Haptic and Tactile Feedback

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Haptics

- Haptic :
  Relating to or based on the sense of touch.
  - Force feedback
  - Tactile feedback

  } Haptic feedback
- Surgical simulation as haptic interaction with virtual surgical environments

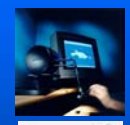
Research Issues in Haptic Interfacing to Virtual Environments

- Haptic interface devices
- Stability of haptic interaction with virtual environments
- Simulation of stiff walls
- Haptic rendering of surface texture
- Haptic interaction with deformable bodies
- Realistic modeling of tool-tissue interaction
  - Cutting, suturing, needle insertion
- Tactile sensing and display

Force Feedback Haptic Devices

Commercial Systems:

- Phantom
  - 3 DOF and 6 DOF versions
- Immersion
  - Impulse Engine
  - CathSim AccuTouch
    - » Endovascular
    - » Bronchoscopy
  - Laparoscopic Interface
- Freedom 6S
  - 6 DOF force feedback



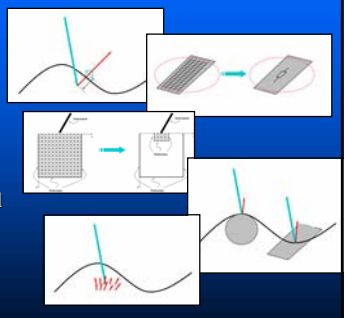




Generation of Force Feedback

Methods for Generation of Haptic Feedback

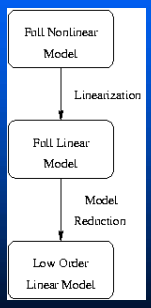
- Constraint-Based Methods
  (Zilles and Salisbury 1995)
- Norton Equivalent Models
  (Astley and Hayward 1998)
- Multirate Simulation with Local Low Order Approximation
  (Cavusoglu and Tendick 2000)
- Planar and Spherical Local Approximations
  (d'Aulignac et al. 2000)
- Force Fields
  (Montgomery et al. 2002)

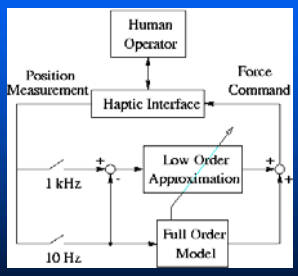


Haptic Interaction with Deformable Bodies in VE's

- Deformable bodies are simulated with very high order dynamical models
- Haptic interaction require bandwidth of ~1kHz, but these high order models can only be simulated at ~10Hz
- This affects the stability and fidelity of interaction

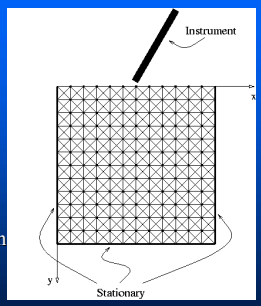
Low Order Linear Approximation to Model Intersample Behavior



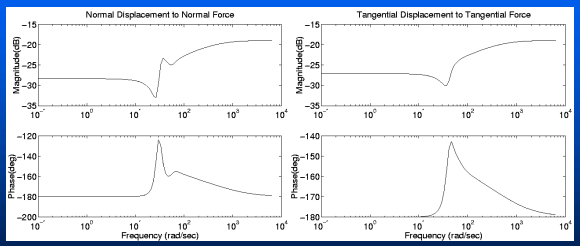


Model Reduction

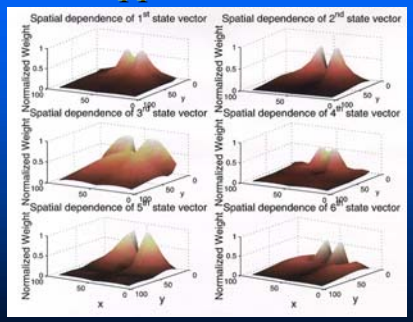
- 12x12 2-D lumped element model
  - 2 input 2 output dynamical system
  - 524th order dynamics
- Balanced model reduction
  - 10th order approximation with less than 1% error



