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Development of the "mirror system": a computational model

Single neuron recording and microstimulation in the monkey have shown that the premotor cortex is not just another big motor area [1]. On the contrary it contains visually responsive neurons. These neurons are thought to encode visual characteristics of objects in motor terms. For example, area F5 contains neurons that respond both when the monkey grasps an object and when it only fixates the object (canonical neurons) [2]. Irrespective of the intention of actually performing that particular motor act, the brain keeps a representation of the potential motor acts. F5 is quite a remarkable area. It contains also another class of visuomotor responsive cells called "mirror neurons" [3] They too fire when manipulating an object but also when one is watching somebody else performing the same sort of manipulation. Pretending the gesture does not make the neurons to fire: that is, the action has to be goal-directed. There is evidence of a similar system in human. Rizzolatti et al. [4] proposed an intriguing hypothesis linking the mirror system to language.

We are studying the development of the mirror system from a computational perspective with the ultimate goal of realizing a physical implementation. We use an anthropomorphic robot as development platform. The body of the robot provides the physical interaction between the computational structure and the environment.

We propose a working hypothesis that accounts for the response of the neurons in F5. Grossly simplifying, F5 can be imagined as the result of a two-stage process. During the first stage a representation, analogue to the canonical neurons, is acquired. This procedure indeed only requires an error signal about the success or failure of the manipulative action, e.g. if grasping of a cup is successful then associate its description (size and orientation) to the visual and motor description of the action of grasping the cup. The second stage accounts to associating, in a single mirror cell, an observed action to the one's internal representation acquired at stage one. For example, watching the action of grasping the cup can be put in correspondence with the canonical representation of it. The goal becomes the reinforcing signal asserting whether both action and object were the same in the two cases.

We will present a partial implementation of the system on our robots [5, 6]. This includes some basic visuomotor behaviors, ocular movements, and head/arm coordination.

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