Technical Paper on Multimodal Human Input and Bravo 7 Robotic Arm Teleoperation

Zachary R. Speiser
Oregon State University
August 26th, 2023

Abstract:

This paper presents a comprehensive technical description of three research projects, supporting two research areas. It involved the creation of an artificial seabed floor, simulated seabed floor testing, and teleoperation of an underwater Bravo 7 robotic arm. The project involves using a continuous self-report device and integrating a wearable motion capture system. Additionally, it makes use of the Robot Operating System (ROS) framework to control a virtual robotic arm. The first project I started with was the design and construction of a mock seafloor. This provided a platform to aid in the repeatability of experiments, while also providing a visually appropriate floor for conducting underwater grasping experiments. Afterward, I took on the task of designing and building a continuous self-reporting device for my second project. This device was aimed at recording confidence values from the test participants. In my third and final project, I controlled a virtual Bravo 7 robotic arm in the first part of my project. This virtualization involved the use of ROS in combination with the Movit robot control software. I controlled the virtual arm using a Python script. The second part of my third project involved the integration of Xsens motion capture (MoCap) software with the virtual arm. This integration will allow me to control the robot arm using human arm movements. The paper discusses the objectives, methods, and results of each project component, contributing to a deeper understanding of underwater robotics and teleoperation.

Introduction:

Underwater robotics has become one of the most essential fields in underwater science due to the innovation that has happened in automated robotics. As these new technologies have become available they have enabled us to work in otherwise inhospitable environments and created an industry in robotics. This introduction presents an overview of three central components that make up my study. This paper will present a technical description and review of three projects focused on an underwater robotic arm grasping objects on the seabed floor autonomously. My research goal is to overcome three of the challenges involved with underwater object manipulation. The essence of my research is involved in addressing some of the challenges associated with manipulating objects underwater. These components include the simulated seabed creation and setup, the design and construction of a continuous self-report device to track participant confidence levels while each grasp is carried out, and the control of the Bravo 7 robotic arm. Therefore, this paper embarks on a journey to uncover the complexities of manipulating objects underwater.

Background

The field of underwater robotics has had some remarkable advancements in recent years, driven by the growing demand for autonomous exploration, environmental monitoring, and underwater intervention. In this context, the creation of innovative testing methodologies and control systems has become important. The ability to simulate underwater environments and assess robotic systems' performance has significant implications for enhancing their capabilities and reliability. The integration of human interaction within these systems through teleoperation and feedback mechanisms introduces another layer of complexity and potential for refinement. The convergence of simulated environments, human-robot interaction, and sophisticated control techniques define the landscape within which this research project unfolds. A seminal work in the field of underwater robotics was a study conducted by Pusalkar, Giolando, and Adams at

Oregon State University's robotics lab, presenting a pioneering "Decision Support System for Autonomous Underwater Robot Grasping" [1]. In this paper, Pusalkar, Giolando, and Adams [1] describe the challenges faced by marine robots in underwater environments, stating, "Underwater environments present numerous challenges for marine robots, such as noisy perception, constrained communication, and uncertainty due to wave motion" [1]. Their entire research presents a comprehensive study encompassing the implementation of human-computer interaction, and the autonomous operation of robots, aiming to contribute to the evolving realm of underwater robotics and its practical applications.

Continual Self-Report Devices

For the human-robot interaction aspect of this experiment, a continuous self-report device was engineered that participants interacted with to gauge their confidence during each grasp execution. Rotary knob controllers, slide/fade controllers, touch screen interfaces (e.g., iPads), and software implementations (e.g., user interface) have been employed in the past. MIDI technology, such as used in music production, may be employed to convert and save files for analysis but involves expensive equipment. The rotary knob has been rejected along with using touchscreens or software GUI implementations due to increased distractions these methods impose on the participant; the participant’s attention must remain solely on the robot.