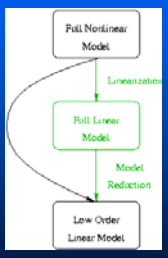
Model Reduction

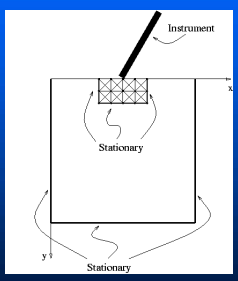


Reduced Order Model Is a Local Approximation

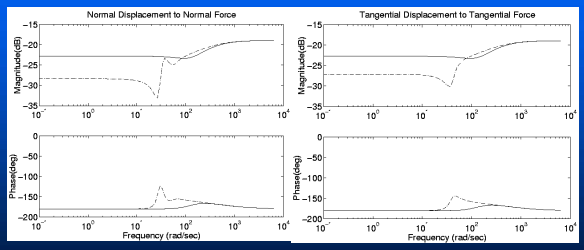


Constructing a Local Model in Real Time





Constructing a Local Model in Real Time



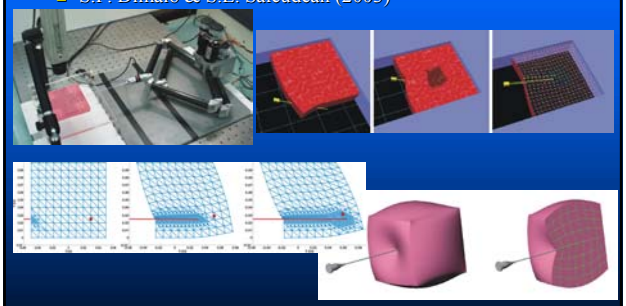
Discussion

- This method is applicable only if the local modes are dominant.
- Interaction stability is improved significantly.
- It is informative to study other local models.

Needle Insertion

Needle Insertion

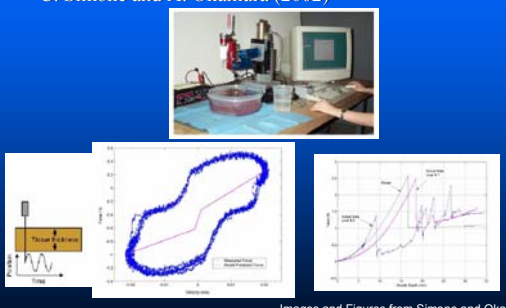
- S.P. Dimaio & S.E. Salcudean (2003)



Images from DiMaio and Salcudean (2003)

Needle Insertion

- C. Simone and A. Okamura (2002)



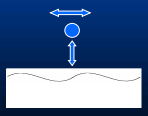
Images and Figures from Simone and Okamura (2002)

Human Factors for Enhanced Force Feedback in MIS

Simulated Surface Compliance Discrimination

- Psychophysics literature on compliance has measured difference thresholds
- Surgeons often need to detect spatial variation in surface compliance, e.g. to detect embedded lesion
- Two tasks:
  - spatial variation in compliance
  - temporal oscillation in force

Compliance Stimuli

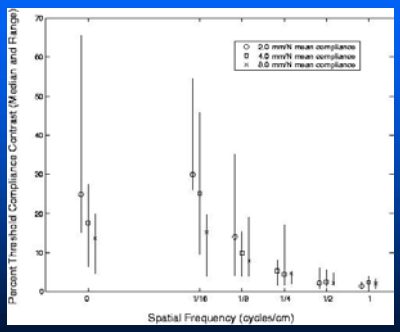


Force Stimuli

Methods

- Phantom 1.5 haptic interface
- Adaptive 2-down 1-up procedure (corresponds to 71% accuracy)
- 8 subjects
- 3 mean compliance levels: 2, 4, and 8 mm/N
- 3 mean force levels: 0.5, 1, and 2 N

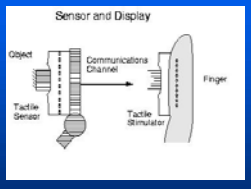
Compliance Discrimination and Contrast Sensitivity



Experimental Results from Dhruv and Tendick (2000)

Tactile Sensing and Display

Tactile Sensing and Display



8x8 1mm² Tactile Sensor Array

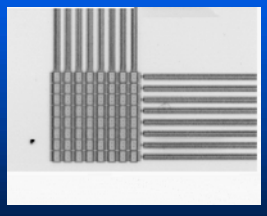
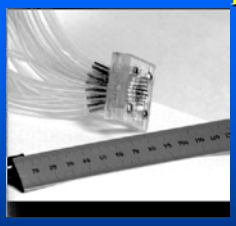


Image courtesy of Gray and Fearing

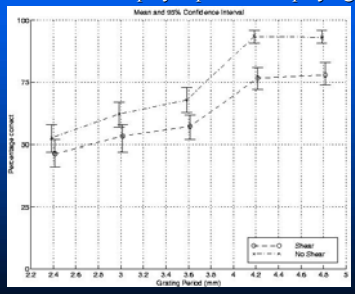
Tactile Display Technology



Images courtesy of Fearing et al.

Human Factors in Tactile Sensing and Display

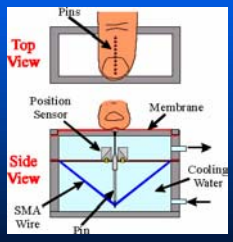
- Do we need a tactile display capable of displaying shear stress ?



Experimental results from Moy and Fearing (1998)

Tactile Feedback

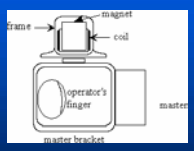
- SMA based tactile display
- DC servomotor based tactile display

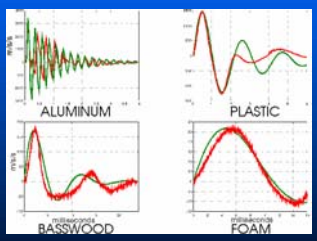


Images courtesy of Howe et al.

Tactile Feedback

- Vibrotactile Feedback





Images courtesy of Howe et al.

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