BOSTON UNIVERSITY ACADEMY

Title: Investigating Maneuverability of Underwater Vehicles

Author: Skyler Cheung

Abstract:
Tuna fish are fast swimmers with relatively rigid bodies, and yet they are exceptional in their ability to maneuver underwater at high speeds. They possess the ability to dynamically change their stability through retractable ventral and dorsal fins, which can make them maneuverable when deployed and stable when retracted. Tuna instantaneously twist their bodies to take advantage of the forces acting upon them. Their sheer prowess in balancing between their stability and agility provide inspiration for similar mechanical designs of underwater vehicles. Here, we build on earlier findings to investigate the hydrodynamic coefficients describing an underwater vehicle and apply our findings to an autonomous underwater vehicle (AUV) named Morpheus. We pay special attention to the effect of the location of the dorsal fin on the hydrodynamic coefficients and overall vehicle maneuverability.

We used an automated tank to perform the experiments and collect data regarding the underwater vehicle's maneuverability, including its roll moment, yaw force, and angular velocity. We contrasted these values during various stages of the vehicle, such as with and without an attached rudder to the vehicle's body and with and without attached dorsal fins. We also included trials with a shroud on the tail-end of the vehicle, which surrounds the rudder fins.

We found that the vehicle's rudder acts as a significant stabilizing force on the bare vehicle; without a rudder, the vehicle would be extremely unstable. The addition of the dorsal fin increases the vehicle's maneuverability, especially when the fin is attached ahead of the center of rotational motion but behind the aerodynamic center. This effect is confirmed through a computer simulation calculating the relationship between the vehicle's angular velocity and speed as a function of the fin's location. We also observed that a certain threshold value for the rudder exists for it to maintain its stabilizing effect. Similarly, we found that the fin must be of similar size to the rudder. All of these aspects would improve maneuverability metrics such as the vehicle's turning radius and angular velocity.

These findings demonstrate a strong correlation between the vehicle's mechanical design and observations of tuna fish. This underscores the fact that tuna have evolved to substantially increase their maneuverability at high speed. Our results have significant implications for the design of maneuverable underwater vehicles.