A Gestural Language for a Humanoid Robot

Aaron Edsinger

Artificial Intelligence Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

http://www.ai.mit.edu

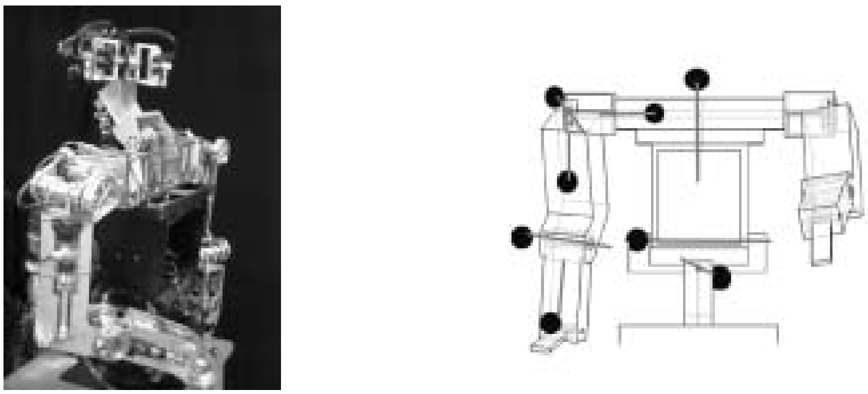

Figure 1: (left) Cog, the humanoid research platform. (right) A kinematic schematic of the 8-DOF used in this work.

The Problem: Humanoid research has long been concerned with the quality of the robot's movement. However, obtaining the elusive tempo and grace of the human motor system has proven to be a very difficult problem. The complexity of controlling high degree of freedom (DOF) humanoid robots, combined with insights provide by neurophysiological findings, has lead researchers to look at motor primitives [6] as an organizing methodology. We are investigating a data-driven approach to motor primitives in building a motor language for the humanoid robot Cog. The proposed model is implemented on Cog and applied to the task of human motor mimicry.

Motivation: The difficulty of the posed problem comes in part from the complexity of the human motor system. The human arm, for example, contains seven degrees of freedom and 26 muscle groups. It is a highly redundant system. A task such as pointing to an object in the world can yield an infinite number of solutions, yet the human system utilizes just a few. This in itself suggests that it is necessary to look for methods to simplify and structure the problem in such a way that it becomes tractable.

The approach taken in this work can be considered a variant of what are commonly referred to as motor primitives. The crux of this approach, supported by biological findings, is that we compose complex motor acts out of a small set of simpler motor acts. This small set of motor primitives provides the building blocks of our complete set of movements. It also provides a means for representing movements such that they can be compared and categorized in learning situations.

Previous Work: The motor primitives approach is grounded by findings in neurophysiology. The work of [1] in looking at convergent motor force fields in frogs, and of [4] in developing a nonlinear force fields model, is pivotal to our understanding of motor primitives.

In humanoid robot research, [6] and [3] have applied the motor primitives model to actual robots. The latter group takes an unsupervised learning approach to deriving the motor primitives from actual human motion data and uses them to replicate scripted motor trajectories.

Approach: The approach we take is to learn the motor primitives from a large motion capture data set. Then, by representing the data set in terms of the primitives, we can evaluate temporal sequences of primitives to find a

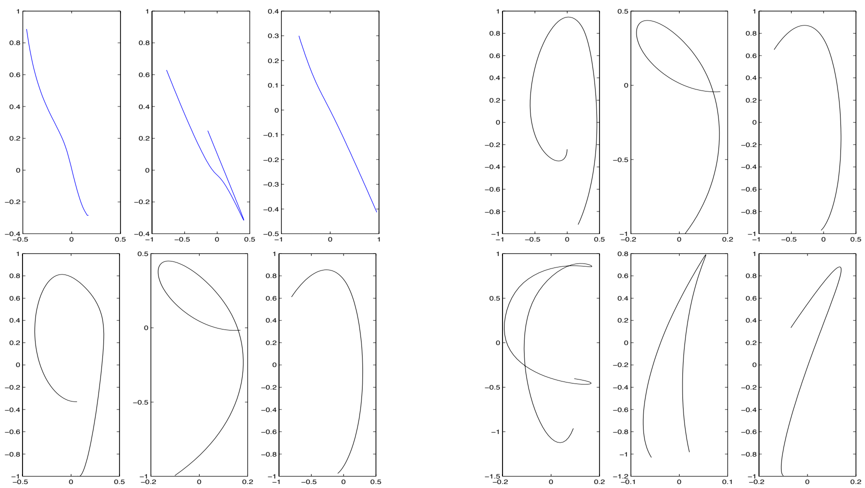

Figure 2: The response of the gestural language to the motor mimicry task. The response and perceptual input are displayed as the 2D projection of the end point trajectory. For each triplet: (left) the perceptual input as animate trajectory; (middle) the selected gestural response based upon search through the gestural language; (right) the actual response arm hand trajectory generated by the robot.

motor primitive grammar that the robot can execute in response to the environment. Finally, we apply the grammar to a motor mimicry task. This task requires that the robot mimic perceived human arm and hand trajectories, using a perceptual system developed by [5].

The motion capture data set is generated using the robot to generate time series of joint angles. The time series are segmented and normalized using a B-Splines representation. Unsupervised learning techniques such as PCA and clustering are then applied to derive the basis set of primitives. Finally, the data set is represented in terms of the primitives through a binary tree representation.

Applying the gestural language to the motor mimicry task involves developing an evaluation metric which computes the response of a given primitive to a perceptual stimuli. For this, we first map the primitive from joint coordinates to visual coordinates. This allows us to compare the primitive to the visual trajectory generated by an interacting human. By performing a search based on the metric, we are able to find and execute an appropriate motor response to the visual stimuli. More details on the implementation can be found in [2].

Research Support: This work was funded by DARPA as part of the ”Natural Tasking of Robots Based on Human Interaction Cues” project under contract number DABT 63-00-C-10102.

References:

[1] Emilio Bizzi, F. Mussa-Ivaldi, and Simon Gistzer. Computations underlying the execution of movement: A biological perspective. *Science*, 253:287–291, July 1991.

[2] Aaron Edsinger. A gestural language for a humanoid robot. Master's thesis, MIT AI Lab, Cambridge, MA, May 2001.

[3] Ajo Fod, Maja Mataric, and O. C. Jenkins. Automated derivation of primitives for movement classification. In *Proceedings of the First IEEE-RAS conference on Humanoid Robotics (Humanoids 2000)*, Massachusetts Institute of Technology, Cambridge, MA, September 2000.

[4] F.A. Mussa-Ivaldi. Nonlinear force fields: A distributed system of control primitives for representing and learning movements. In *Proceedings of IEEE International Symposium on Computational Intelligence in Robotics and Automation*, Monterey, CA, 1997.

[5] Brian Scassellati. Discriminating animate from inanimate visual stimuli. In *Proceedings of the Seventeenth International Joint Conference on Artificial Intelligence*, 2001. To appear.

[6] Matthew Williamson. Postural primitives: Interactive behavior for a humanoid robot arm. In Maes and Mataric, editors, *Fourth International Conference on Simulation of Adaptive Behavior*, pages 124–131. The MIT Press, 1996.