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A Survey of Visuo-Haptic Simulation in Surgical Training

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Outline

- **Haptic technology**
- Haptic device characteristics
- Visuo-haptic systems for surgical training
- API and frameworks
- Laparoscopic Surgical Procedures
- Conclusions

Haptic technology (1)

- Derived from the Greek *ἁπτικός* (*haptikos*), means pertaining to the sense of touch

- 5 senses: sight, smell, taste, touch, and hearing

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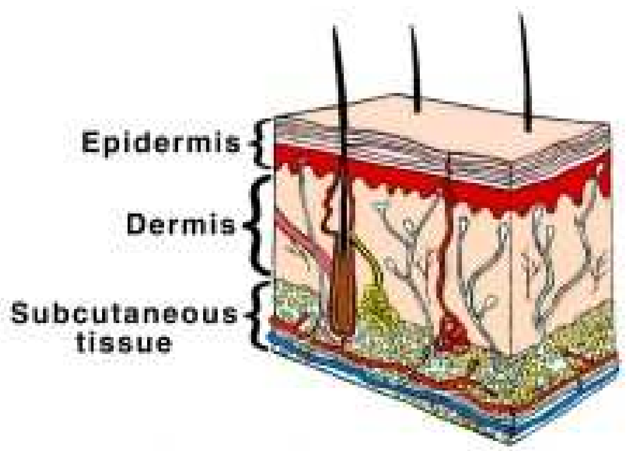
Haptic technology (2)

- Provides important feedback about environment.
- Is key sense for someone who is visually impaired.
- Somatosensory System - the ability to sense touch
- Stimulus received via receptors in the skin (2500/cm^2):
  - Thermoreceptors – heat and cold
  - Nociceptors – pain
  - Mechanoreceptors – pressure
  - Proprioceptors – sense the position of different parts of the body

  (some instant, some continuous)

- Some areas more sensitive than others e.g. fingers
- Kinethesis - awareness of body position
  - affects comfort and performance.



Haptic technology (3)

- P channel, as measured in threshold experiments typically operates over the vibratory frequency range of 40-800 Hz - *Bolanowski*

