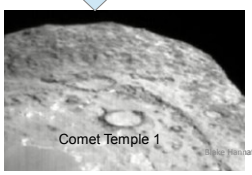
Outline

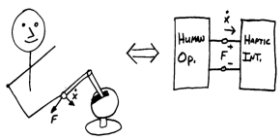
- Overview: big ideas
  - Haptics
  - Teleoperation
  - Surgical Skill
- Raven Surgical Robotics Research Platform
  - Goals
  - Adventures
  - Raven II
  - Architecture
- Intelligent Augmentation
  - Virtual Fixtures
  - Kinect Haptics
  - Laser liver resection demo (video)
  - Fundamentals of Laparoscopic Surgery Benchmark
  - Golf course/ Jetstream
- Behavior Trees

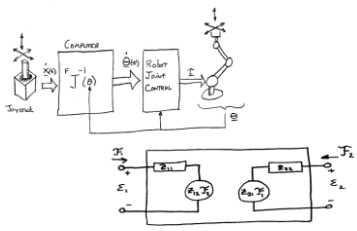
Overview

Haptics

Touch!







$$Z = \begin{bmatrix} h_{11} = \frac{\mathcal{E}_1}{\mathcal{F}_1}\Big|_{\mathcal{E}_2=0} & h_{12} = \frac{\mathcal{E}_1}{\mathcal{E}_2}\Big|_{\mathcal{F}_1=0} \\ h_{21} = \frac{\mathcal{F}_2}{\mathcal{F}_1}\Big|_{\mathcal{E}_2=0} & h_{22} = \frac{\mathcal{F}_2}{\mathcal{E}_2}\Big|_{\mathcal{F}_1=0} \end{bmatrix}$$

h_{11}	Input Impedance with Free Slave Motion.
h_{12}	Force Feedback Gain with Locked Master, λ_f.
h_{21}	Forward Velocity Gain with Free Slave Motion, λ_p.
h_{11}	Input impedance with Free Slave Motion.

6.3 2-Port Network Models

Linearity

$$A \begin{bmatrix} \mathcal{F}_1 \\ \mathcal{F}_2 \end{bmatrix} + B \begin{bmatrix} \mathcal{E}_1 \\ \mathcal{E}_2 \end{bmatrix} = 0 \tag{10}$$

Where A and B are 2×2 matrices.

$$\begin{bmatrix} \mathcal{E}_1 \\ \mathcal{F}_2 \end{bmatrix} = H \begin{bmatrix} \mathcal{F}_1 \\ \mathcal{E}_2 \end{bmatrix} \tag{12}$$

where H is a 2×2 "Hybrid Matrix".

We then use the H parameters (i.e. the elements of H) to study the system. Let's express the definition of the h_{ij} elements in terms of the mechanical effort and flow variables:

$$h_{11} = \frac{f_1}{\dot{x}_1}\Big|_{f_2=0} \tag{16}$$

$$h_{12} = \frac{f_1}{f_2}\Big|_{\dot{x}_1=0} \tag{17}$$

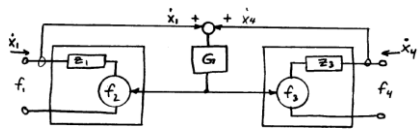
$$h_{21} = \frac{\dot{x}_2}{\dot{x}_1}\Big|_{f_2=0} \tag{18}$$

$$h_{22} = \frac{\dot{x}_2}{f_2}\Big|_{\dot{x}_1=0} \tag{19}$$

h_{11}	Input Impedance with Free Slave Motion.
h_{12}	Force Feedback Gain with Locked Master, λ_f.
h_{21}	Forward Velocity Gain with Free Slave Motion, λ_p.
h_{11}	Input impedance with Free Slave Motion.

- Each *h* parameter corresponds to an important aspect of performance
- Each *h* parameter corresponds to a mathematical boundary condition
- Each *h* parameter corresponds to a well defined physical measurement

10 Position error-based Master-Slave Teleoperation



$$\begin{bmatrix} f_1 \\ \dot{x}_4 \end{bmatrix} = H_{cs} \begin{bmatrix} \dot{x}_1 \\ f_4 \end{bmatrix} \quad (28)$$

You can show:

$$H_{cs} = \begin{bmatrix} Z_3 + G\left[1 - \frac{G}{Z_3+G}\right] & \frac{G}{Z_3+G} \\ \frac{-G}{Z_3+G} & \frac{1}{Z_3+G} \end{bmatrix} \quad (29)$$

