Interaction Capture and Synthesis

Dinesh K. Pai

University of British Columbia

Rutgers University

[with Paul G. Kry]

Haptics ≡ The sense of touch

≡ Force sensing and display?

Haptics ≡ Contact

Contact is multisensory

with

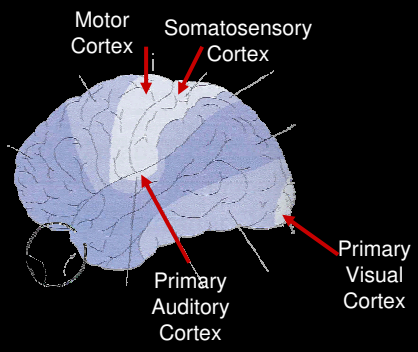
forces

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]

Modal renderer

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

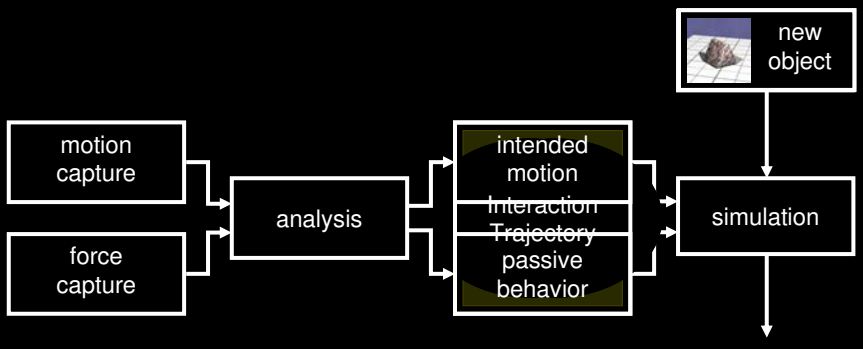
Motivation

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

[Feldman 66; Hogan 84; Bizzi et al. 92; etc.]

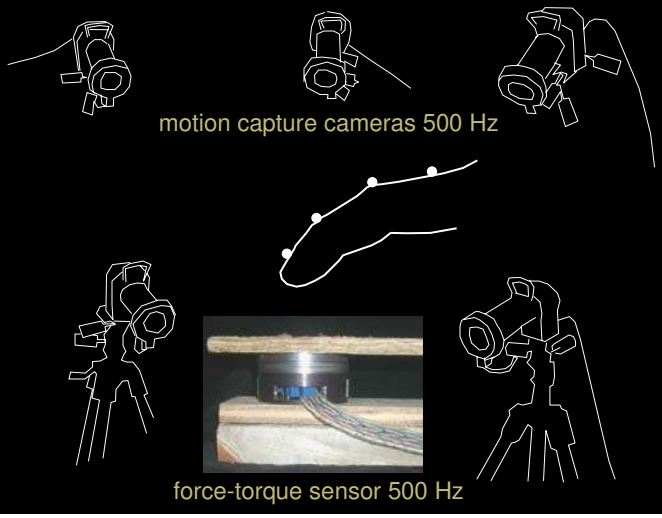
- Brain actively controls the passive behavior of the musculoskeletal system
  - Depends on task, geometry, intent, style
  - Important for stability

Interaction Capture and Synthesis



Overview Example

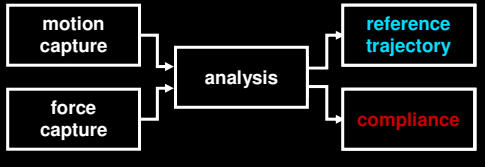
Overview Example

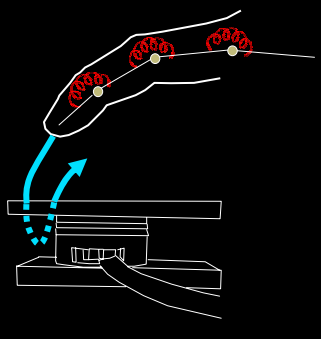


Overview Example

Overview Example

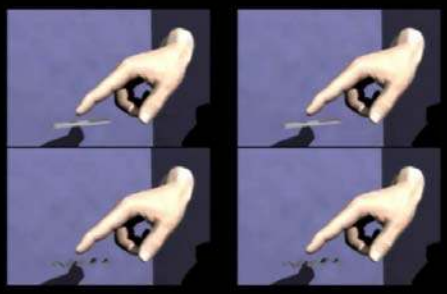
- Estimate the *Interaction Trajectory*
  - Compliance (inverse of stiffness)
  - Reference trajectory (motion without contact)