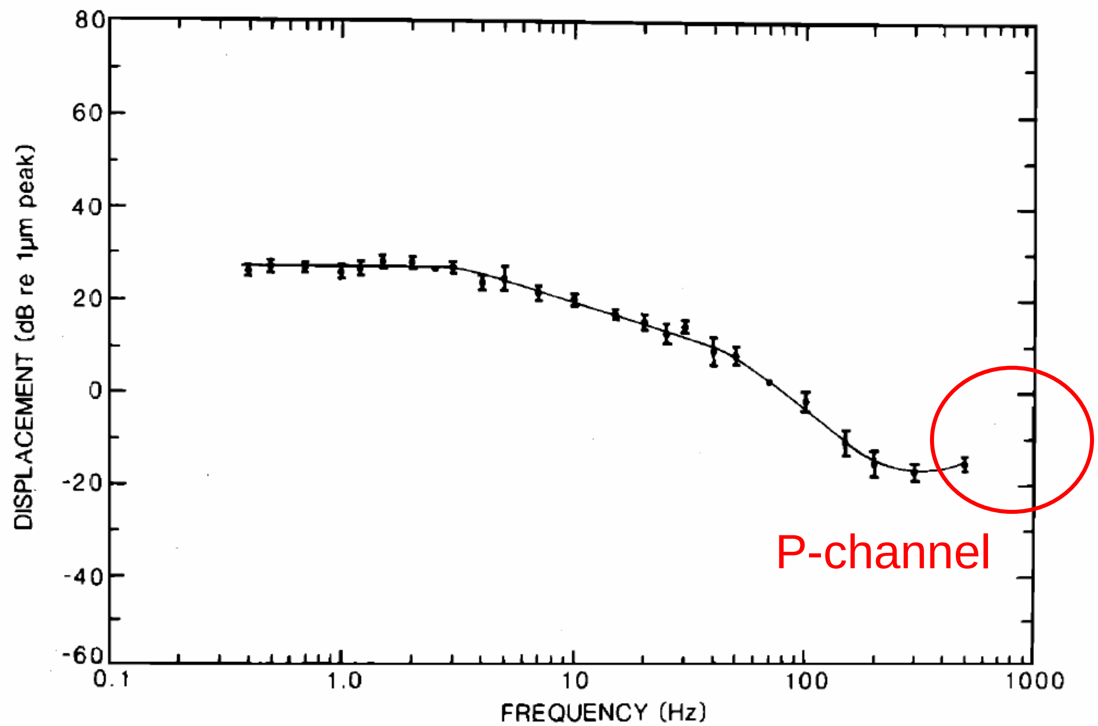


FIG. 1. Threshold-frequency characteristic relating stimulus intensity to stimulus frequency. The results are the averages of five observers. The error bars in this and the figures to follow signify the standard error of the means, their absence indicating that the error was too small to be depicted. Skin-surface temperature was maintained at 30 °C. Stimulus contactor size was 2.9 cm^2.

(!) 1000 Hz

Haptic Technology (4)

physical reference point

virtual reference point

- Robotic arm that tracks position and orientation of user's hand.
- Updates position and orientation information every ms (1KHz)
- Visual representation of physical reference point within virtual application.

Haptics – early R&D (1800)

- Ernst Heinrich Weber (1795-1878)
  - the results of many of his experiments in De Tactu ("The Touch") in 1834.
  - response to weight, temperature, and pressure
  - determined that there was a threshold of sensation that must be passed before an increase in the intensity of any stimulus could be perceived
  - "Two objects touching the skin simultaneously seem to us to be separated by a shorter distance, the lower the tactile acuity of the touched parts."

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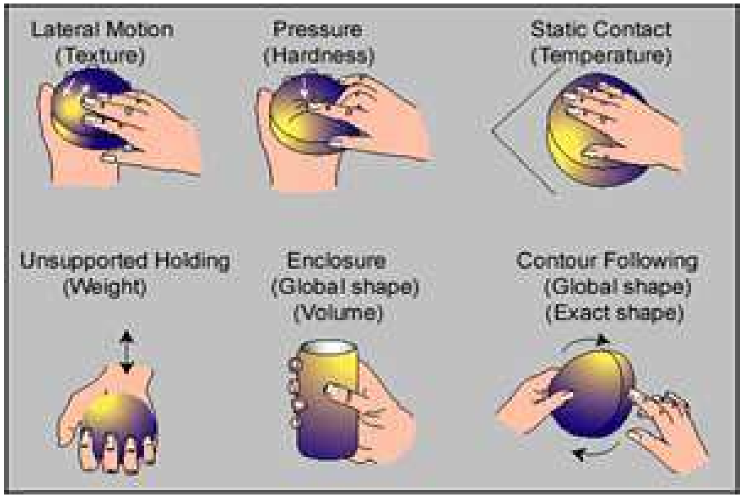
Haptics – early R&D (1980)

- 1987 Lederman and Klatzky (1987) summarized 4 basic procedures for haptic exploration
  - **lateral motion** (stroking) provides information about the surface texture of the object
  - **pressure** gives information about how firm the material is
  - **contour following** elicits information on the form of the object
  - **enclosure** reflects the volume of the object.



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Haptics – R&D (1990)

- Shortcoming in simulation products were identified.
- Graphics and animations looked incredibly realistic however they **could not convey** what it actually feels like to break through a venal wall with a needle, for example.
- Immersion was founded in 1993
  - Video games
  - Medical simulators

