Underwater path-following for a Videoray Pro 4 ROV

Simulations and experimental testing results

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Introduction

The control of Remotely Operated Vehicles (ROVs) is, as the name suggests, performed remotely by a human operator, normally with the use of a controller with joysticks. Having an operator to control the ROV may be expensive, and errors related to human intervention are an ever-present concern when dealing with equipment of high cost. Basic, automatic control system features can be used to control, for instance, the depth and heading of the ROV. Later, more advanced control strategies like tracking or path-following algorithms can be developed in order to perform a greater variety of tasks. This puts ease on the operator, and may ensure that the operation is successful in a safe and efficient manner.

Objectives and scope

- Study the lateral thruster and develop code to control it in a satisfactory manner
- Set up the Qualisys Motion Tracking (QMT) system to receive the ROV's position and orientation in Matlab
- Create a simulation model of the Videoray Pro 4 ROV using Matlab and Simulink
- Develop, implement and perform experimental testing of automatic controllers for heading and depth for both the simulation model and the Videoray ROV.
- Develop, implement and perform experimental testing of a path-following methodology for both the simulation model and the Videoray ROV.
- Experimental testing will be conducted in the MC-lab

The Videoray Pro 4 ROV

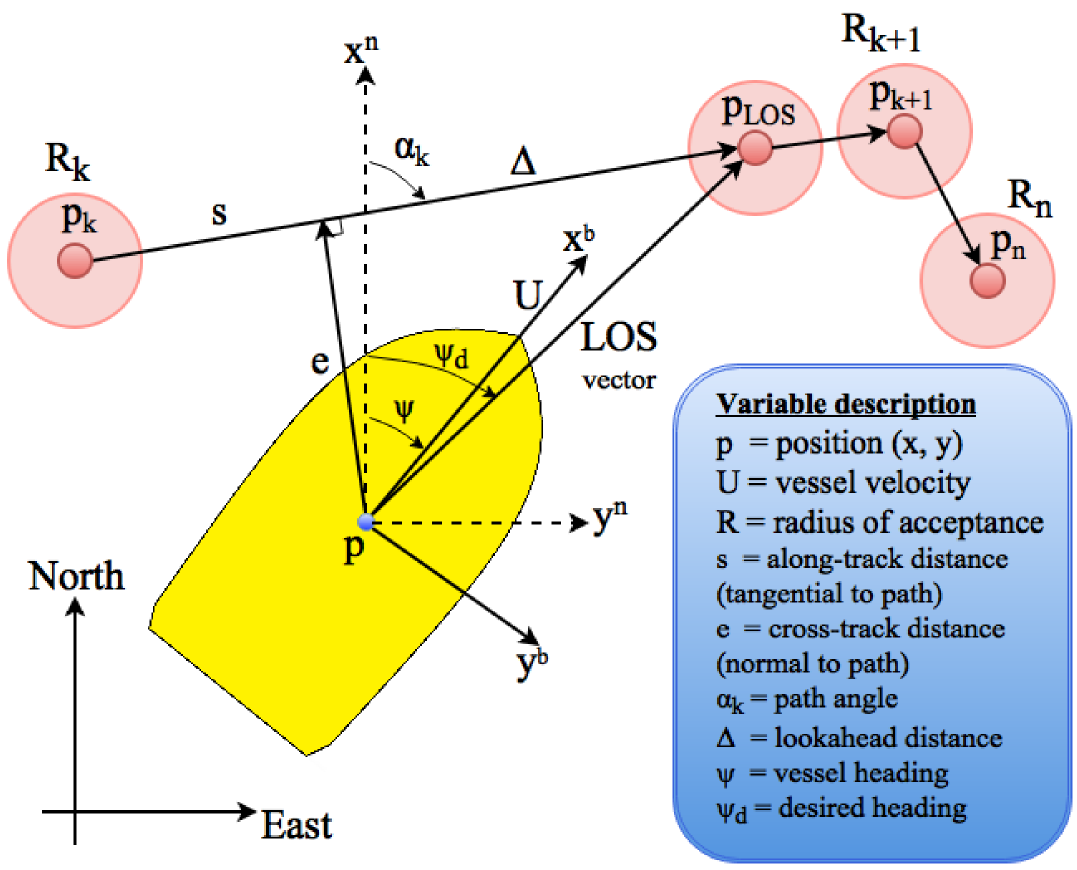
The Videoray Pro 4 is a small-sized ROV. It is equipped with three operable thrusters, allowing movement in surge, yaw and heave. To control the ROV, a hand-held Dualshock 3 /sixaxis controller is used (see figure).

The ROV has been equipped with an «off the shelf» lateral thruster created by the manufacturers of the ROV.