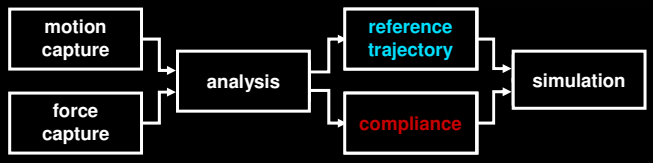




Overview Example

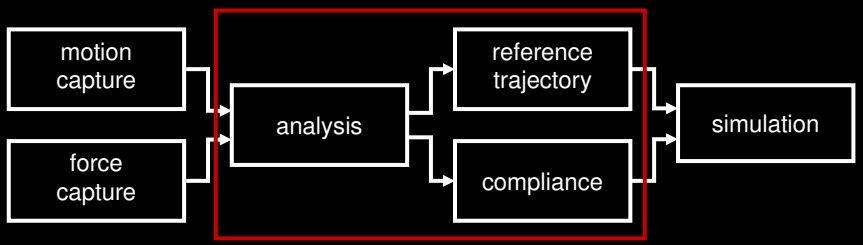
- Environment
  - Fully dynamic simulation
- Character
  - Contact from quasi-static simulation
  - Dynamics from reference trajectory





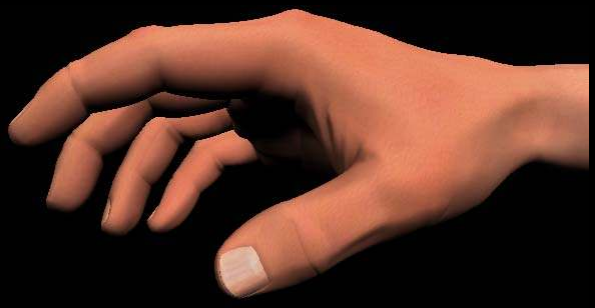
Outline

- ***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

(rad/Nm)	Exploring	Scratching
Wrist	0.35	0.15
MP	0.99	0.47
PIP	0.67	< 0.84
DIP	2.01	< 0.84

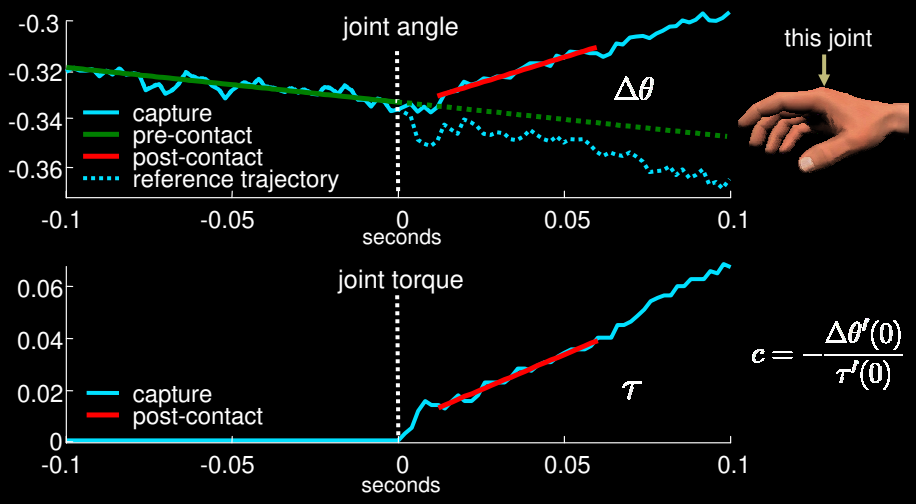
Compliance Estimation

- 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

Capture Data at time of contact



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

(rad/Nm)	Exploring	Scratching
Wrist	0.35	0.15
MP	0.99	0.47
PIP	0.67	< 0.84
DIP	2.01	< 0.84

