individual components of the system, specifically the person, task, robot, and environment, as well as the interaction between each of these components. A human factors approach will consider the capabilities and limitations of the person and robot, in relation to the task demands and the complexity of the operational environment (i.e., in this context, coral reefs).



Figure 1. A diver controlling the robot using a cue-card [3]

3. APPROACH

A human factors approach was used to analyze video footage of HRI in sAUV experiments. The videos were recorded between 2010 and 2013 during field trials [2,3]. 25 videos were analyzed with an average duration of 60 seconds each. During each video presentation, a sAUV subject matter expert (SME) described the scenario. The SME's think aloud was audio recorded. Three human factors researchers were present during the think aloud video session, and noted human factors challenges individually. A challenge was coded as related to the human(s), robot, task, or environment. For example, if the SME discussed buoyancy challenges related to surge, this was coded as "environment, external disturbance." The think aloud video session lasted approximately 2 hours. After the data was collected, the three researchers reviewed their individual notes to refine their identified factors, and begin to organize and categorize the factors. Next, the three researchers collaboratively compared their data. Discrepancies in categorization were discussed, and a final categorization of factors was determined. This collaborative analysis took place over 2 hours, until consensus was met. The final categorization of human, robot, task, and environment factors are depicted in Figure 2. The interaction between these factors was also recorded.

4. RESULTS

The preliminary human factors model is presented in Figure 2. The model categorizes the components of the system – human, robot, task and environments. The following sections provide an overview of each component and discuss select factors.

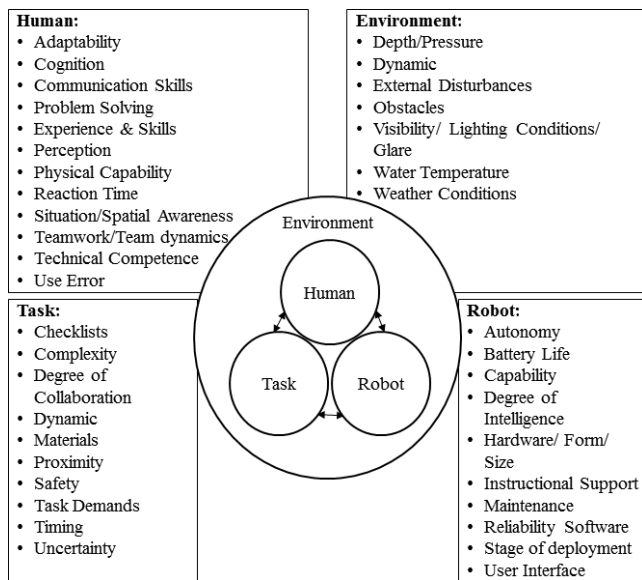


Figure 2. Human factors model for the sAUV HRI

4.1 Human

The primary human interacting with the sAUV is the operator. The operator has a large number of capabilities and limitations relevant to using the sAUV, ranging from adaptability to technical competence. During each interaction the operator must not only maintain an awareness of the ocean environment, but must also maintain a relatively stable position. Novice scuba divers found stabilization difficult, and thus negatively affected their efficiency in providing commands to the robot. The operator had to also communicate with the surrounding divers as a team, primarily relying on hand gestures. The SME described several physical/cognitive challenges to diving, such as the “Martini effect” (described as cognitive impairment equivalent to 1 martini per 10 meters of depth), the ability to maintain a proper body temperature, and fatigue from diving for long periods of time. The SME made clear that the identified challenges discussed above occur simultaneously. The operator had to constantly use/interact with the robot, adapt to changing environmental conditions, and interact/communicate with other divers. This multitask scenario likely places working memory demands on the operator.

4.2 Robot

The robot depicted in the video data was an Aqua2 [1] vehicle, however there are many different types and brands of sAUVs. The hardware/software capabilities and the level of autonomy of any sAUV will impact the nature of the HRI. In the current research, this particular robot reads tags with a QR code, and displays menu options on a small interface. The small screen real estate limited the amount of output that could be displayed on the menu interface, creating a deep navigation hierarchy. Although tedious, the method appeared to be successful, and the developers were able to create a menu system with four different tags. Sometimes if an error occurred the divers needed to respond adaptively and physically intervene to stop the robot from colliding with the seafloor, or from moving in the wrong direction. When a proper command was given, the robot autonomously moved through the environment and collected video data. The operator then switched to a supervisory role.

4.3 Task

Before the dive, the operator needed to ensure that the equipment was well prepared, and did this typically through the use of maintenance checklists. While diving, the method of input was via the QR code tags. The operator had to physically hold/stabilize the sAUV while scanning each tag. Scanning each tag via the robot’s rear camera would activate a menu system. The diver needed to manipulate the QR tags, held together on a ring, to choose different tags for different commands. Close proximity to the robot was important during all aspects of the task: providing input, monitoring the robot’s behavior, and ensuring not to lose the robot under dark/murky environmental conditions.

4.4 Environment

The coral reef environment studied in this context is dynamic. Surge and current caused the diver and robot to drift. Many obstacles in the environment, such as coral, marine life, or shipwrecks/debris, were dangerous for the divers. Interaction with these obstacles also affected the robot’s operation and task completion, because robot/human collision with delicate coral, uneven ocean floor, or marine life would be damaging to the well-being of the reef. Weather was also a challenging factor; storms or thunder would prevent the research from occurring. Finally, visibility was also a major factor of SME discussion. Light would reflect off the tags, making scanning difficult. The divers disturbing ocean floor sand or darkness due to depth also affected visibility.

5. DISCUSSION

This model is a first step in gaining an understanding identifying the factors involved in sAUV HRI. This study provided data about the challenges of operating sAUVs. By identifying these issues we lay a foundation to begin to consider human factors interventions to potentially increase safety, efficiency, and performance of sAUV operations. Future work can aim to eliminate some of these identified challenges so that divers and sAUVs can safely research marine life and coral reefs, and promote the health of our oceans.

6. ACKNOWLEDGEMENTS

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