Constrained Control for Surgical Assistant Robots

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Presentation Outline

- Summary
  - Project Overview
  - Paper Selection
- Problem
- Experimental Methods
- Results
- Analysis & Conclusions

Overview

- Cochlear Implant: medical device used to restore hearing
  - External: Microphone, Speech Processor, Transmitter
  - Internal: Receiver/stimulator, Electrode Array
- Problem
  - Difficulty of inserting electrode array manually
- Project goals
  - Image the cochlea using 2 different types of OCT Imaging
    - Bulk Scan
    - Side-view Probe
  - Create Models from OCT images
  - Create Virtual Fixtures for use in inserting electrode array

Paper Selection

- Virtual Fixtures
  - Increase safety and precision of procedure
  - Filter out hand tremor
  - Keep surgical instruments in pre-defined safe zones

- Creating VFs for cochlear implant insertion is a main goal of our project

Goals of Paper

- Task Primitives
  - Stay on a point
  - Maintain a direction
  - Move along a line
  - Rotate around a line
  - Stay above a plane
- Hard and Soft Constraints
  - Preferred regions
  - Safety regions
  - Forbidden regions

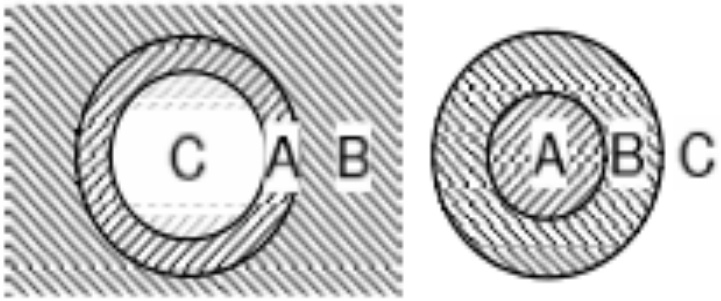


Image credit: Kapoor et al.

Problem

- Virtual Fixtures are useless without algorithms to implement them
- Paper provides customizable implementation algorithm

Experimental Methods

- JHU Steady-Hand Robot
- Prescribed Motion: Sinusoidal Curve

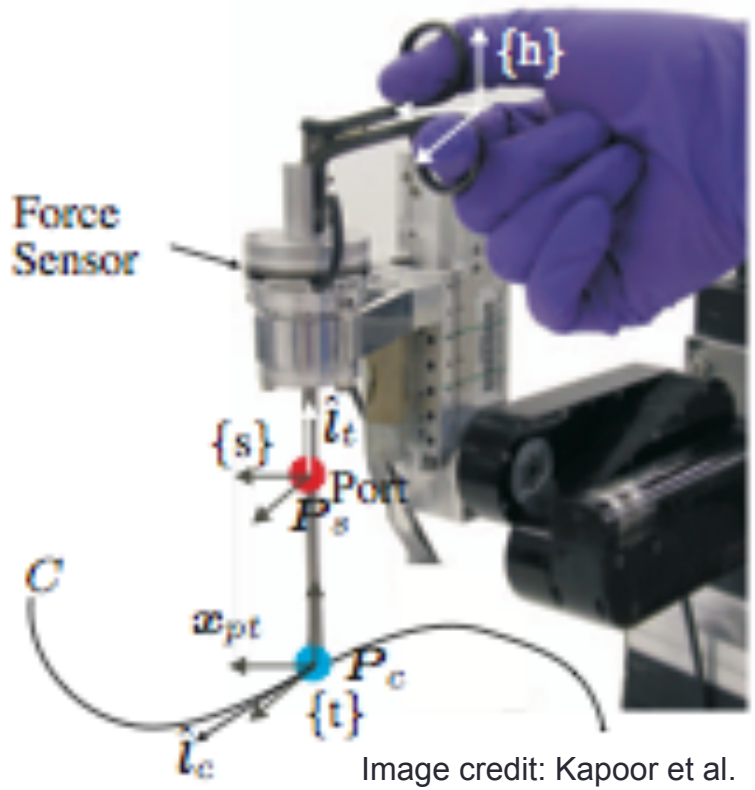


Image credit: Kapoor et al.

