ALFA Task 2 Deliverable M2.3.2: Shared Autonomy Intervention for Underwater Vehicles

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1 Introduction

This report outlines marine field demonstrations for manipulation tasks with a semi-Autonomous Underwater Vehicle (sAUV). The vehicle is built off a Seabotix vLBV300 platform with custom software interfacing it with the Robot Operating System (ROS) [Lawrance et al., 2016]. The vehicle utilizes an inertial navigation system available from Greensea Systems, Inc. based on a Gladiator Landmark 40 IMU coupled with a Teledyne Explorer Doppler Velocity Log to perform station keeping at a desired location and orientation. We performed two marine trials with the vehicle: a near-shore shared autonomy manipulation trial and an offshore attempted intervention trial. These demonstrations were designed to show the capabilities of our sAUV system for inspection and basic manipulation tasks in real marine environments.

2 Intervention trial

2.1 Overview

The first trial combined autonomous navigation with handover to a human operator for manipulation of a fixed target in poor-visibility conditions. Our goal was to demonstrate that autonomous modes such as station-keeping and waypoint-following can be used to assist a human operator in navigating in a globally-fixed frame, while leveraging the human operator for the challenging maneuvers required for manipulation using only the visual camera. The trial was performed in Yaquina Bay on June 19, 2017. At the time of the trial (nearing mid-tide) the surface current was approximately 0.5 m/s. The water had limited visibility of around 1.5 m.

We constructed a basic manipulation target (Fig. 1) where the goal was to grasp an 8 cm diameter steel U-bolt located approximately 1 m above the sea floor at a depth of approximately 5 m. The robot was (manually) driven to the target and attached by grasping the U-bolt with the sAUV gripper arm. Then, the robot was manually released, commanded to autonomously navigate to a waypoint 7 m south at a depth of 3 m and then return to the original target position and station-keep until the human operator took command. The human operator successfully re-grasped the target using only the visual camera. The entire process (from release to re-grasp) took approximately 100 s. For comparison, an operator familiar with the robot and task took approximately 50% more time to complete the task with a fully manual vehicle. Much of the time difference can be accounted for by the operator being required to constantly switch attention between data sources (navigation, sonar, camera) in order to maintain orientation and check whether target locations have been reached.

Figure 1: Photograph, onboard camera still image and ROS rviz visualization (clockwise from top left) of grasp target for shallow-water intervention trial (note that the time and date on the video overlay are incorrect, the trial was conducted on 19 June 2017).

The results in Fig. 2 represent the vehicle's own position estimate, and we do not have a true globally-referenced position of the vehicle. However, the grasp target was placed in the vehicle's frame of reference at the start of the trial to match its global position, and the target was weighted and did not move (in the global frame) during the trial. At the end of the trial the vehicle navigation frame had drifted approximately 0.7 m with respect to the true (globally stationary) position of the target. This was close enough that the human operator could see the target on the camera and manually complete the grasp.

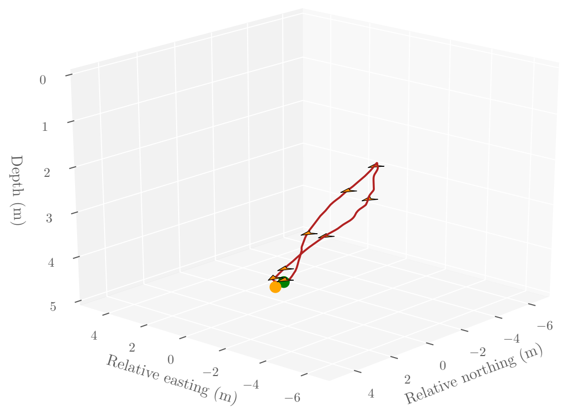
2.2 Data description

Associated data from the intervention trials are provided with this report. The data is provided in the form of a plain text comma-separated values (csv) file consisting of records from the navigation estimate during the sequence of trials. There are two data files from the Yaquina bay intervention trial:

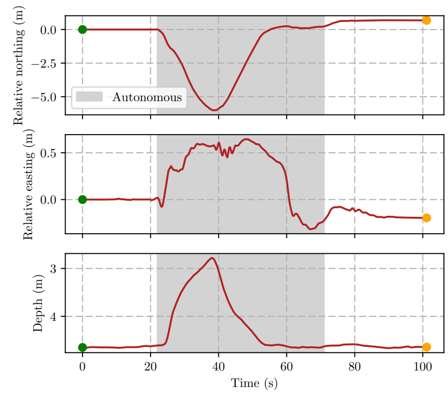
- `grasp_trial1_p.csv` contains navigation solution estimates from the full set of attempted grasp and regrasp missions, and
- `grasp_trial2_p.csv` contains a trimmed instance of a single successful grasp and regrasp trial (as shown in the results in Fig. 2).

The data are saved in *.csv files with a header row describing the data contained in each column, and then subsequent rows of numerical data, where one row is all data recorded at a single time instance. Some of the more useful fields are:

- `unix_time_sec` time stamp in Unix time (s),



(a) 3D position track.



(b) Northing, easting and depth history.