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Study Design

- Measure positions, forces and torques in MIS procedures
- 30 subjects, 7 subtasks each
- Experiments using R1-Expert surgeons on animals (pigs)
- Experiments performed in Center for Videoendoscopic Surgery
- IACUC approval

Rendering by Jeff Brown

Brown, Rosen, Barecca, Sinanan, Chang

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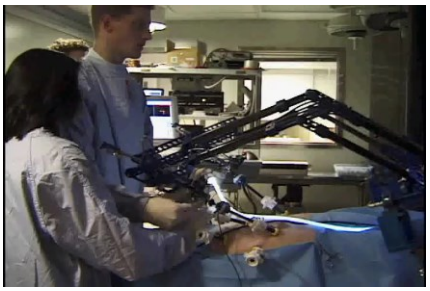

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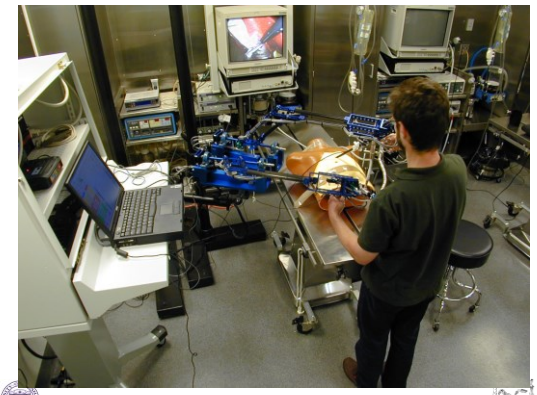

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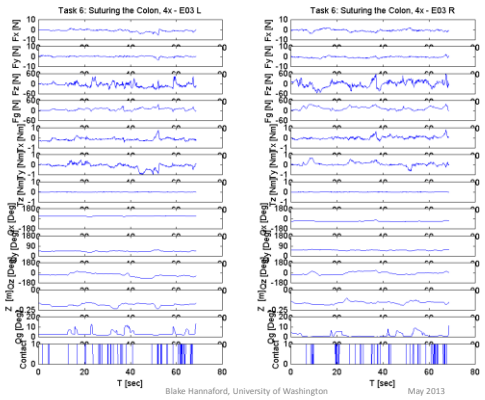

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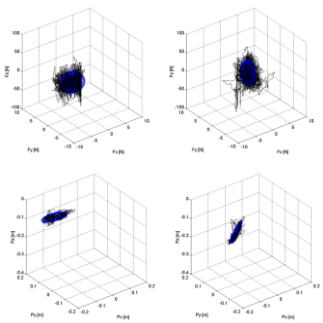
Typical Data

- Expert surgeon
- Forces and Positions



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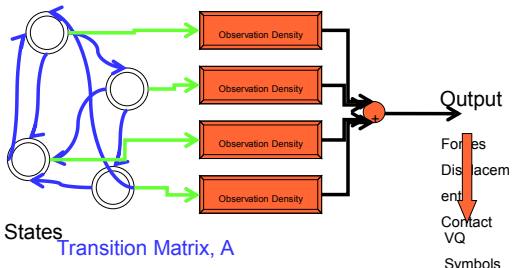
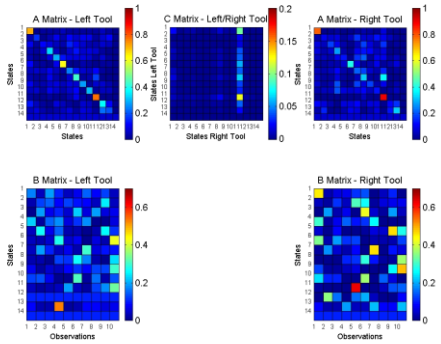
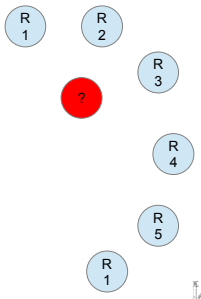
Hidden Markov Model



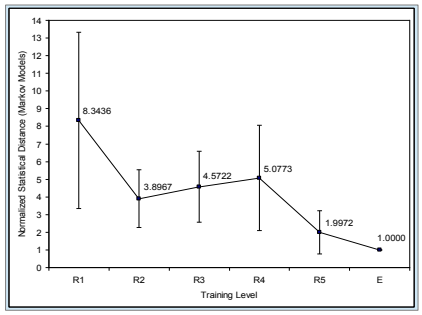


HMM Approach

- Train a HMM for each seniority group
- Compute distance measure
- Skill assessment is group with closest distance



HMM Distance Measure



Video Analysis Score