Haptic Interface for Surgical Manipulator System

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Goal: Create intuitive haptic interface for dexterous surgical manipulator

Dexterous manipulator

PHANTOM Premium haptic device

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Sensible Technologies, Inc.
Paper selection


• Why?
  – Teleoperation using force feedback (FF) for medical applications
  – Characterize forces observed during dexterous surgical task
  – Improve user performance using:
    • Haptic feedback
    • Sensory substitution

• Why haptics?
What is haptics?

- Force + tactile feedback

[Link to image of haptic device](www.eng.uwaterloo.ca/~fhaque/img/sensible-haptics_lg.jpg)
[Link to image of puppy tickled](www.funnypuppysite.com/pictures/tickle_tickle.jpg)
Bilateral telemanipulation
Bilateral telemanipulation

Surgeon console

Intuitive Surgical, Inc.
Advantages of robot-assisted surgery

- Reduced tremor
- Increased accuracy
- Higher degree of freedom (DOF) and dexterity
- Magnified, 3D visual feedback
- → safer, more effective
Problems with robot-assisted surgery

• Loss of force feedback
• Longer, more technically challenging procedures
• Steep learning curve
Suture manipulation for cardiac surgery

- Challenging environment
- Dexterous
- Force control critical
- Measurable functional outcomes

www.clarkescope.com/techniques.html
Significance

• Increase sense of telepresence
• Intelligent assistance (ex. virtual fixtures)
• In vivo tissue modeling
Experiment

• Different levels of force feedback
  – Manual

Ideal forces!

Methods for haptic feedback in teleoperated robot-assisted surgery
Experiment

• Different levels of force feedback
  – Manual
  – Instrument (with or without force feedback)
Experiment

• Different levels of force feedback
  – Manual
  – Instrument (with or without force feedback)
  – Robotic

Methods for haptic feedback in teleoperated robot-assisted surgery
Hypotheses

- Forces could be applied more accurately with resolved force feedback than without.
Hypotheses

 Forces could be applied more accurately with resolved force feedback than without

Measured:
suture tension

Methods for haptic feedback in teleoperated robot-assisted surgery
Hypotheses

 Forces could be applied more accurately with resolved force feedback than without.

% of trials that showed difference in force magnitudes from hand-tie

- Instrument tie
- Robot tie

Difference inconclusive
Hypotheses

- Precision improved with inclusion of resolved force feedback in robot-assisted system

Coefficient of variation (CV) of force for instrument ties indistinguishable from hand ties
Hypotheses

Repeatability improved with inclusion of resolved force feedback in robot-assisted system
Experiment

• Different types of telemanipulation control laws
  – Problems!

Position exchange control vs. Position forward/force feedback control

Sensor-actuator asymmetry

Methods for haptic feedback in teleoperated robot-assisted surgery
Effect of limiting DOF of force sensing

Bending forces

Grip forces

(a)

(b)

Methods for haptic feedback in teleoperated robot-assisted surgery
Completely realistic haptic feedback: hard!

Q: How can we overcome limitations of impedance control?

- Adaptive control
- Pseudo-admittance control
- Virtual fixtures
- Sensory substitution
Methods for sensory substitution

- Methods for haptic feedback in teleoperated robot-assisted surgery
Methods for sensory substitution

Methods for haptic feedback in teleoperated robot-assisted surgery
Importance

• Haptics: justified?

Sensible, Inc
Relevance

- Dexterous manipulation?
- Dynamic environment?
- Accuracy?
- Precision?
- Virtual fixtures?
Critique

- Learning curve shortened using haptic feedback?
- User performance throughout course of procedure?
- Quantify effect of indirect view during the robotically executed task?
- Time?
Next steps

• Sensor hardware
• Safety of lack of passivity
• Force and tactile feedback
• Virtual fixture geometry
• Tissue modeling
Conclusions

• Force feedback does improve accuracy and precision for complex surgical tasks
• Axial and gripping forces do not greatly affect user performance
• Sensory substitutions a practical option for haptic feedback
Thank you

Questions?