Robotic Arm Teleoperation

A Bravo 7 robotic arm will be controlled by human movements in a leader-follower approach. A method uses a full-body motion capture suit allowing flexible control using the combination of the ROS (Robot Operating System), Movit control interface, and a motion capture suit used to control the robot in real-time. There are also large human motion databases available that have captured not only human motions but also the motion of the objects they are interacting with which will provide valuable insight into the programming involved in accomplishing my goal. This information provides the numbers and kinematics needed to control the arm. Software called Xsens can be used for teleoperating robots through human motion using an Xsens suit. The use of this platform will create a much more natural interaction between the robot and the item it is grasping by creating the positioning values created by using motion capture technology. Advancements have been made in robotics to implement requisite system components such as hand/arm manipulation, whole-body motion transfer, teleoperation methods, underwater motion analysis, robotic database development, and humanoid robot control that will help in my research. Different approaches, including inertial motion capture, neural networks, and cable-driven systems, present various possibilities that can be used alone or in conjunction to enhance human-robot interaction and imbue robots with significantly more human-like control and capabilities.

Project 1: Seabed Floor

Seafloor Objective

The first project was to design and fabricate the simulated seafloor supporting the underwater manipulation research into the submarine grasping capabilities of a robotic arm. The creation of an environment as close to the real thing was crucial in the entire experiment being conducted. The objective was to manufacture an artificial seafloor that simulates a seabed environment to match an actual seabed environment under the ocean. The surface of the simulated seabed floor contained predetermined locations where the camera could best pick up and identify each object being presented for a grasp. These locations were then cut out to provide a place for the objects to be tested in the same position relative to the other tests. Then, a testbed consisting of a frame and a 3D motion system as seen in Figure 1 is designed to move the robot arm through the water and was placed above the artificial seafloor.

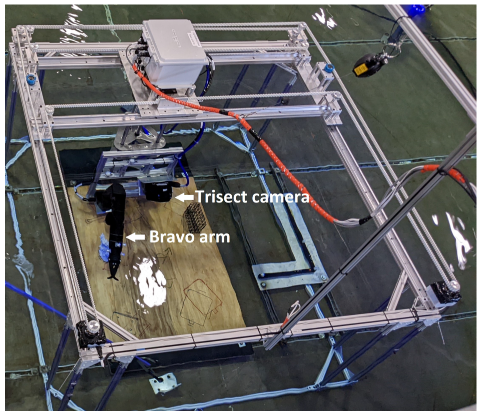

Figure 1: Testbed with Bravo 7 arm
("Decision Support System for Autonomous Underwater Robot Grasping" [1])

Seafloor Design

Figure 2: Simulated seabed floor
(used to place the objects being tested)

The artificial seafloor was fashioned using a plywood base, multiple layers of styrofoam, and a fiberglass shell. The entire apparatus was coated in tan-dyed epoxy with sand sprinkled on the top layer to simulate a sandy seafloor. Plywood was used as the base to provide a strong foundation, and the two layers of foam were epoxied to each other and then glued to the plywood base. The first layer of foam created depth, while the second layer contained the relief for object placement with simulated topography. Previously, the testbed floor consisted solely of a piece of plywood without indentation for the test objects to be consistently tested. The entire testbed was cut to fit as a footprint under the testbed frame that the arm was attached as seen in Figure 3.

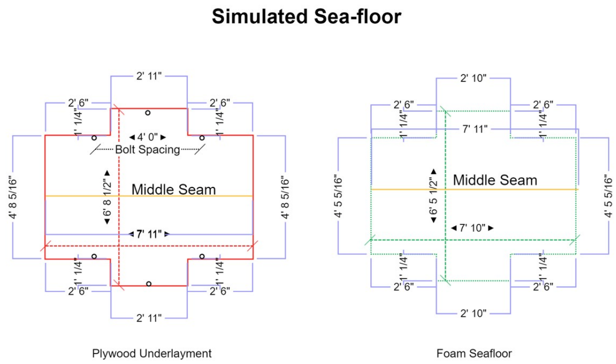

Figure 3: Seabed footprint

The artificial seafloor was also fastened to the floor of the testing pool due to the buoyancy of the foam; the foam's buoyancy created a situation where the weight of the plywood was not enough to keep the entire simulated seafloor from floating to the surface. Fasteners were used to ensure the entire apparatus stayed affixed to the pool bottom throughout the entire experiment. This was accomplished by providing holes in predetermined locations as seen in Figure 3 for the fasteners to interface with the uni-strut anchoring system provided on the pool floor.

