Do salamanders control locomotion in a midline-base reference frame?

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Our neural model of visual steering of central pattern generator (CPG)-based locomotion (both swimming and walking) successfully guides a simulated salamander to targets. This model features intermittent visual control and a vision-based, head-centered reference frame.

The intermittent visual control suppresses the use of vision at times of high self-motion induced retinal slip during the undulatory locomotion cycle. The suppression deals with the motion streaks caused by the side-to-side head movement associated with the salamander's undulatory locomotion by using visual input only just after the reversal of the rotational component of this movement, when visual motion is minimal. This is somewhat analogous to saccadic suppression in higher vertebrates.

At times of visual steering during the locomotion cycle, the control signals to the spinal CPGs are computed in a head-centered reference frame. In the modeled undulatory swimming and walking gaits, the head is constantly moving from side to side. When the head is to the left of a hypothetical midline, the target image is toward the right of the visual field, resulting in rightward steering. Likewise, leftward steering results when the head is right of this midline. With these biases, the model successfully steers the salamander to targets at a variety of bearings in simulation. Such biases may help explain the paths taken by monocularized salamanders.

However, it may be advantageous for the salamander to use a midline-based reference frame, instead of a head-centered frame. This possibility raises some interesting issues. In our intermittent visual control model, the salamander does not actually "see" a view from the midline, since full-field visual motion is near its maximum at the midpoint of the head oscillation; hence, vision is suppressed. A midline frame in our model thus requires that the salamander brain derive midline-based control signals from views near the extremes of the locomotion-induced head oscillation.

In this preliminary study, we have computed a correction to the head-centered control signals using a quickly decaying memory of the amplitude of recent head oscillations. This has produced turns that appear somewhat less precise that the head-centered model. On the other hand, results so far indicate that midline-based control may produce less side-to-side movement during locomotion. This might lead to more efficient gaits, compared with gaits produced by head-centered steering.

The model currently lacks a method for determining the future effects of locomotion control signals on the midline itself. We expect this to be a non-trivial function of the current state of the oscillation at each body segment, and the effect of control signals on that oscillation over the length of the salamander. Furthermore, it is not clear how to determine the midline during turning movements. These are problems to be addressed by future research.