Abstract

Autonomous underwater exploration requires efficient and minimally invasive locomotion to navigate complex seafloor environments. Traditional underwater vehicles, such as remotely operated vehicles (ROVs) and submersibles, rely on thrusters or tracks, which can disturb the environment and struggle with precise positioning on uneven terrain. To address these challenges, this research develops a control framework for SELQIE, a legged underwater robot designed to traverse the seafloor autonomously. Unlike conventional underwater vehicles, SELQIE employs a hybrid locomotion strategy, allowing it to transition between walking, jumping, swimming, and sinking gaits, enabling versatile movement across diverse terrain.

Developed for the Office of Naval Research (ONR), SELQIE is intended to be deployed from an autonomous underwater glider, operate independently in a region of interest, and transmit collected data back to the glider upon mission completion. To achieve this, the robot integrates novel stride generation algorithms for gait control, a hierarchical planner for motion coordination, and sensor fusion techniques for localization. A ROS2-based autonomy stack ensures modularity and scalability, allowing SELQIE to navigate dynamic underwater environments while executing real-time motion adjustments.

The system was evaluated through simulation and real-world experiments, including controlled pool tests and field trials in Wacissa River. These tests demonstrated the effectiveness of the autonomy stack, with SELQIE successfully detecting obstacles, generating optimal gait sequences, and executing stride trajectories with high accuracy. Additionally, a MuJoCo-based MPC experiment validated the control approach for future use on a 3DOF quadruped, confirming precise trajectory tracking and stable locomotion.

While localization drift and terrain-dependent slip remain challenges, the results confirm that SELQIE's hybrid locomotion system is a viable approach for autonomous underwater exploration. The developed framework provides a foundation for future improvements, enhancing SELQIE's ability to operate in real-world seafloor missions, support long-duration deployments, and integrate with existing naval assets for persistent underwater surveillance and environmental monitoring.