Biologically inspired robot grasping through human-in-the-loop robot control

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Research supported by the Japan Society for the Promotion of Science (JSPS)

Collaboration with E. Oztop and E. Ugur

Additional material (like videos) can be found on the following web page:
Overview

1. Main idea
2. Interface
3. Human-in-the-loop control
4. Generalize motion
5. Results + Interpretation
PART I

Main idea and previous work
Some challenges for humanoid/anthropomorphic robots

How to perform complex tasks with so many DOF in a robust way?

How to reproduce human skills on a robot without a good understanding of how human perform the given skill?

Human like human-robot interactions
Robot skill synthesis via human learning

Extensive Human Training for Robot Skill Synthesis: Validation on a Robotic Hand.
In: IEEE International Conference on Robotics and Automation, Roma, Italy

From Biologically Realistic Imitation to Robot Teaching Via
Human Motor Learning in Neural Information Processing:
14th International Conference, ICONIP 2007, Kitakyushu, Japan,
Revised Selected Papers, Part II 2008 Springer-Verlag. p. 214-221
PART II

An intuitive reach and grasp interface
Hardware

Current robotic platform

Gifu hand

PA-10 arm

“Next week” robotic platform

Gifu hand

Motoman arm
An intuitive grasping interface

*Simulator: PAGSim*

*Motion tracking system*

*Robotic platform*

*Gifu hand*

*PA-10 arm*
The mapping

**End-effector tracking**

**Inverse kinematics**

**Mapping hand motion**
Robot arm architecture
Redundancy
Redundant Inverse Kinematics

Elbow is free to move on a circle

Position and orientation of the end-effector is known

The self motion of the elbow can be continuously parameterized

This parameter is used to represent, measure and quantify the redundancy of the system

Moore B, Oztop E (2010.8)
Redundancy parameterization for flexible motion control,
ASME IDETC 2010, Montreal, Canada
PART III

Human-in-the-loop control
Learning to control the simulator

... and the robot
PART IV

Experiment & Control
Grasping task

Unsuccessful attempt

Successful attempt

Reaching motion

Grasping motion (RECORDED)

Record grasp!
Experiment: handle grasping

$\theta = 20^\circ, \ldots, 80^\circ$
Record the **grasping motion** (motion on the **simulator or real robot**, not the human motion).

It contains a sequence of waypoints with the following information:
- Position of the EE
- Orientation of the EE
- The hand joint angle for every trial and every pre-defined object position.
Extracting robust grasps

- Then, recorded motion are replayed on the simulator with perturbation (on position, velocity) and the most robust grasping motion is kept as a representative for each pre-defined object orientation.
Motion generalization

• For arbitrary orientations of the object, we have to generate:
  – Reaching motion
    Generated using
    • cubic splines (end effector position)
    • spherical linear interpolation (end-effector orientation)
    • linear interpolation for the hand finger angles for pre-shaping
      Could also use DMP.
  – Grasping motion (next slide)
Merging grasps (position)
Generic grasping & validation
Grasping on robot
PART V

Analysis of biologically inspired robot grasping
Analysis of human controlled grasping motion
(Preliminary, 1 operator only)

<table>
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<th>Object orient.</th>
<th>(d_G)</th>
<th>(\eta_G)</th>
<th>(d_{PG})</th>
<th>(\eta_{PG})</th>
<th>Number samples</th>
<th>Symbol</th>
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Analysis of human controlled grasping motion
(Preliminary, 1 operator only)

Wrist position at reach and grasp
for different object orientation

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PART VI

Future work
Future work (short term)

• Extend the study
  – Data collection with many human operators
  – .................... with multiple objects and arbitrary positions
  – .................... with real human grasping
  – Improve the visual feedback (use 3D)
  – Use the real robot instead of the simulator
  – Other feedback (tactile, force, …)
Future work – Open questions

• Difference between human grasping and “human-control” robot grasping approach.

• Extract the main features of grasping and combine with a exploring approach to generalized the grasping found by exploration.

• Combine with learning methods (affordance learning) to generalize the knowledge to “similar objects”.

• How does human learn to grasp with the robot?
Thanks!

Questions?