(!) still too expensive for public

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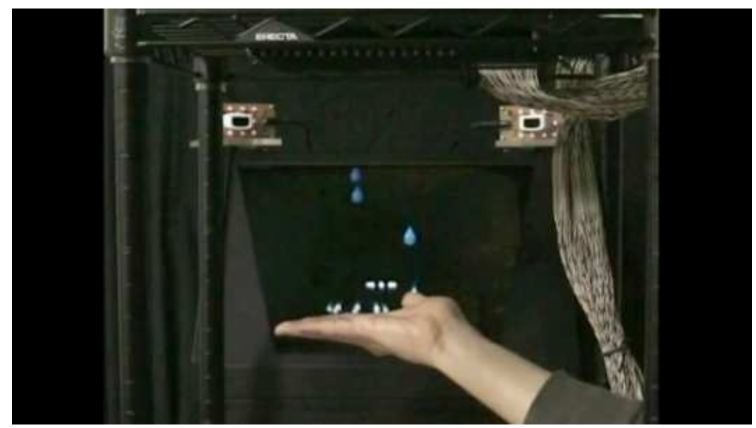
Haptics – R&D (2000)

- Immersion TouchSense® technology is incorporated into gaming systems (Sony, Microsoft)
- 1,500 Immersion Medical simulators have been deployed at hospitals and medical schools
- (2007) Novint released the Falcon, the first consumer 3D touch device
- (2009) University of Tokyo
  - 3D holograms that can be "touched" through haptic feedback using "acoustic radiation" to create a pressure sensation on hands



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Haptic Device Characteristics (1)

- Falcon – Novint

SensAble

Phantom Omni

6 DOF, 450 dpi ~ 0.055 mm.

Phantom Desktop

Resolution: 1100 dpi ~ 0.023 mm

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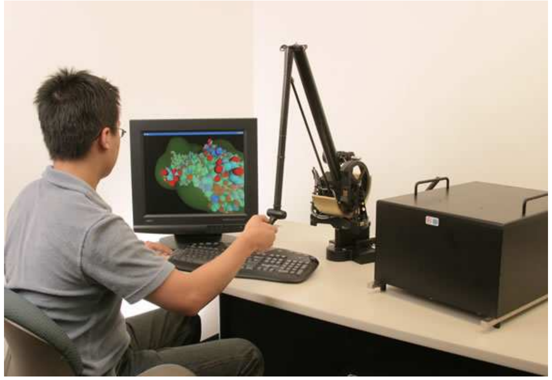
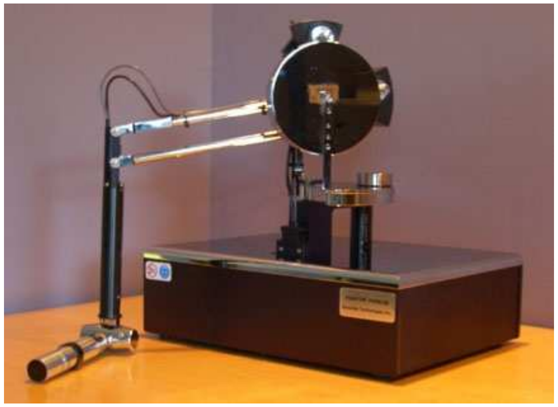
Haptic Device Characteristics (2)



Premium 3.0/6DOF Haptic Device

SensAble



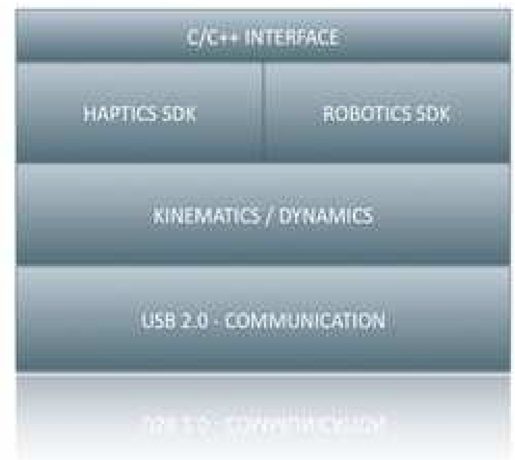
PHANTOM Premium 1.5/6DOF

The PHANTOM Desktop haptic device with the Auto Suture® 5mm Endo Clinch® II device attached.