Communication with the ROV happens in C/C++ through an interface, called a mex-function, allows for code impementation, debugging and execution in Matlab directly. The ROV can be run on both Linux and Windows computers.

Methodology

By using the work of [1], a mathematical model has been carried out for the Videoray ROV. This model is intended for simulations and verification of implemented control strategies, to be further developed for the actual system. Mounting of both a lateral thruster and a rig used for position and orientation data, including uncertainties in the hydrodynamical parameters found in [2] discourages model-based control. Therefore, basic autopilots for depth and heading are implemented as PID controllers. The guidance system comprises a lookahead-based line-of-sight (LOS) steering methodology in [1]. The guidance, navigation and control (GNC) systems are designed for making the ROV capable of following pre-defined paths below the surface.

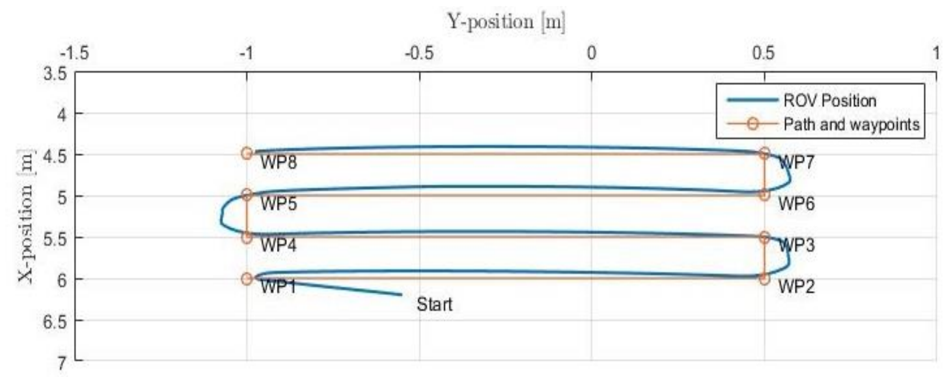


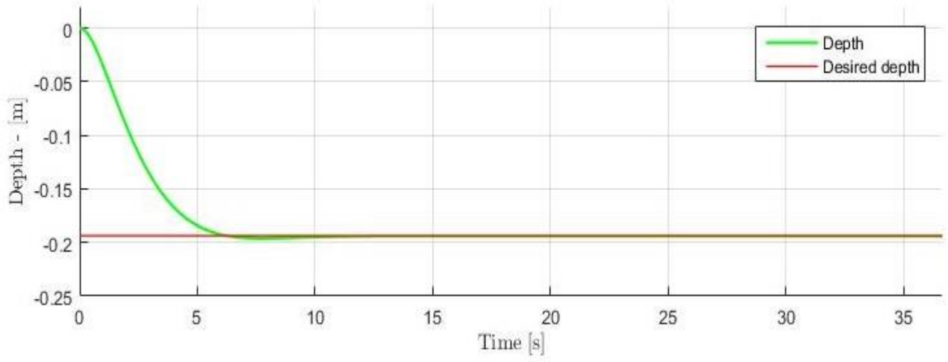
Taking a set of waypoints as input, the guidance system creates a path between each waypoint location. This path is followed by controlling adopting the LOS methodology and a technique for controlling thrust or velocity of the craft.

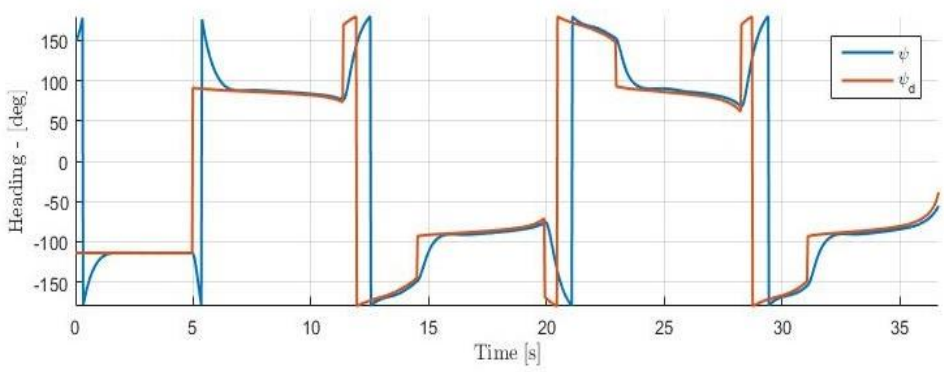
Underwater position can be received by the Qualisys Motion Tracking (QMT) system. Markers are placed on a custom made rig that is mounted on the ROV, which uniquely define an object in terms of position and orientation.

