Development of Imitation in a Humanoid Robot

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The Problem: It is believed that one of the distinguishing skills of humans is that of learning from imitation (it is still debated whether other primates are capable of true imitation). Imitation encompasses a set of different capacities such as recognizing other people's actions, recognizing the goal of a particular action and the objects and/or subjects involved. This project attempts to implement a similar set of abilities in a humanoid robot following a biologically motivated perspective.

Motivation: The biological basis of the project comes from one of the most fascinating discovery of the neurophysiology of the last decade: that is *mirror neurons*. This is a class of neurons found in the monkey's frontal cortex (area F5). A particolar mirror neuron is activated both when the monkey executes an action and when it observes the same action performed by somebody else: hence the name *mirror*. The importance of the discovery lies in the possibility to relate mirror neurons to gesture recognition, language, and imitation learning. The other aspect we would like to stress is the global approach to the problem: that is, not only mirror neurons will be considered, but also other classes of cells which contribute in forming the mirror representation (e.g. *canonical* neurons in F5, parietal cortex, etc.). Further, it is interesting to build a biologically plausible model of how the mirror representation is gradually put together during ontogenesis because this endeavor might advance our understanding of how similar processes are "implemented" in the brain.

Previous Work: The biological aspects of the mirror representation have been mainly investigated by Rizzolatti et al. [1] and Arbib et al. [4]. More recent results provided evidences for the existence of a mirror system in humans [3]. In robotics there has been a lot of interests about the problem of learning by imitation because of course it would be appealing to have a robot capable of learning a new task simply by demostrating it [2]. More recent approaches esplicitely proposed mirror neurons as the basis of the implementation (for example [5]) although the goal was more on providing the implementation *per se* rather than the biologically inspired modeling. Further, the process of learning of the mirror system was not explicitely considered.

Approach: The approach we intend to follow should allow the robot to interact freely with humans and to learn during the continuous interaction with the environment. We do not intend to distinguish between a training phase and a testing stage, as it is usual in machine learning, which would be somewhat unnatural in this case. As prerequisite the robot needs to be able to manipulate the objects in its environment: the robot will build this ability on top of a general attentional mechanism, and reaching and grasping skills. During a first stage it will learn how to correlate the visual description of an object in terms of size and orientation to an appropriate action type such as, for example, grasping or poking. This stage will build an understanding of objects in "pragmatic" terms. In a subsequent stage object information will be integrated with the information concerning the particular action being performed (either by the robot or the human experimenters). Eventually mirror neurons can be regarded as identifying when the goal of an action is the same irrespective of who executes it (the robot or a person interacting with the robot). Figure 1 shows the experimental setup that will be used for the experiments.

Impact: Of course, if fully successful the project might impact how robot are programmed nowadays (i.e. mostly a manual procedure). On the long term it might transform "programming" to something qualitatively different closer to "demonstating". The mirror neurons though are only a part of the story because the robot should be able not only to imitate but also to adapt the task to its own kinematics and dynamics as well as to extend it to similar situations. On the other hand, the humanoid robot might become a testbed for cognitive teories of imitation and learning. Whether this will be feasible will depend on how close the model will take into account the existing biological evidence, the level of detail, etc. (this is still a controverse issue).

Future Work: Possible extension of this work might include the automatic acquisition of new tasks thus effectively extending the robot repertoire autonomously, and as mentioned above, the possibility to generalize among tasks in order to obtain not only the mere imitation but rather a flexible one.

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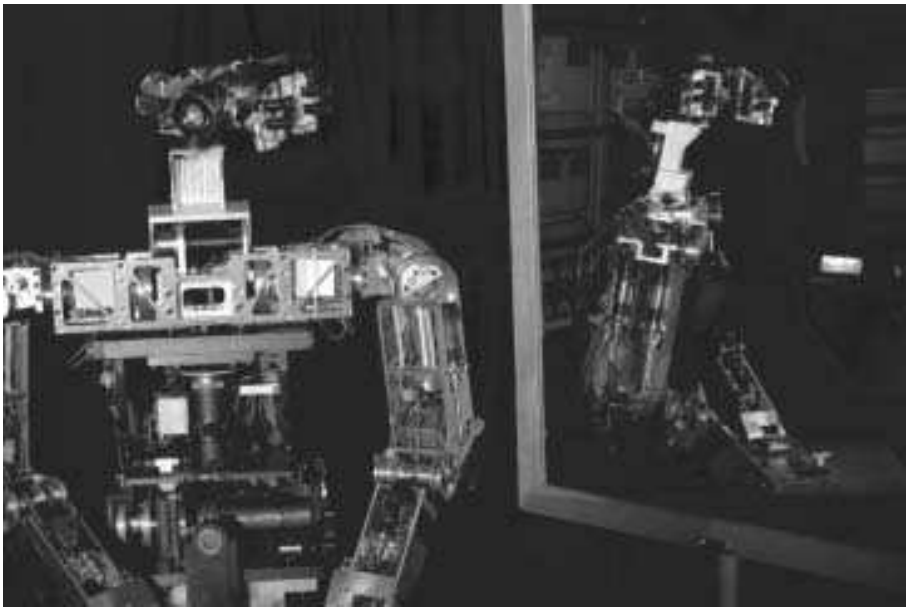

Figure 1: The experimental setup - COG