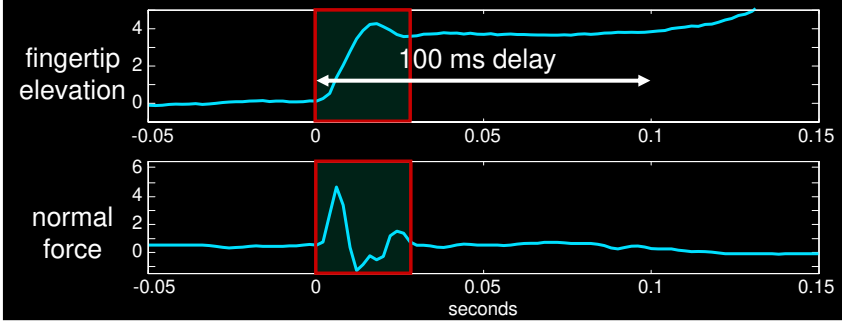
Validation

- Perturbation via spring loaded platform

1/5 speed

Validation

$$f(t) = m\ddot{z}(t) + b\dot{z}(t) + kz(t) + f_0$$



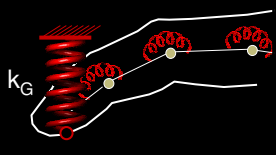
Validation

$$f(t) = m\ddot{z}(t) + b\dot{z}(t) + kz(t) + f_0$$

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

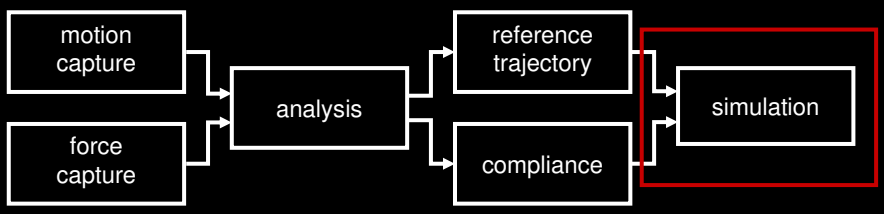
OUR METHOD

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



Outline

- ***Interaction Synthesis***

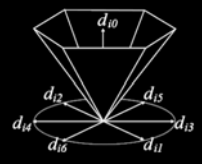


Interaction Synthesis

- 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

$$\min \Delta u^T f_{\text{tangent}}$$
$$f \in \text{friction cone}$$

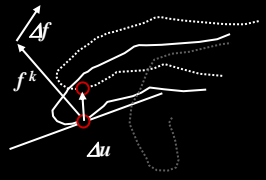
Interaction Synthesis



Discretized friction cone

$$\min \Delta u^T f_{tangent}$$
$$f \in \text{friction cone}$$

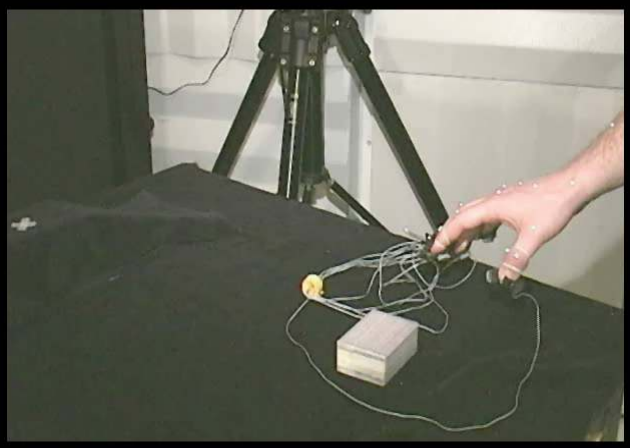
$$Mz - q = w \perp z$$



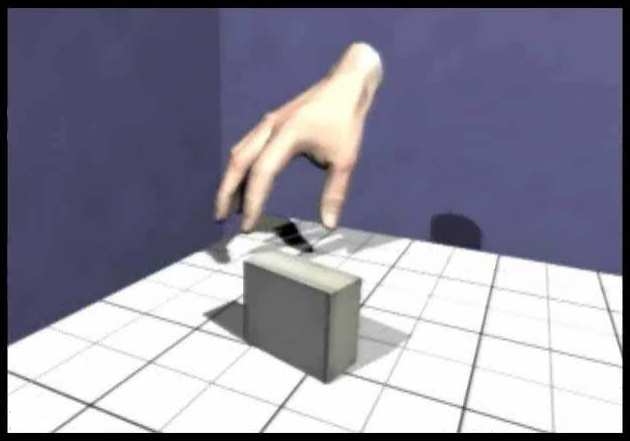
Contact Point Motion
- Reference trajectory
- End point compliance
- Dynamic environment