Haptic Device Characteristics (3)

Omega 3

Omega 7



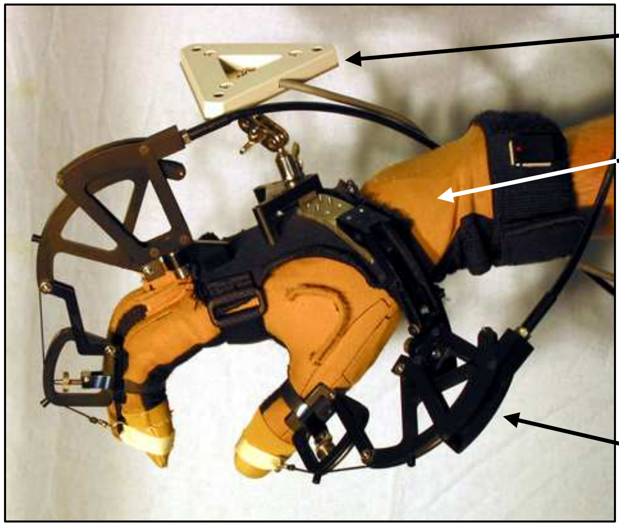
(!) CHAI3D Libraries

3 active translations
3 passive rotations
1 active grasping

Force Dimension

Haptic Device Characteristics (4)

- CyberGlove™ instrumented glove
  - 22 bend sensors
  - calibrated for dexterous manipulation
- CyberGrasp™ fingertip force feedback
  - lightweight exo-skeleton
  - uni-directional force feedback
- Logitech hand tracker
  - ultrasonic transducers and sensors
  - 6 DOF position and orientation



[CyberGlove and CyberGrasp are products of Immersion Corporation]

Haptic Device Characteristics (5)

Butterfly Haptic – magnetic levitation

Maglev 200™
Magnetic Levitation
Haptic Interface

Butterfly Haptics

Haptic Device Characteristics (6)

Planar 3D

CRT –
Shutter
Glasses

SenseGraphics

Projector based

LCD Based

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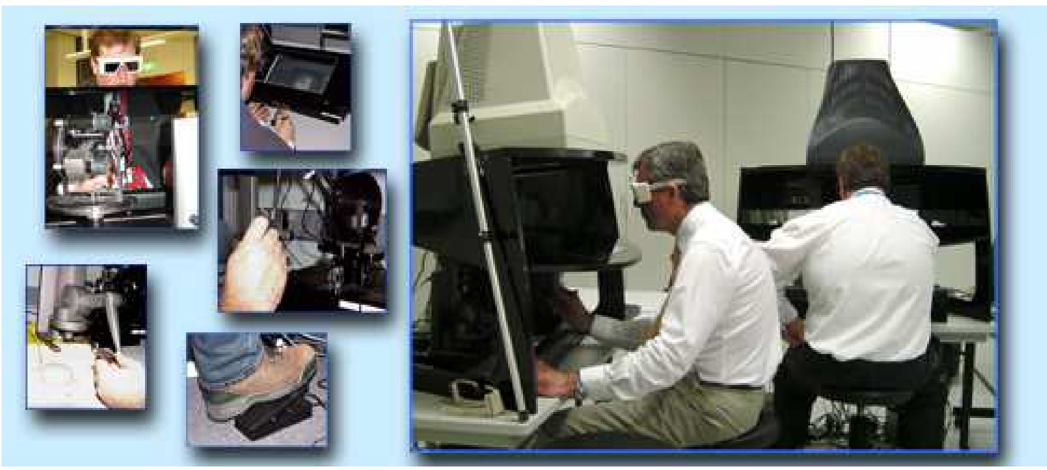
Visuo-haptic systems for surgical training

