Simulating active touch with a simple embodied agent

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In the present paper, we simulate the differentiation of sensory- and motor-like interfaces, and their dynamics in an agent of novel architecture. This paper reconsiders the boundary between an agent and its environment. In the standard framework, we tend to assume that the physical boundary between the agent and its environment exists due to the independent physical devices of its sensory and motor interfaces. The boundary between agent and environment thus appears as a static and rigid boundary. We contest this view by creating a simple simulation model in which this boundary can vary dynamically. Thus we argue that an agent's perception is an outgrowth of the complex interference between the efferent and afferent copies of its action patterns.

The agent consists of a body with two straight arms that move freely from -90 to 90 degrees. Those arms are controlled by a continuous-time neural network. The neurons connected to the arms sometimes receive body states from the arms (the afferent copy) and then will move the arm in order to explore the environment (efferent copy). The role of sensory system and motor system are thus switching temporally, and there is no explicit sensory-motor flow.

There are some neuro-psychological experiments supporting the above dynamic view. For example, Yamamoto and Kitazawa (2001) demonstrated that with their arm-crossing experiment in which the perceived temporal ordering of haptic stimuli on a subject's hands is reversed when successive stimuli are temporally very close together. This experiment implies that we may be able to explain our perception by something based on body image rather than just by reactions to sensory input.

The agent in this simulation is trained via a standard genetic algorithm. The agent was intended to learn to distinguish between fans with differing numbers of wings which the agent can touch and manipulate using its arms. From this experiment we draw two primary conclusions:

1) The two arms become differentiated into sensor-like and motor-like arms, and the agent can successfully distinguish different fans by touching them

2) The agent's active and passive touching of the fans is driven by the stability of dynamic attractors associated with those touching behaviours. By placing time delays into the neural connection from the arm neurons to the body neurons, we notice that motor-like arms appear more fragile than sensor-like arms, and the attractor associated with active touch is more fragile than that associated with passive touch.

Our simulation demonstrated that the differentiation of sensory and motor functions emerged by mixing free and constrained arm motion conditions. When there are no obstacles, the arm moves freely and the neural network activations maintain coherence. This coherence could be taken as a sensation of body image. When there are obstacles present, however, this coherence is lost, and this interruption is transmitted as sensory information. By investigating the coherence/decoherence events of these internal neural dynamics, we will argue that the interference between efferent and afferent sensory copies drives sensation.