Project 2: Continuous Self-Report Device

Confidence Tracking Device Objective

The second project was to create a continuous user input solution to record the human-robot interaction through a value of confidence created by a test participant. A way was needed to extract that data from the interaction between the test participant and the robot and visualize our research data after the experiment. Participants would select a grasp displayed on a user interface and then observe the robot arm execute the grasp. The continuous self-report device (CSD) records values given by the test participants regarding their confidence in each grasp while observing the arm execute each grasp. The CSD needed to be designed so as not to distract the test subjects who were experimenting as their focus needed to be on the screen at all times. Therefore, I employed a slide controller because it creates a linear path with which the participant doesn't need to look down at the device to know what values they are representing; it was designed with a minimal interface that didn't require any visual interaction. The input from the device was converted into values from negative one hundred to one hundred (with zero being the center or neutral position) of confidence. These values were then recorded, along with a timestamp, in a file.

Confidence Tracking Device Design

The CSD was designed using a quarter-size Arduino microprocessor, a 120mm slide potentiometer, and a housing created using a 3D modeling environment and then printed on a 3D printer using the model in Figure 4.

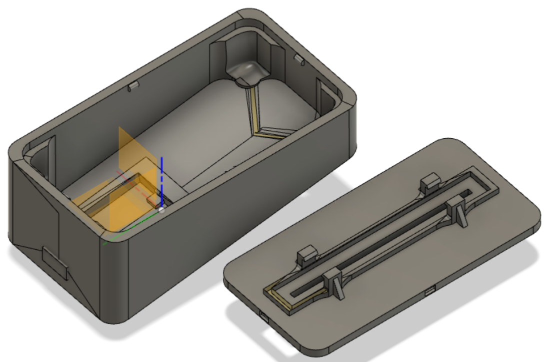

Figure 4: Tracking device housing model.

The slide potentiometer was then mounted inside the 3D-printed housing with only the slide exposed. Then the slide potentiometer connects to the microprocessor’s analog port, the 5V, and the ground giving it power and connecting to it for input. The microprocessor connects to a computer via a USB cable via a communications port inside the computer. These files can be used to represent the data acquired from the experiment and can be used to create visual representations of the participant’s confidence.

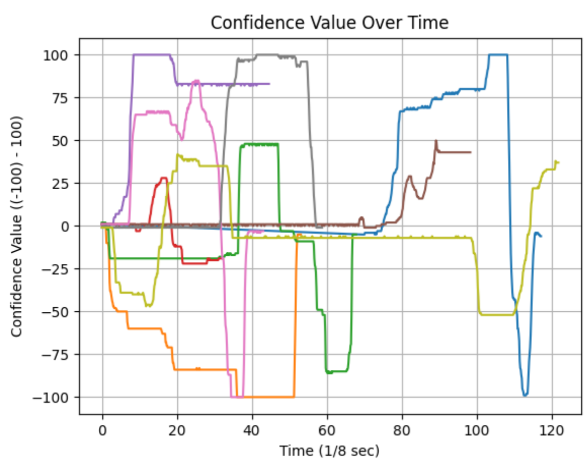

Figure 2: Participant confidence values

TODO: Talk about how it was deployed to support the Hinsdale experiments.

Project 3: Bravo 7 Teleoperation

My last objective is to use motion capture technology and inverse kinematics for the humanoid movement of the robotic arm. By using motion capture technology called Xsens we can capture and analyze human movement data to aid in controlling the Bravo 7 robotic arm while improving its performance underwater.

I started by installing Linux and then ROS on my computer followed by acquiring the URDF (universal robot description) file for the Bravo 7 robotic arm and installing it into a Moveit workspace. With this, I can then simulate and control the robot simulation in a three-dimensional environment. After that, I created a Python script that can interact with the robot node created by the Moveit software. I will eventually modify the code to interact with the data I will collect using the Xsens motion capture suit. It will provide me with the kinematics of how the human arm moves using sensors and markers on the Xsens suit. The data will consist of the raw numbers involved in human arm movements giving the robot arm human-like movement. At that point I can simulate the robot using the data to test, troubleshoot, and eventually control the actual robotic arm.

