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Agile, Hovering AUVs For Naval Special Warfare Operations

Horner, Douglas; Taylor, Ian

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AGILE, HOVERING AUVS FOR NAVAL SPECIAL WARFARE OPERATIONS

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Project PI: Dr. Douglas Horner, Research Assistant Professor, Mechanical and Aerospace Engineering, Center for Autonomous Vehicle Research
Student Participation: Ian Taylor, LT, USN, Mechanical and Aerospace Engineering

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Research POC Name: Daniel Steward CAPT (Ret.)
Research POC Contact Information: Daniel.Steward@navy.mil6, 619-537-1724

EXECUTIVE SUMMARY

Project Summary

Historically, maritime Autonomous Underwater Vehicle (AUV) development has focused on long-range, open-ocean applications. However, a large number of applications, particularly for Naval Special Warfare (NSW) missions, require operation close to objects (e.g., the seafloor, ships, submarines, submerged structures, other AUVs, and even divers). This study investigated the use of agile, hover-capable AUVs during NSW operations. Ongoing research at the Naval Postgraduate School (NPS) is focused on developing an agile, hover-capable AUV that is suitable for operations in close proximity to any or all of the above (close quarters operations). Continued research is required in precise platform control and dynamic stabilization, precision terrain-relative navigation, 3D mapping and obstacle avoidance, joint diver-robot operations with autonomous and semi-autonomous modes of operation, and autonomous intervention. Building on ongoing efforts, this effort will specifically investigate the use of an AUV in support of NSW missions. Through this program, students will have the opportunity to research the challenges associated with proximal AUV operations, including control, terrain-relative navigation, 3D mapping and obstacle avoidance, and intervention.

Background

A variety of Naval commands would benefit from precise AUV control and navigation in cluttered dynamic undersea environment. It requires a leap in current AUV/ROV autonomy technology that includes improvements in hydrodynamic modeling, adaptive control and exteroceptive sensor feedback.

An accurate hydrodynamic model can help in the development of precise AUV control and navigation in two ways. First, it can be used for conducting simulation. This can determine initial performance without taking the AUV out to sea. Second, the dynamic model can be used to improve controller performance. Past research emphasized hydro-dynamical modeling of the REMUS 100 vehicle but it didn’t consider cross tunnel thrusters and assumed a fixed velocity.

One mission area that requires variable speed consideration is autonomous underwater docking. It is an important capability for AUVs. It permits the vehicles to recharge its battery and communicate mission results and receive additional new tasking. Previous approaches assume a fixed speed into the docking station. This can damage the AUV and docking station. The fixed velocity during terminal homing was required since the control fin requires flow over the surfaces to maneuver the AUV. An AUV with cross tunnel thrusters can hover in front of the docking station and potentially provide a more robust, safer solution.

Findings and Conclusions

A successful, three-degree of freedom, variable speed, hydrodynamic model was created for the NPS REMUS 100 cross tunnel thruster AUV. The model was validated against actual NPS REMUS 100 operations conducted in Monterey Bay, CA. When a variable depth standard mission was compared with the model, the mean error was -12.8 cm with a standard deviation of 34.4 cm. A second test confirmed the performance of the REMUS cross tunnel thrusters. It again compared the REMUS real world mission versus the model behavior. Again the results were very good. The mean error was 8.8 cm with a standard deviation of 43.4 cm.

In summary, the 3DOF model provided an accurate variable speed model of the REMUS AUV with cross tunnel thrusters in the X and Z planes. The assumptions made in this model did not impact its fidelity dramatically and allows for a simulated prediction of the REMUS vehicle's behavior in the field. With the development of the 3DOF model, a better understanding of the capabilities of a REMUS vehicle with cross-tunnel thrusters has been accomplished. The 3DOF model can simulate a REMUS vehicle's cross-tunnel thruster and variable speed behavior during docking missions, mimic the vehicle's depth control, and RPM capabilities, and can be consulted when designing future REMUS docking stations.

Recommendations for Further Research

The following goals can be pursued in future work:

1) Calculation and verification of the minor coefficients used in the 3DOF model.
2) Expansion of the 3DOF model to a 6DOF model.
3) Create a 3DOF model that can accept environmental inputs such as wave action and currents.
4) Create a virtual simulation to display the REMUS vehicle's behavior.
5) Design a better PID controller to minimize the REMUS vehicle's behavioral errors during the initialization period of the model.
6) Integration of the 3DOF model into the REMUS vehicle's secondary controller.

7) Implementation of a neural network to learn and predict the REMUS vehicle's behavior.

References

Bermudez. (2016). *Terminal homing for autonomous underwater vehicle.* Naval Postgraduate School, Mechanical and Aerospace Engineering. Monterey: NPGS.

Healey, D. B. (2001). Command, control, and navigation experimental results with the nps aries auv. *IEEE Journal of Oceanic Engineering , 26* (4), 10.

Prestero, T. (2001). *Verification of a six-degree of freedom simulation model for the REMUS autonomous underwater vehicle.* Massachusetts Institute of Technology, Mechanical Engineering. Boston: MIT.

Sgarioto, D. E. (2007). *Control system design and development for the remus autonomous underwater vehicle.* Australia Defence Technology Agency. Sydney: DTA.