Human Models for Human-Robot Interaction

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Abstract. This paper discusses various human models required in human-robot interaction study. Good human models are critical for robots to realize effective interactions. For example, human behavior model is necessary to choose appropriate cost functions to determine robot actions that are comfortable for humans. We will present several case studies that attempt to model the human physiology and behavior, as well as their application to humanoid and character control.

Keywords. Human-robot interaction, neuro-muscular human model, learning by demonstration

1 Introduction

Human-robot interaction is very different from conventional robots in the sense that one or more humans are continuously involved in the task execution. It is also different from most human-operated machines in the sense that robots are expected to adjust their behaviors to individual humans, rather than humans adjusting themselves to various systems. These features require robots to have extensive knowledge about the human physiology, perception, and behavior.

One of the key components of interactive robots is the cost function used for planning robot actions. Robots' actions should be determined not only to maximize the task efficiency but also to minimize the physical and mental stress on the human. It is therefore necessary to consider human physiological and perceptual models in the cost function.

Interactive robots also need a set of tasks and behaviors. One of the major approaches for this purpose is the learning by demonstration framework [1] where robots acquire the tasks or behaviors by observing humans performing those tasks and trasferring the motions to the robots' own body. In this case, the robot has to abstract the observed motions at various levels because the raw data from human performance are often useless due to the differences in kinematics and dynamics.

This paper will review our previous work on modeling human physiology and behaviors that hopefully will serve as building blocks for interactive robots. Please refer to original papers [2,3,4,5] for more details on the specific techniques.

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2 Human Physiology Model

Human body model has been studied extensively in the biomechanics field to analyze and simulate human motions, but has not been considered useful for human-robot interaction until recently. Although the required level of detail is an open question, human physiology model is essential for interactive robots to decide actions that are appropriate for humans.

We have been building a detailed human musculoskeletal model [2] and a neuro-muscular network model [3]. There are several possible usage of this model in human-robot interaction:

- Formulating physical comfort: The model can estimate muscle tensions and bone stress during a given motion. We would therefore be able to consider the physical comfort in the cost function for robot action planning.
- Estimating human internal state: Based on external observations of human motions, the model will give detailed internal state of humans that can be used as the initial state for the planning.
- Predicting human response: The current neuro-muscular network model can simulate the somatosensory reflex, which can be used to plan robot actions considering human responses. The current model will be able to predict humans' short-term response to various stimula. By including models of high-level motion planning, we will be able to predict more longer-term behaviors.

3 Human Motion Transfer

Learning by demonstration is a powerful framework for building a large set of behaviors for robots. However, adjusting human motions to robots' kinematics and dynamics can be a critical issue. An approach to address this issue is to abstract the human motion using a high-level description. Then robot motions can be generated by defining a mapping function that transforms the high-level description to the robot's kinematics and dynamics.

In our previous work [4], we described an algorithm to control a biped humanoid robot using human motion capture data. The algorithm utilizes a balancing controller based on an inverted pendulum model to abstract the whole-body motion. This abstracted description can be used for balance control of many types of legged robots including quadrupeds.

Another work [5] focuses on motion transfer to robots with different proportion and/or topology by a statistical model called shared Gaussian Process Latent Variable Model (GPLVM) [6]. In this case, the abstract description is in the latent variable space that is common to both human and robot motions.

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