The Role of Active Sensing in Locomotion

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Active sensing is the generation of energy for the purpose of sensing and can be achieved by producing a sensory signal or through movement. This summer, we used control theoretic approaches to investigate how the nervous system of the Glass Knifefish, *Eigenmannia virescens*, uses movement to acquire sensory information via feedback. The Glass Knifefish naturally swims to maintain its position in a moving refuge. It uses two sensory modalities, vision and electrosense, to achieve this tracking behavior. When the fish tracks the refuge, the difference between the refuge position and fish position is the tracking error, which results in 'sensory slip.' The nervous system of the fish uses this slip for processing the motion of the refuge (Fig. 1).

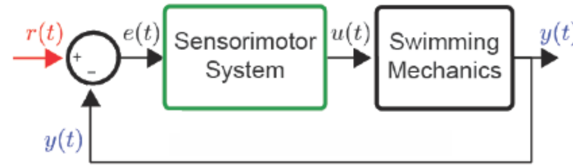

Figure 1: *y(t)* represents the fish's position while *r(t)* represents the shuttles position. The sensory slip, *e(t)=r(t)-y(t),* is encoded by the nervous system which sends a command, *u(t),* to fish's motor system which results in a new fish position, *y(t)*.

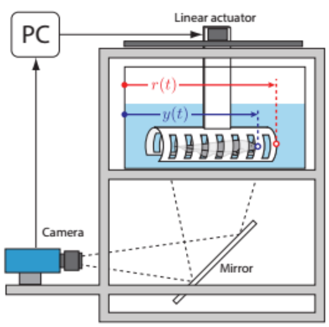

Figure 2: A linear actuation allows a computer-controlled refuge to move longitudinally through the tank. A high speed camera captures the refuge and fish position, *r(t)* and *y(t)*, respectively, which are digitized and can be used later for data analysis. The camera sends the fish position into a LabVIEW Script, which sends a command to the linear actuator to specify the movement of the shuttle.

Previous experiments reveal that the fish smoothly tracks the refuge when it has visual information. However, in the dark, the fish makes large back and forth movements (in addition to tracking), which require around three times more energy. We hypothesized that these movements are a form of active sensing and are used to enhance the neural processing of the error ('sensory slip') signal. To determine the role of these movements, we developed a computer program that can track the fish's position in real time and move the shuttle in response. This allows us to artificially suppress (move with the fish) or enhance (move opposite the fish) these active movements by adjusting the position of the refuge (Fig. 2)

Preliminary results indicate that during suppression the fish moves more and during enhancement the fish moves less. This supports our hypothesis that the movements could be used to obtain a desired sensory slip. Across all conditions, the absolute value of the sensory slip remains fairly constant. This suggests that the fish is adapting its locomotive behavior to achieve a desired amount of sensory feedback.

These experiments demonstrated the ability of the real time tracking system to enter fish's the feedback loop, which enables us to the study the sensorimotor control mechanisms of the fish during active sensing. This behavior can only be examined while the feedback loop is intact. Future research will examine the neurophysiology of the fish during active sensing, using the same closed-loop experimental infrastructure.

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