A computational model of visual guidance in salamander locomotion

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We are investigating possible neural mechanisms of salamander navigation with emphasis on visual control of locomotion. Our fundamental hypothesis is that undulatory movements characteristic of salamander swimming and terrestrial trotting can give a wide range of head rotational velocities in the horizontal plane. Since the eyes do not move in the head, head movement implies eye movement. This movement can be synergistic with motion sensitive visual neurons.

The working hypothesis of salamander locomotor control is that the commanded direction of movement is encoded, translated by, and to some degree computed by, projections from the optic tectum (OT) to the mesencephalic locomotor region (MLR). The MLR is a very small area in the salamander's dorsolateral tegmentum which has been shown to directly influence locomotion gaits. There are known projections from the OT to the tegmentum. The OT is the most important visual area in the salamander brain. It receives direct retinal input, has retinotopic organization, and is known to control visually guided feeding behavior (e.g., snapping). However, in salamanders, the OT has hardly more neurons than the retina has ganglion cells, so the neural resources of the tectum must be used parsimoniously.

Our proposed mechanism for neural generation of locomotion guidance is that a hypothetical tectal neuron sums visual inputs for a single direction of movement with respect to the head. These neurons together form a coarse coded population vector for the direction of movement. The activity of each neuron is the weight of the tendency to move toward the neuron's preferred direction. The commanded direction is a (possibly non-linear) function of all weighted tendencies.

We call this neural vector a "saliency vector", since the tectum is presumed to command locomotion toward salient locations. Presumed parsimony in the use of tectal resources suggests that saliency is largely encoded by the retinal ganglion cell (RGC) inputs to the OT, with minimal tectal processing needed to tranlate the code into a preferred direction of motion. [1]

We further hypothesize that, via the MLR, the spinal central pattern generator (CPG) of locomotion gaits is modulated based on the commanded direction. Since the commanded direction is relative to the animal's head, and since the head is constantly, rhythmically moving from side to side during locomotion, the commanded direction changes constantly, with the net direction of movement emerging through temporal integration.

This work builds on Ijspeert's model of CPG control of salamander locomotion, which included a biologically realistic neuromechanical animated salamander locomotion simulator. The contribution of the present work is to investigate biologically plausible mechanisms of visual modulation of the CPG.

[1] Further research includes the incorporation of aversion to salient stimuli into this basic model. Beyond that, we will investigate the modulation of this tectal computation by other brain regions, accounting for motivation, multimodal sensory integration, and visual memory.