Results

Simulations

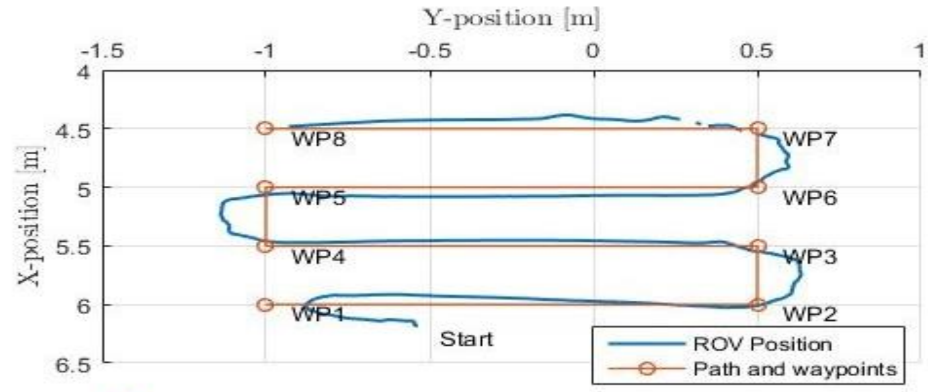


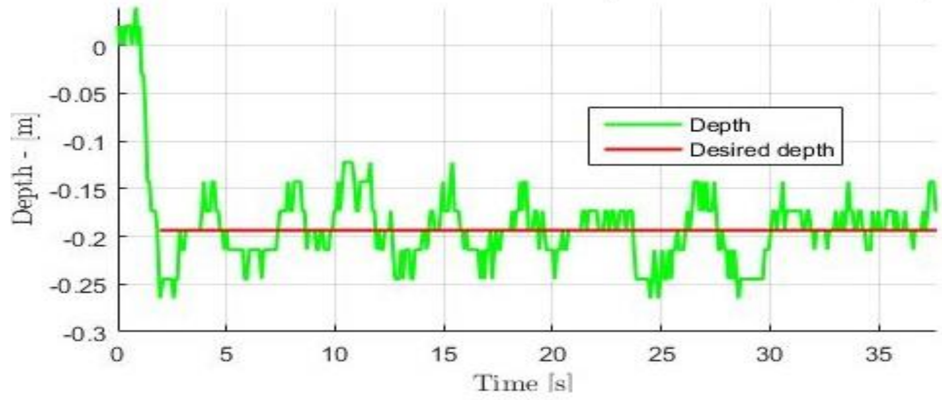


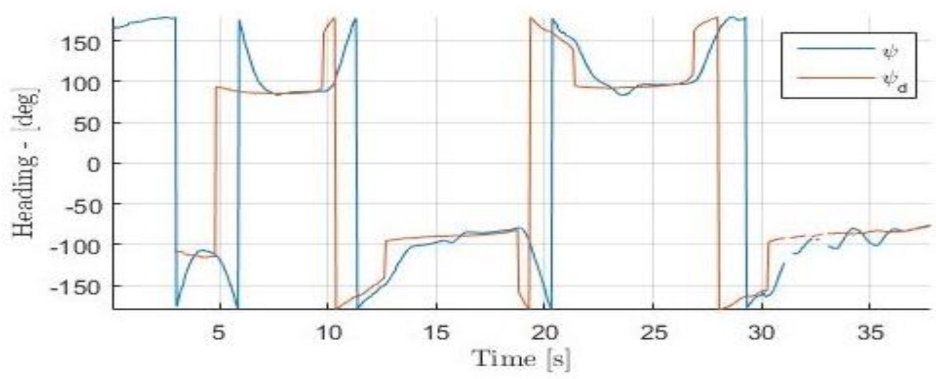


Simulation results verify that the mathematical model of the ROV is able to reach desired heading, depth and to follow the desired path with a very small error. When reaching the waypoint, the vessel will have a small velocity, resulting in an overshoot. Low-pass filters and saturating elements on the produced thruster forces are installed for more realistic and comparable results.