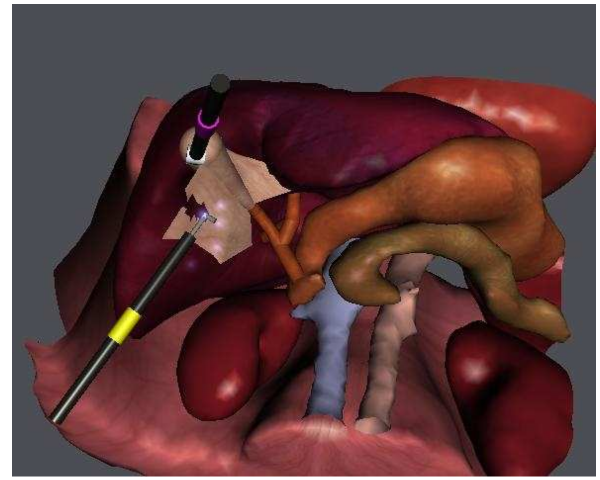
1. The LapVR Surgical Simulator

2. AccuTouch® endoscopy Surgical Sim.

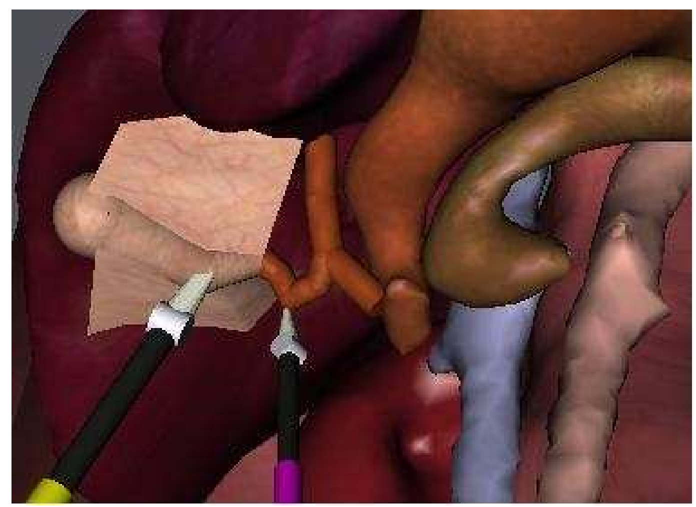
3. CathLabVR System

Visuo-haptic systems for surgical training





Gallbladder Surgery
Telepresence



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API and frameworks (1)

1. ReachIn – is a provider of state of the art human computer interface technology and is the world-leading haptic software solution provider.

2. CHAI 3D – an open source set of C++ libraries for computer haptics, visualization and interactive real-time simulation

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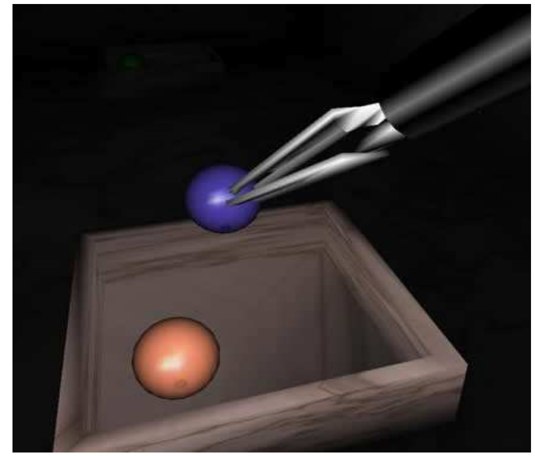
API and frameworks (2)



3. **Spring** – a real-time soft-tissue simulation platform for building and running surgical simulators to be used in medical education of surgeons. (HAVNET)

4. **SOFA** – Software for Observing Force-feedback Algorithms is an aid in debugging haptic algorithms and providing custom haptic device implementation.

API and frameworks (3)

5. GIPSI – General Physical Simulation Interface
   - an open source/open architecture framework for developing organ level surgical simulations.
   - facilitate shared development of reusable models
   - heterogeneous models of computation
   - framework for interfacing multiple heterogeneous models.

