Investigating PID Control for Station Keeping ROVs

K. L. Walker, A. A. Stokes, A. Kiprakis and F. Giorgio-Serchi
The University of Edinburgh

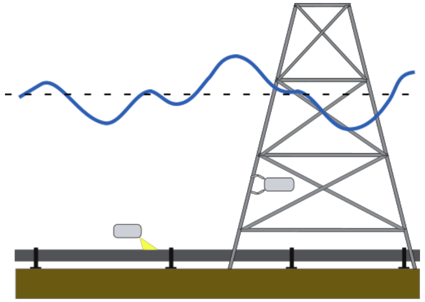
Introduction & Motivation

- Underwater vehicles, such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) currently lack the ability to sufficiently operate in shallow water environments where wave disturbance are prevalent.

Fig. 1: Typical ROVs; SeaBotix vLBV300 (left) and the BlueROV2 (right).

- If a suitable control methodology can be developed, ROVs could be used to reduce the cost of inspection and maintenance of shallow water offshore structures such as marine renewables.

Fig. 2: Example missions that a work class ROV may undertake.



Methodology

- The vehicle is considered a rigid body with 2DOF (surge/heave), represented in each plane by the dynamic equation:

$$m_{dry}\dot{v_a} + m_{add}\dot{v_r} = F_T + F_D \quad (1)$$

- A thruster model was utilised to improve the reliability of the station keeping results, as the motor time response influences performance:

$$F_T = K_T \rho_f D^4 |n| n - \frac{1}{3} v_f \rho_f D^3 |n| \quad (2)$$

- A wave model was reconstructed using real wave data [3] and Airy Wave Theory to demonstrate performance in a typical scenario. A section of this wave train is shown in Fig. 7.

- A time series trace of positional error at 15m operating depth shown in Fig. 7 displays significant error in both surge and heave.
- Positional error was assessed for a range of non-dimensional wave height and characteristic vehicle depth. (Fig. 4 – 7).
- Results display a specific region of sharp increase in positional error for both maximum and mean positional error.

Results & Analysis

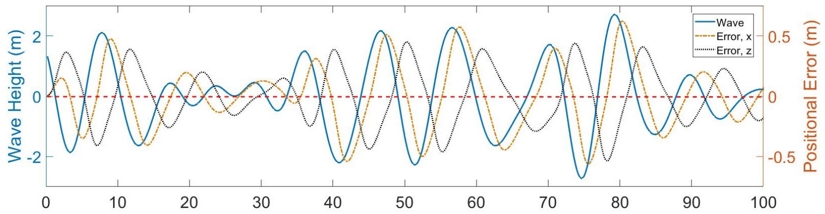


Fig. 3: Time series positional error at 15m operating depth

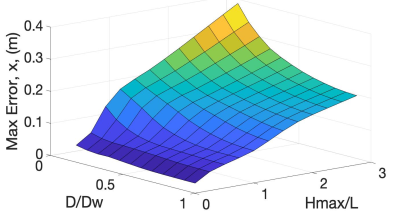


Fig. 4: Maximum positional error, surge.

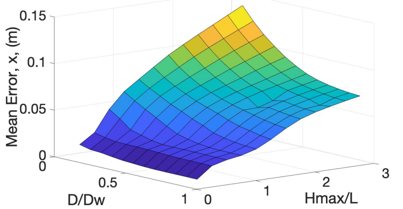


Fig. 5: Mean positional error, surge.

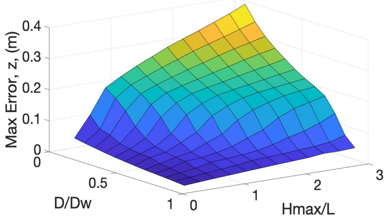


Fig. 6: Maximum positional error, heave.

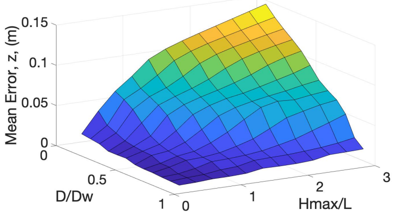


Fig. 7: Mean positional error, heave.

Conclusions & Future Work

- Evaluation of PID control shows excessive maximum positional error for non-dimensional wave heights >1.5 for any assessed depth in the surge. This shows that a more effective control method is required for station keeping in shallow water environments.
- To this end, Model Predictive Control (MPC) will be investigated. Alternatively, Cable Driven Variable Stiffness Manipulators will be investigated which can grasp structures and constrain motion.

Acknowledgements & References

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[1] K. L. Walker et al. ; Impact of Thruster Dynamics on the Feasibility of ROV Station Keeping in Waves; OCEANS 2020 MTS/IEEE *(In Press).*
[2] ___ Investigating PID Control for Station Keeping ROVs; UK-RAS20 Robotics and Autonomous Systems Conference 2020 *(In Press).*
[3] D. C. Fernandez and G. A. Hollinger, "Model Predictive Control for Underwater Robots in Ocean Waves," *IEEE Robotics and Automation Letters*, 2017.