Results

- Algorithm models VFs using least squares problem
- Solving least squares problems with linear constraints more efficient than solving nonlinearly constrained problems
- Higher accuracy with nonlinear constraints

# Hyperplanes	4	8	16	32	Nonlinear
Time(ms)	2.2680	4.1225	7.2842	14.3549	9.4017

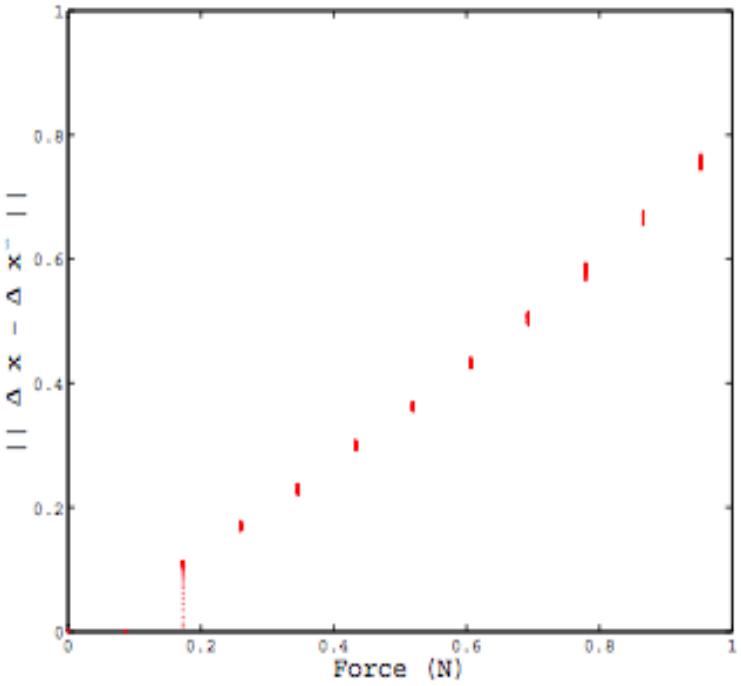
Image credit: Kapoor et al.

Results

- "Soft" Virtual Fixtures
  - Provide resistance, do not halt movement
  - Useful in Safety Regions
- "Hard" Virtual Fixtures
  - Completely stop movement
  - Useful in Forbidden Regions

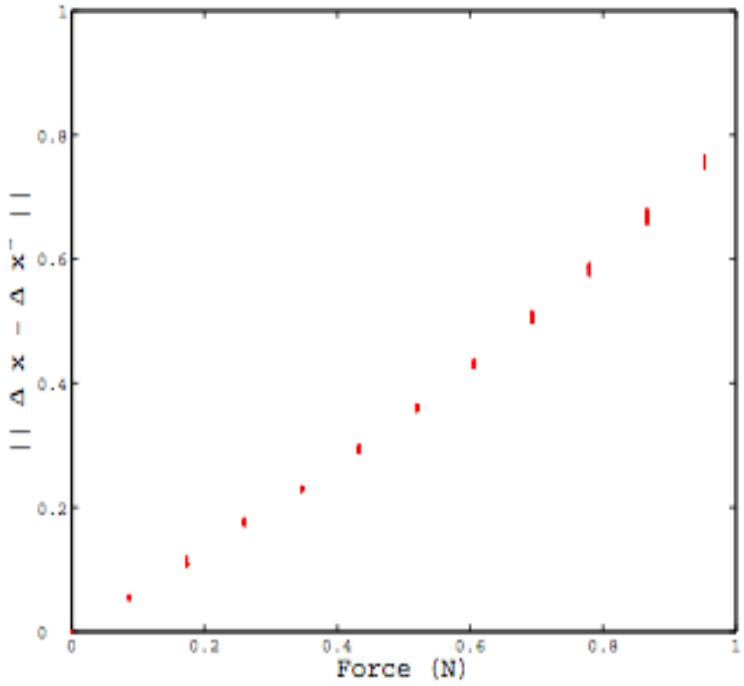
Results

Soft Constraint



(a)

Hard Constraint



(b)

Image credit: Kapoor et al.

Analysis & Conclusion

- Relevance
  - Framework for creating complex virtual fixtures
    - Broken in to Task Primitives
    - Can be used for inserting cochlear implant along cochlear axis
  - Uses of Soft and Hard Constraints
    - Preferred region: axis of cochlea
    - Safety region: close to edges of cochlea
    - Forbidden region: touching or nearly touching edges of cochlea
- Future Work
  - Experiment on other robots
  - Form changing tools

Questions?

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