Mechatronics 21 (2011) 272–284

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

Transferring human grasping synergies to a robot

Tao Geng *, Mark Lee, Martin Hülse

Intelligent Robotics Group, Department of Computer Science, Aberystwyth University, Wales, UK

ARTICLE INFO

Article history:
Received 23 February 2010
Accepted 12 November 2010
Available online 24 December 2010

Keywords:
Human–robot skill transfer
Synergy
Robotic grasping

ABSTRACT

In this paper, a system for transferring human grasping skills to a robot is presented. In order to reduce the dimensionality of the grasp postures, we extracted three synergies from data on human grasping experiments and trained a neural network with the features of the objects and the coefficients of the synergies. Then, the trained neural network was employed to control robot grasping via an individually optimized mapping between the human hand and the robot hand. As force control was unavailable on our robot hand, we designed a simple strategy for the robot to grasp and hold the objects by exploiting tactile feedback at the fingers. Experimental results demonstrated that the system can generalize the transferred skills to grasp new objects.

1. Introduction

1.1. Transferring human skills to robots

Humans have remarkable motor skills and outperform most robots over a variety of complex motor tasks. By transferring human skills to robots, we may avoid a long and costly searching process when designing the robot controller. New skill-learning in the robot can also be speeded up if it is based on the transferred skills. To transfer a human skill to a robot, two problems have to be solved: (1) how to extract or model the human skill; (2) how to implement it on the robot whose configuration and sensory-motor systems are quite different from that of humans. Different methods have been proposed for transferring human skills to robots in various tasks and scenarios. Cortesao and Koeppe [1] transferred human skill in the peg-in-hole insertion task to a robot. While a human performed this task, the forces, torques and velocities of the peg were recorded as a function of its pose. Then a neural network trained with these data was used to control the robot in the same task. In another study [2], human expertise in a manipulative task was modeled as an associative mapping in a neural network and implemented on a direct-drive robot. Yang and Chen [3] represented human skills in tele-operation as a parametric model using hidden Markov models. The sensory-motor data representing human skills sometimes have unknown models and are redundant. To deal with this problem, Cortesao and Koeppe [1] proposed a sensor fusion paradigm composed of two independent modules. One module was for the optimised fusion via minimizing the noise power. The other module was a Kalman filter that filters unknown variables. Unlike the above mentioned methods that explicitly model human skills, a human-to-robot skill transfer framework proposed by Oztop [4] exploited the plasticity of the body schema in the human brain. Firstly, their system integrated a 16 DoF robotic hand into the experimenter's body schema (i.e., the neural representation of his own body). Then the dexterity exhibited by the experimenter with the external limb, the robotic hand, was used for designing the controller of the robot.

Another widely used mechanism for the human-to-robot skill transfer is by imitation, where a robot observes the execution of a task, acquires task knowledge, and then reproduces it. In [5], a robot imitated the grasping and placing of a human model. Skill transfer was realized when the robot learned a goal-directed sequences of motor primitives during the imitation. In [6], a continuous hidden Markov model was trained with characteristic features of the perceived human movements. Then the hidden Markov model was used in a simulated robot to reproduce the human movements. Rather than using robots to observe or imitate human movements, in a recent work [7], a communication language was developed for transferring grasping skills from a non-technical user to a robot during human–robot interaction.

Although these methods are effective in transferring skills to robots, in most cases, the robots can only learn the demonstrated tasks and it is difficult to generalize to new tasks.

1.2. The synergies in human grasping

While grasp synthesis is still a tough problem for robot hands (see [8] for a review), humans can grasp and manipulate various objects effortlessly. One challenge in robotic grasping is how to coordinate the several joints of the fingers to generate an appropriate grasp posture for a specific object. Humans and animals have

* Corresponding author.
E-mail address: runbot05@gmail.com (T. Geng).

0957-4158/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2010.11.003