Control of humanoid robots with motion primitives

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Outline

1. Introduction
2. Inverse kinematics and linear control approach
3. Spinal force fields
4. Parametric primitives
Why Motion Primitives?

- multiple movement trajectories
- high dimensional state space (RL)
- stability during motor activity
- adapt muscle stimulation: boost weights
- learn new complex movements
Strategies

idea: combine basic set of modules

- movemes (data from motion capturing)
- spinal force fields (vector field combination)
- parametric primitives (linear combination of activation parameters)
- probabilistic models (EM, hidden model - image of the real world)
- ...
Idea

- increase stability during motor activity
- reduce high dimensionality
- reduce nonlinearities

Figure: balancing hoop-2 task, [Hauser 2007]
HOAP-2 balancing task

Figure: (a) degrees of freedom (b) support polygon for stable gestures, [Hauser 2007]
Joint angle lookup table

get the joint angles with a given pseudo Center Of Projection offset (pCoP)

| Sx | Joint 1 | Joint 2 | Joint 3 | ...
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12</td>
<td>42</td>
<td>50</td>
</tr>
<tr>
<td>0.1</td>
<td>21</td>
<td>43</td>
<td>34</td>
</tr>
<tr>
<td>0.2</td>
<td>34</td>
<td>44</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure: joint angle offset lookup table
Linear PID controller

to hold the pCoP in the center of the support polygon

Figure: simple pid-controller, [Hauser 2007]
Results

<table>
<thead>
<tr>
<th></th>
<th>x-direction</th>
<th>z-direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>forward</td>
<td>backward</td>
</tr>
<tr>
<td>without control</td>
<td>+10.6°</td>
<td>−8.6°</td>
</tr>
<tr>
<td>with control</td>
<td>+20.1°</td>
<td>−22.3°</td>
</tr>
<tr>
<td>improvement</td>
<td>89.6%</td>
<td>159.3%</td>
</tr>
</tbody>
</table>

Figure: increased robustness for balancing task, [Hauser 2007]

Summary

- increased stability with simple linear controller
- maps a single control parameter to all joints
- 12 DOF

Outlook

- real HOAP-2
- learning algorithms
- new task: walking
Measurement of force fields

Figure: measured forces with a 6-axes transducer, [Mussa-Invaldi 2000]
Time dependency of the measured vector fields

Figure: vector fields after stimulus with an equilibrium point, [Mussa-Invaldi 2000]
Introduction
Inverse kinematics and linear control approach
Spinal force fields
Parametric primitives

Simplified model for a two joint mechanism

Figure: simplified model of spinal force fields, (d) smooth pulse, (e) gradient of a gaussian potential function multiplied with a smooth pulse, [Mussa-Invaldi 2000]
Learning with spinal force fields

Figure: learn to adapt perturbations, [Mussa-Invaldi 2000]
Summary

- biologic point of view
- preprocessing in the spinal cord
- can adapt perturbations
- how many force vector fields suffices
- 2 DOF

Outlook

- choice of force fields
- learn combinations
Parametric primitives and imitation learning

input: joint angles of the demonstrator

Figure: Imitation learning, [Amit 2002]
Framework of the control architecture

Figure: framework of the control architecture, [Amit 2002]
Primitives

- postural primitives (joint angle offset)
- oscillatory primitives (time varying torque)
- adaptive primitives (modularize control, chosen by the designer)
Learning

- build self organized maps of feature vectors
- select the best
- update all neighbors
Results

Figure: trajectory of the demonstrators hand, [Amit 2002]
Results the of learning process

Figure: trajectory of the imitators hand, [Amit 2002]
Summary

- higher intelligence: not all animals can imitate movements
- learn new complex movements (task is not to imitate)
- primitives are independent of speed and size
- real world problem: obtain joint angles
- 2 DOF, oscillatory movements

Outlook
- discrete movements
Thank you for your attention!
References

- Hauser 2007: “Kinematic Motion Primitives to Facilitate Control in Humanoid Robots”; Hausner H.