Experimental testing







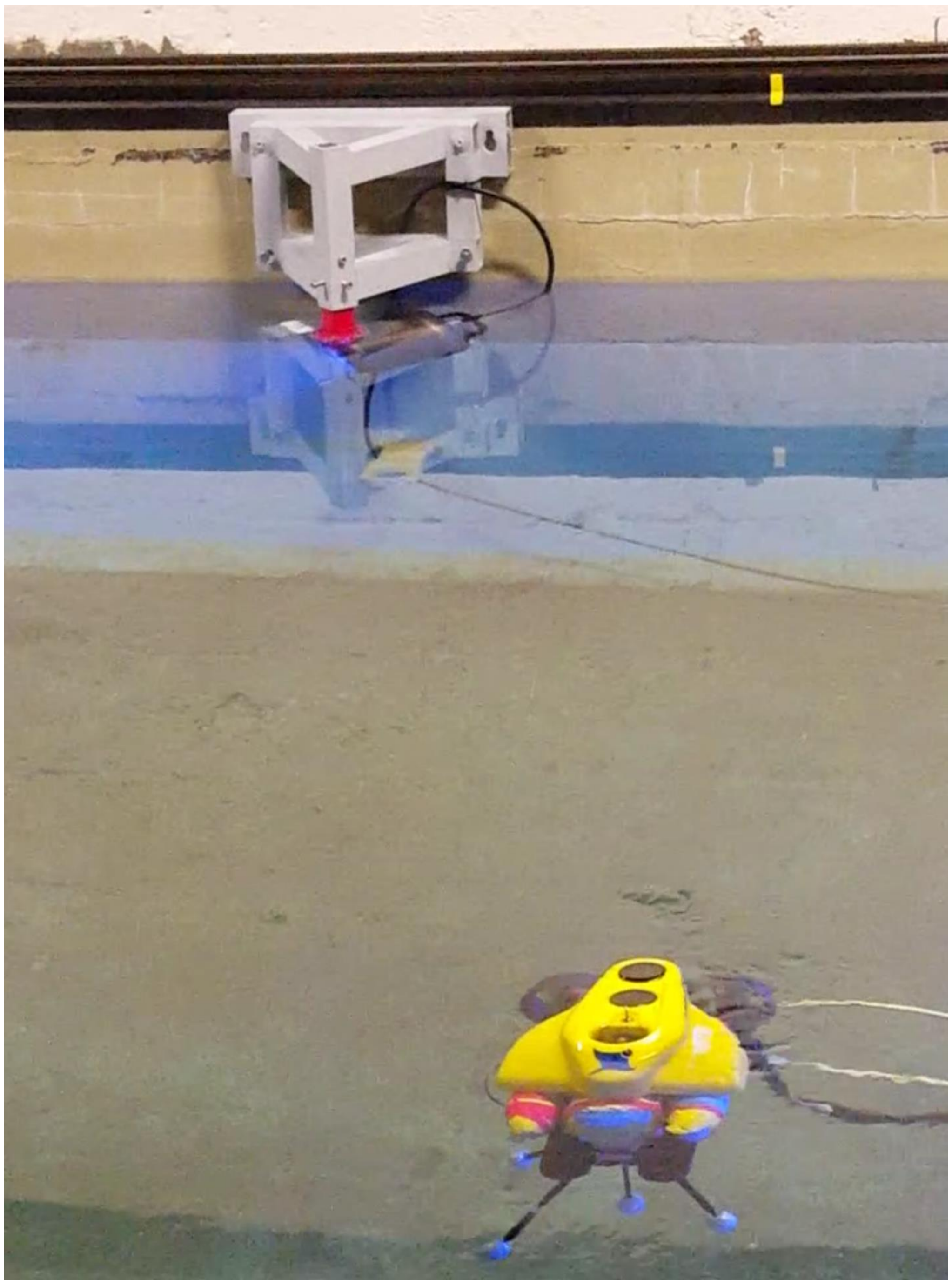
Results from experimental testing show that the ROV follows the path nicely. Position data are available throughout the entire run, except for a small time period after about 30 seconds, resulting in difficulties stabilizing the heading. Because no method for braking exists, the craft has a small velocity when reaching a waypoint, creating a small overshoot at the desired waypoints.

Conclusions

In the later stages of the thesis work, the lateral thruster has been made to work. Scarce documentation and difficulties making contact with the developers of the thruster limited the development process.

A method for using the Qualisys underwater positioning system in Matlab has been further developed, tested and verified.

Both the simulation model and the Videoray Pro 4 ROV adopts PID control laws for heading, depth, and a lookahead-based LOS guidance law for path-following. Experiments show that depth can be maintained within 2.5-5 cm, and that heading is kept with an error below 5 degrees. Unfortunately, the starboard thruster cartridge seal has less oil than what is needed to properly lubricate the propeller shaft, meaning that the thrusters cannot produce forces below certain limits. This reduces the heading controller performance, and the seal needs to be replaced. Still, as can be seen from the results, successful underwater waypoint guidance and path-following was achieved in the MC-lab basin. Further work should make use of the lateral thruster to regulate the cross-track error to zero for enhanced performance.



References

[1] Fossen, T.I., 2011. Handbook of marine craft hydrodynamics and motion control. John Wiley and Sons.
[2] Eidsvik, O.A., 2015. Identification of hydrodynamical parameters for remotely operated vehicles. Master's Thesis, NTNU.