Interaction Capture and Synthesis

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Haptics ≡ The sense of touch
≡ Force sensing and display?

Haptics ≡ Contact
Contact is multisensory with forces sounds deformation motion discontinuities …
The AHI Audio-Haptic Interface

DiFilippo and Pai UIST 00
See also [Doel and Pai 96], [Doel, Kry and Pai, SIGGRAPH 01]

Contact Interaction with Integrated Audio and Haptics

Derek DiFilippo
Dinesh K. Pai

University of British Columbia
Precomputed Acoustic Transfer
[James, Barbic, Pai SIGGRAPH 2006]

Motivation: Whole hand interaction with the Tango
[Pai, et al. World Haptics 05]
• Whole hand passive haptic interface
• 32 x 8 capacitive sensor, 3 axis accelerometer
Motivation: Motion capture animation techniques difficult to use with contact

Motivation: Whole hand interaction with the Tango
Motivation

- Need to capture how humans move
  - Impedance (stiffness) of muscles...
  - Feed-forward control

- Brain actively controls the passive behavior of the musculoskeletal system
  - Depends on task, geometry, intent, style
  - Important for stability

Interaction Capture and Synthesis

- motion capture
- force capture
- analysis
- intended motion
- interaction
- trajectory
- passive behavior
- simulation
- new object
Overview Example

- Motion capture cameras 500 Hz
- Force-torque sensor 500 Hz
Overview Example

- Estimate the *Interaction Trajectory*
  - Compliance (inverse of stiffness)
  - Reference trajectory (motion without contact)
Overview Example

- Environment
  - Fully dynamic simulation
- Character
  - Contact from quasi-static simulation
  - Dynamics from reference trajectory

Outline

- *Interaction trajectory estimation*
Compliant hand model

Effective end-point compliance

Compliance is Task Dependent

• Controlled by the brain in addition to motion
  – Scratching has half the compliance of exploring

<table>
<thead>
<tr>
<th>(rad/Nm)</th>
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<th>Scratching</th>
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<tbody>
<tr>
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Compliance Estimation

• Previous work
  Arms [Xu, Hollerbach, Hunter 91; Gomi, Kawato 96; etc.]
  Fingers [Hajian 97; Milner, Franklin 98; Hasser, Cutkosky 02]
  • Stiffness, some measure damping and inertia too
  • End points, joints, static poses, during movement

• Approach in common is perturbation
  – Complicates capture, changes the motion

Compliance Estimation without extra perturbation

• Contact provides a natural perturbation
  – Exploits slow speed of spinal reflexes
Assumptions & Limitations

- Independent compliance estimations
- Natural perturbation must be observable
- Complex ‘pre-programmed’ motion
Validation

- Estimates show task dependence
  - Scratching has half the compliance of exploring

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Validation

- Perturbation via spring loaded platform
Validation

\[ f(t) = m \ddot{z}(t) + b \dot{z}(t) + k z(t) + f_0 \]

Parameter | Exploring | Scratching |
-----------|-----------|------------|
\( f_0 \) (N) | 0.677 | 1.345 |
\( m \) (kg) | 0.017 | 0.018 |
\( b \) (Ns/m) | 2.04 | 3.86 |
\( k \) (N/m) | 89.16 | 257.04 |

Estimates reasonable given values in previous studies [Hajian 97; Milner et al. 98; Kuchenbecker et al. 03]
Outline

• Interaction Synthesis

Interaction Synthesis

• Quasi-static simulation
  – Alternative is fully dynamic simulation
  – Capture already contains character’s dynamics
  – Focus on synthesizing contact perturbations
  – Compute the new forces with Coulomb friction

\[
\min_{\Delta u} u^T f_{\text{tangent}}
\]

\[ f \in \text{friction cone} \]
Interaction Synthesis

- Linear Complementarity Problem (LCP)
  - New algorithm for compliant contact and friction

Results
Grip Adjustment

- Object unexpectedly heavier than expected
  - Tighten grip by reducing compliances after a small delay

Grip Adjustment

- Expected changes
  - Similar motor program, adjusted due to object appearance
  - Gradually reduce compliance when slip is imminent
Example Using Tango Capture

- motion capture
- force capture
- previously estimated compliance

Analysis

Reference trajectory

Compliance

Simulation

Tango captures at 100 Hz

Conclusions

- Interaction capture
  - Extends motion capture to handle contact
  - Compliance estimation from natural movement
- Interaction synthesis by simulation
  - New algorithm for compliant contact with friction
• Download data at http://www.interactioncapture.org

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