The first challenge I faced was learning how to install and then use Linux, the operating system ROS uses. Once I got past that hurdle my next challenge was to get ROS installed and familiarize myself with the operating system. The application of the Moveit software with the Bravo 7 arm presented the biggest challenge, its installation and configuration are poorly documented. Through trial and error, I eventually was able to simulate the robot and then move the arm with the Moveit plugin software. At this point, I had to learn how to write code using the libraries provided by ROS and Moveit to create a Python script that would send commands to the robot node created by Moveit to control the arm. This is as far as I have progressed in my research and I am still working on creating a Python script that can interact with the Xsens software and Movit to control the robot simulation due to the amount of challenges faced.

Conclusion

In this study, we embarked on a comprehensive exploration of underwater robotics through the use of a simulated seabed environment, a continuous self-report device, and the teleoperation of the Bravo 7 robotic arm. Each component of our research has contributed to the advancement of robotic technology and has also shown possible new research and applications. Through our testing, we created a controlled environment for assessing the Bravo 7 arm's underwater grasping capabilities. This research not only demonstrated the effectiveness of our constructed setup but also highlighted the important role of simulated environments in refining robotic systems. This finding impacts all underwater robot applications ranging from marine exploration to disaster response. The engineering and application of the continuous self-report device created a way to record human interaction and has pointed out the importance of human-robot interaction. The real-time confidence tracking helps refine the arm's grasping performance and points towards a future where robots can adapt their behavior based on human cues. This science is crucial not only for teleoperation but also for the broader field of human-robot collaboration. My research into teleoperation taught me of both challenges and potential future applications. While simulating the Bravo 7 arm's motion in ROS and figuring out motion capture integration presented hurdles, these lessons have given me ideas for further investigation, possibly next summer. The integration of wearable motion capture gives the robot its natural teleoperation, making it more human-friendly and adding more user-friendliness to underwater robotic systems. This study investigated the interaction between simulation, human interaction, and technological innovation. The continuous self-report device and simulated environment have possibilities for enhancing robotic system performance, while new teleoperation science is furthering the technology of human-robot interaction. I want to end with the recognition that this research is a small part of a future where underwater robotics use human guidance and the autonomous capability of underwater exploration.

Acknowledgments:

I would like to acknowledge everyone involved in this experiment and their efforts. The members include Julie Adams, Mark-Robin Giolando, Christina Wilson, Sean Buchmeier, Heather Knight, Stefan Lee, Joe Nguyen, Prakash Baskaran, Kyler Jones, and Hunter Brown and I would just like to thank everyone for their hard work. I would also like to thank the robotics department at Oregon State University for allowing me this opportunity and supporting my research

References:

[1] Arduengo, M., Arduengo, A., Colome, A., Lobo-Prat, J., & Torras, C. (2021). Human to robot whole-body motion transfer. *2020 IEEE-RAS 20th International Conference on Humanoid Robots (Humanoids)*. https://doi.org/10.1109/humanoids47582.2021.9555769

[2] Himonides, E.; (2017) Music Technology and Response Measurement. In *King, A. and Himonides, E. and Ruthmann, SA, (eds.) The Routledge Companion to Music, Technology, and Education. (pp. 427-436)*. Routledge: New York, NY, USA. https://discovery.ucl.ac.uk/id/eprint/1535439/1/Himonidesfinalchapteronresponsemeasurement.pdf

[3] Kobayashi, F., Kitabayashi, K., Nakamoto, H., & Kojima, F. (2013). Hand/arm robot teleoperation by Inertial Motion Capture. *2013 Second International Conference on Robot, Vision and Signal Processing*. https://doi.org/10.1109/rvsp.2013.60

[4] Neha Pusalkar, Mark-Robin Giolando, and Julie A. Adams. 2023. Decision Support System for Autonomous Underwater Robot Grasping. In *Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction (HRI '23 Comanion), March 13-16,2023, Stockholm, Sweden.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3568294.3580071

[5] Rodriguez-Barroso, A., Khan, M., Santamaria, V., Sammarchi, E., Saltaren, R., & Agrawal, S. (2023). Simulating underwater human motions on the ground with a cable-driven robotic platform. *IEEE Transactions on Robotics*, *39*(1), 783–790. https://doi.org/10.1109/tro.2022.3197338