Paper Presentation:
An integrated system for planning, navigation and robotic assistance for skull base surgery

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Outline

• Paper Selection
• Motivation
• Materials and methods
  – Components
  – Registration & Calibration
  – Virtual fixture implementation
• Experiments and Results
  – Phantom
  – Cadaver
• Conclusion
• Relation to our project
• Question & Answer
Paper Selection

• **Title**: An integrated system for planning, navigation and robotic assistance for skull base surgery

• **Authors**: Tian Xia, Clint Baird, George Jallo, Kathryn Hayes, Nobuyuki Nakajima, Nobuhiko Hata, Peter Kazanzides

• **Journal**: THE INTERNATIONAL JOURNAL OF MEDICAL ROBOTICS AND COMPUTER ASSISTED SURGERY

• **Time**: September 2008

• **Reason**: The platform (where we start our work)
Motivation

- Image-guided surgery
- Limit:
  - Fatigue & dexterity
  - Cannot prevent surgical error
- Cooperatively controlled robot
- Image guidance
- Virtual fixture
Major Components

• NeuroMate robot
  – An Image-guided robotic system for stereotactic procedures in neurosurgery

• StealthStation navigation system
  – Navigation system

• 3D Slicer
  – Visualization (Can display virtual fixture)
  – Define virtual fixture
  – Postoperative analysis
NeuroMate & StealthStation

3D Slicer

Major Components

Registration and calibration

Virtual Fixture

- six-sided convex hull (one side open)
- 3 regions design
  - Safe zone (Free)
  - Boundary zone (Restricted)
  - Forbidden zone (No)
- Control law
Virtual Fixture (cont’d)

- Control law

\[ \dot{q} = J^{-1}(q) \times K(d) \times G(f) \times \begin{bmatrix} F_w \\ T_w \end{bmatrix} \]

- \( J^{-1} \) inverse Jacobian
- \( G(f) \): admittance gains
  - High speed for coarse positioning
  - Fine motion control
  - Exponential functions

- \( K(d) \): motion constraints
  - Safe Zone
    - Identity Matrix
  - Boundary Zone
    - Scale down (\( K(d) \))
  - Forbidden Zone
    - Only leaving motion is OK
Experiment: Phantom

• Plastic skull phantom + fixture + foam block (target)
• Six foam blocks
  – 3 same registrations
  – Last 3 different location/orientation
• Use calipers for measurement
• Error: $|E_p| + E_d/2$
• SD1: Robot system repeatability
• SD2: Overall system performance

Experiment: Cadaver

- Bone surrounding the internal auditory canal (IAC)
- Both the left and right
- First trial failed

Experiment: Cadaver

- 3D-Slicer Transform virtual fixture to postoperative CT image
- Results
  - Overcut
  - Typically 1-2 mm
  - Max 3 mm

Conclusion & Future work

• Faster + Safer
• Placement error: 0.6 mm
• Dimensional error: 0.6 mm
• Overcut:
  – Typical: 1-2mm
  – Max: 3mm

• Future work
  – Virtual fixture model
  – VF control algorithm
  – Tools for postoperative assessment
Thank You