Title
How do we Scratch an Itch: A Model of Self-Reaching

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How do we Scratch an Itch: A Model of Self-Reaching

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How do we Scratch an Itch?

Imagine a simple situation: you have an itch on your left arm, and you reach with your right arm to scratch it. Scratching an itch at first seems like a simple, automatic task, but a little more reflection shows that it can actually be quite complicated. We do not need to see; rather, we can accomplish the task knowing only where the itch happens to be on our body, and how far our limbs are flexed or extended: we need only somatosensory information. We move the reaching arm and the itching arm together -- they are coordinated. This bimanual coordination allows us to reach arbitrary parts of our body: we are able to scratch anywhere on either arm. The task cannot always be accomplished just by moving the reaching hand in a straight line; sometimes other parts of our body -- or the itching arm itself -- become obstacles which must be avoided or moved. How are the movements of two arms coordinated to avoid collisions? How is the body-as-a-target represented? How do we reach for a target that may change location in space? How is the brain able to create a motor trajectory that will coordinate the body's limbs, avoid self-collisions, and still achieve the goal of reaching the itch? A framework for this problem is pictured in Figure 1, and some example configurations of the model framework are shown in Figure 2.

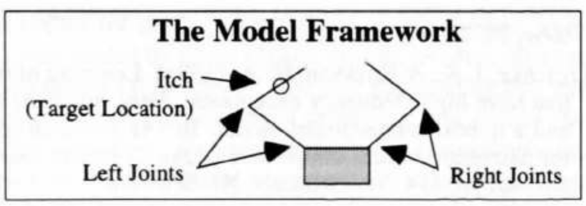

Figure 1: A sketch of the scratch-an-itch problem. The model consists of two arms, each with two joints, which allow both arms to move freely in two dimensions in front of the body. A target can be chosen on either arm. The problem for the model is: given an arbitrary starting position, find a way to move the arms so that the tip of the scratching arm touches the itch (target location), avoiding self-collisions on the way.

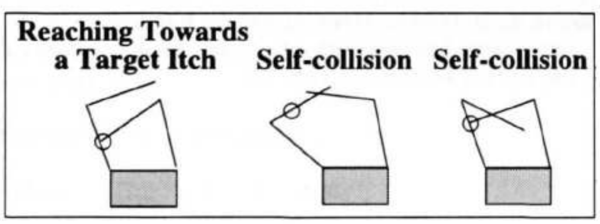

Figure 2: Example configurations of the model.

One way to model the scratch-an-itch task is to break it up into separate elements -- bimanual coordination, somatotopic task specification, and avoidance of self-collisions. We can then build a system or systems that handle each part. These interacting systems provide a framework in which to address high-level questions of coordination and planning.

Bootstrapping a Connectionist Model

We would like to have a "brain-like" solution to this problem, one that might tell us something useful about the brain mechanisms serving bimanual coordination. One way to do this is to train one or more neural networks solve the problem. During training, a neural network's internal structure is altered so that it replicates an input/output mapping which captures the essential character of a solution to the problem. In the process, it develops internal representations appropriate to the problem it is trying to solve. But where do we get the input/output data to train a network? The approach we use is to first build a "traditional" artificial intelligence solution. The problem is viewed as one of planning with goals which are repeatedly decomposed into easily executable subgoals. The AI model of movement planning then executes the task and in so doing can provide input/output data to train a network. While the network is constrained to emulate the input/output behavior of the AI model, its internal representation(s) of the problem need not be the same.

Predictions of the Model

After training, the network's solution to the problem -- its internal structure -- is also a prediction of how the problem may be solved by the brain (Zipser, 1992). This prediction can be tested against neurobiological observations. This verification process involves creating a mapping between units and relations in the model and anatomical or functional substrates in the brain, and using tools to "probe, poke, and push" the model in several ways to compare its behavior to that of the brain and its neurons. For example, the representational behavior of unit activations in the model can be compared with the averaged spiking of single neurons in the motor cortex. The connectivity of the trained network can be compared with the pattern of anatomical projections within the motor cortex. The neural network model provides a framework in which to ask and answer questions about the brain mechanisms serving motor planning and coordination.

References

Zipser, D. (1992) Identification models of the nervous system. *Neuroscience*. 47(4):853-862.