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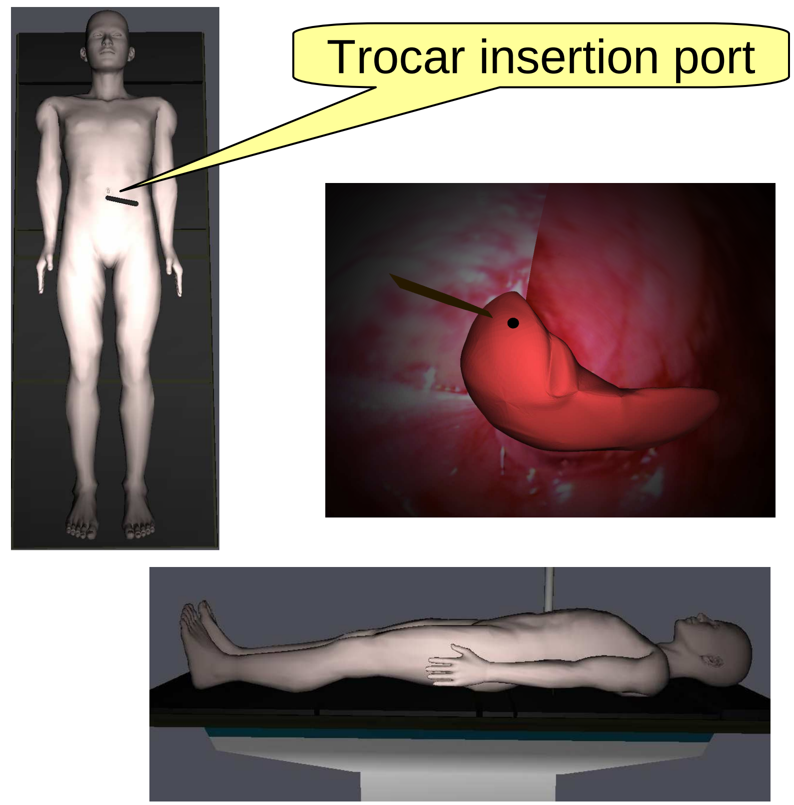
Laparoscopic Surgical Procedures (1)

Basic tasks: (surgical task set)

- Laparoscope attachments manipulation
- Camera manipulation and navigation
- Light source manipulation and navigation
- Tissue manipulation (e.g. grasping)
- Tissue properties investigation (e.g. soft touch)
- Knot-tying



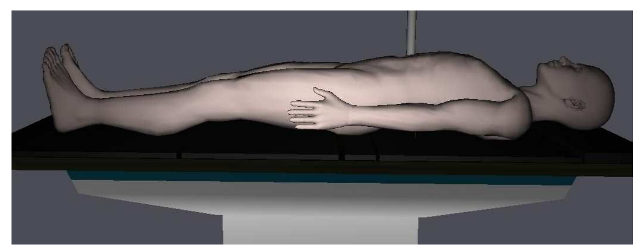
Laparoscopic Surgical Procedures (2)

Skill set:

Basic skills: e.g. spatio-visual orientation and exploration ability, perceptual abilities, hand-eye coordination, two handed maneuvers, objects relocation.

Intermediate skills: knowing and correctly utilizing the laparoscopic surgery tools for specific cases and the ability to correctly execute the surgical procedure.

Advanced skills: knowledge of the laparoscopic procedures, manual dexterity and precision control.



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Laparoscopic Surgical Procedures (3)

Skill assessment:

1. ***Face validity*** is determined by the appearance of the interface of the simulated task addressed by the test.

2. ***Content validity*** is determined by the expert surgeons based on the detailed examination of the test content.

3. ***Construct validity*** is determined by the capability of the test to differentiate among performance levels.

4. ***Concurrent validity*** is determined by the capability of the test to return equivalent results with other similar tests.

5. ***Predictive validity*** is determined by the predictive capability of the test, i.e. the evaluated surgeon will have the same performance level in a real scenario.

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Conclusions

- APIs and frameworks are currently not interoperable
  - usage of XML-based standards to achieve syntactic and structural interoperability

- From the integration in a hospital setup perspective, the main challenges are:
  - *budget*
  - *time commitment*
  - *suitable space*

- Partnerships between industry and education, to employing lower fidelity, inexpensive simulators that can be **as effective as** expensive simulators for specific tasks

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Acknowledgements

<u>HapticMed</u>: Interfaces with haptic feedback in medical applications

http://hapticmed.info

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