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

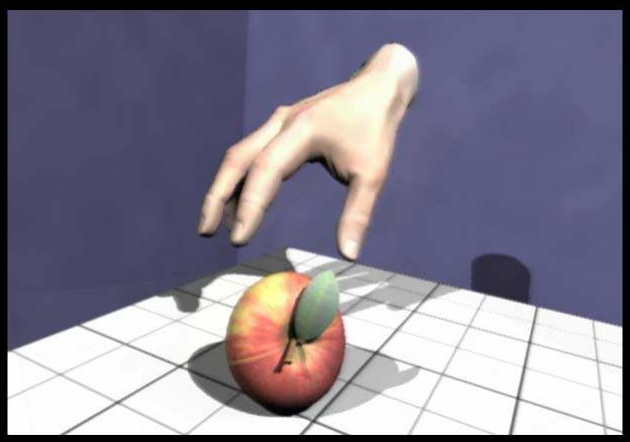
Results



Results

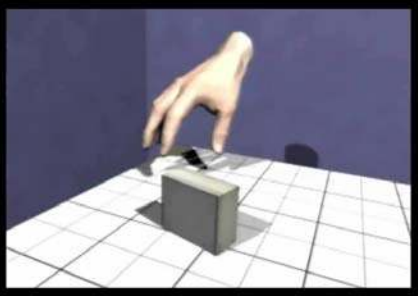


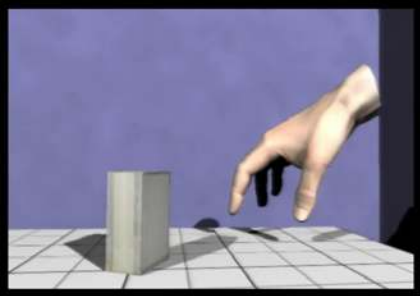
Results



Grip Adjustment

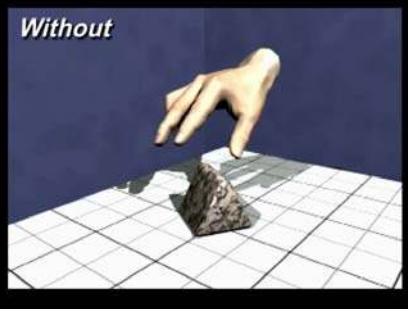
- Object unexpectedly heavier than expected
  - Tighten grip by reducing compliances after a small delay

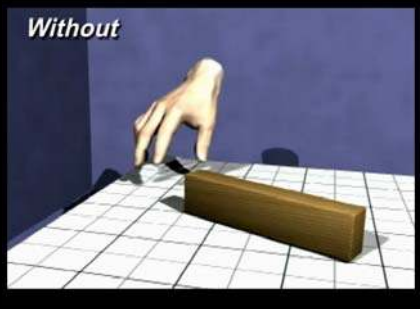




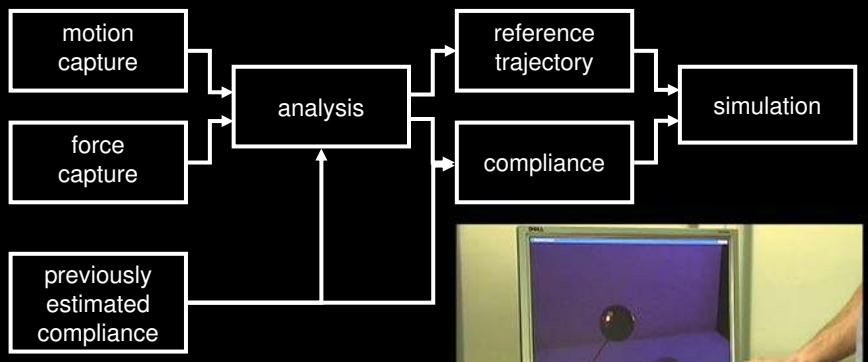
Grip Adjustment

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

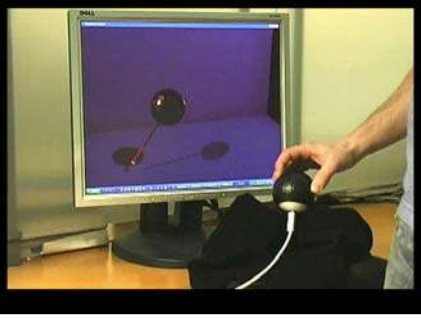




Example Using Tango Capture



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

Thanks to the support of

- NSF grants IIS-0308157, EIA-0215887, ACI-0205671, EIA-0321057
- NIH CRCNS 1R01NS050942
- Canada Research Chair