Figure 2: Navigation estimates during manipulation trial. Note that the vehicle had grasped the target at the start and end of the trajectory, so that the green (start) and yellow (end) positions of the trajectory should be approximately the same location in a fixed global frame. Heading arrows in 2a are shown in 5 s increments during autonomous motion. The grey region in 2b indicates the time during which the vehicle was under autonomous control.

- `relative_position_x` the x position of the vehicle (m),
- `relative_position_y` the y position of the vehicle (m),
- `relative_position_z` the z position of the vehicle (m), and
- `heading` bearing of the vehicle relative to magnetic North (deg).

Provided with the data set is a Python script to load the data and produce the graphs provided in this report. Additional detail is available in the provided README file. The Python code and data set have been submitted for inclusion in the Department of Energy data repository.

3 AutoAMP platform deployment

For the second trial we assisted in deployment of the AutoAMP platform at a depth of 60 m and a location around 2 km offshore near Newport, OR (44° 33.0′ N, 124° 13.75′ W) on August 15, 2017. The primary goal for the AUV was to locate the platform and estimate the orientation after deployment to confirm that it had settled in a suitable position on the seafloor. A secondary goal was to perform a manipulation operation on the platform, namely grasp a U-bolt of similar dimensions as used in the previous trial. We successfully located the platform using sonar on the AUV and moved close enough to perform a visual inspection. We successfully surveyed the lander site and visually confirmed its position and orientation. Unfortunately, a malfunction of the Doppler velocity log navigation system resulted in poor navigation performance so we were unable to record navigation data or perform fully autonomous operations around the lander. We attempted manually grasping the lander but we did not want to risk damaging fragile equipment on the lander and due to currents and very limited operational time at the lander site we did not successfully complete a grasp. Images from on-board cameras can be seen in Fig. 3.

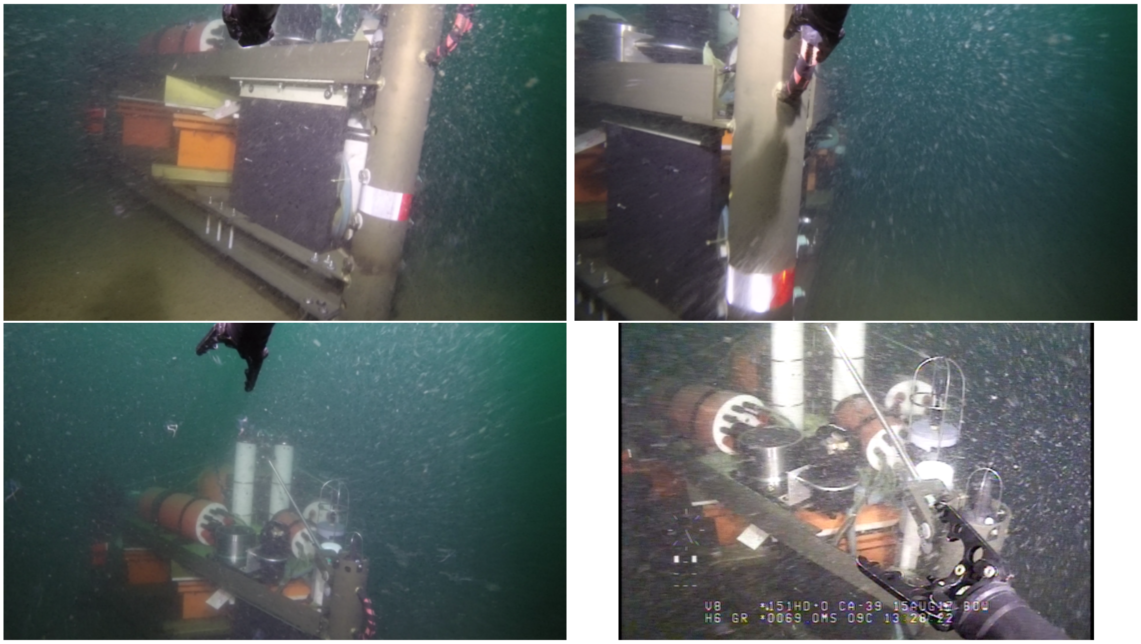


Figure 3: Images recorded by the AUV during inspection on the AutoAMP platform deployment at 60 m depth.

4 Summary

Overall, these results and datasets demonstrate the feasibility and potential for semi-autonomous intervention in environments relevant to marine hydrokinetic arrays. The deployment in Newport Bay demonstrates time savings versus an unassisted operator who took 50% more time to grasp an 8 cm diameter handle in an environment typical of ocean current energy harvesting devices. The offshore deployment of the AutoAMP platform demonstrates the potential for vehicles in deeper water environments (e.g., those typical of wave energy harvesting), but also illustrates a number of challenges. The vehicle's navigation system was less reliable in these scenarios, and ship support was difficult due to the requirement to move the ship as the tethered vehicle moved around in the underwater environment. These results motivate further research into semi-autonomous navigation and manipulation in challenging marine environments capable of dealing with these issues.

References

[Lawrance et al., 2016] Lawrance, N., Somers, T., Jones, D., McCammon, S., and Hollinger, G. (2016). Ocean deployment and testing of a semi-autonomous underwater vehicle. In *Proc. IEEE/MTS OCEANS Conference*, Monterey, CA.