JOHNS HOPKINS UNIVERSITY

JOHNS HOPKINS MEDICINE

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 Kazanzides1
- **Journal**: THE INTERNATIONAL JOURNAL OF MEDICAL ROBOTICS AND COMPUTER ASSISTED SURGERY
- **Time**: September 2008

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

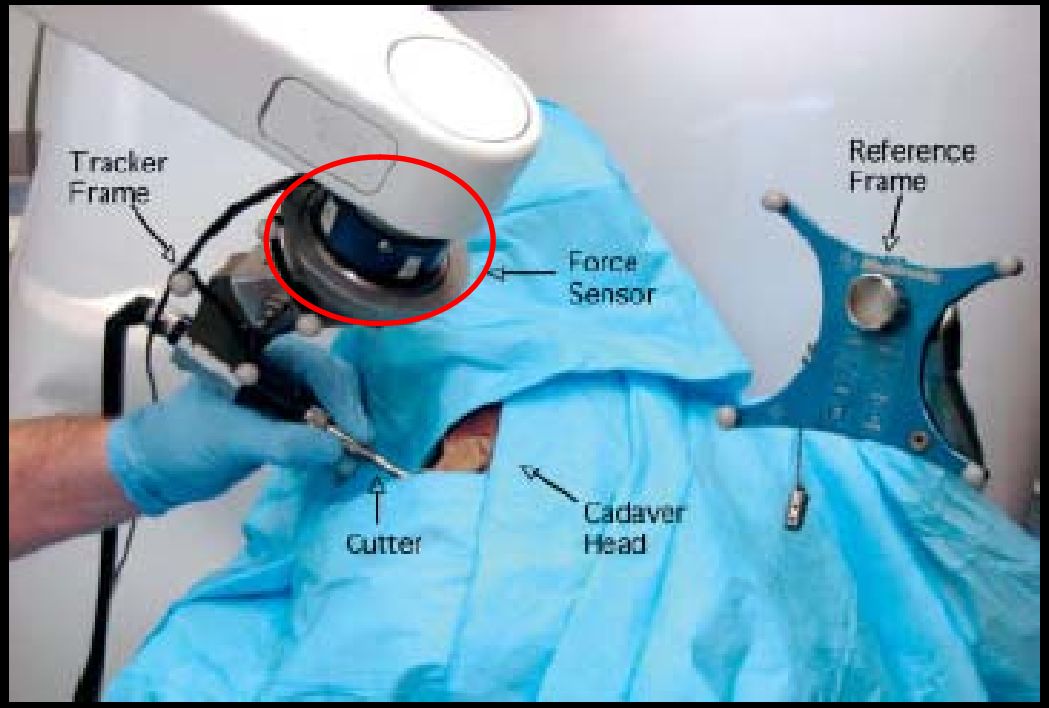
Motivation

- 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



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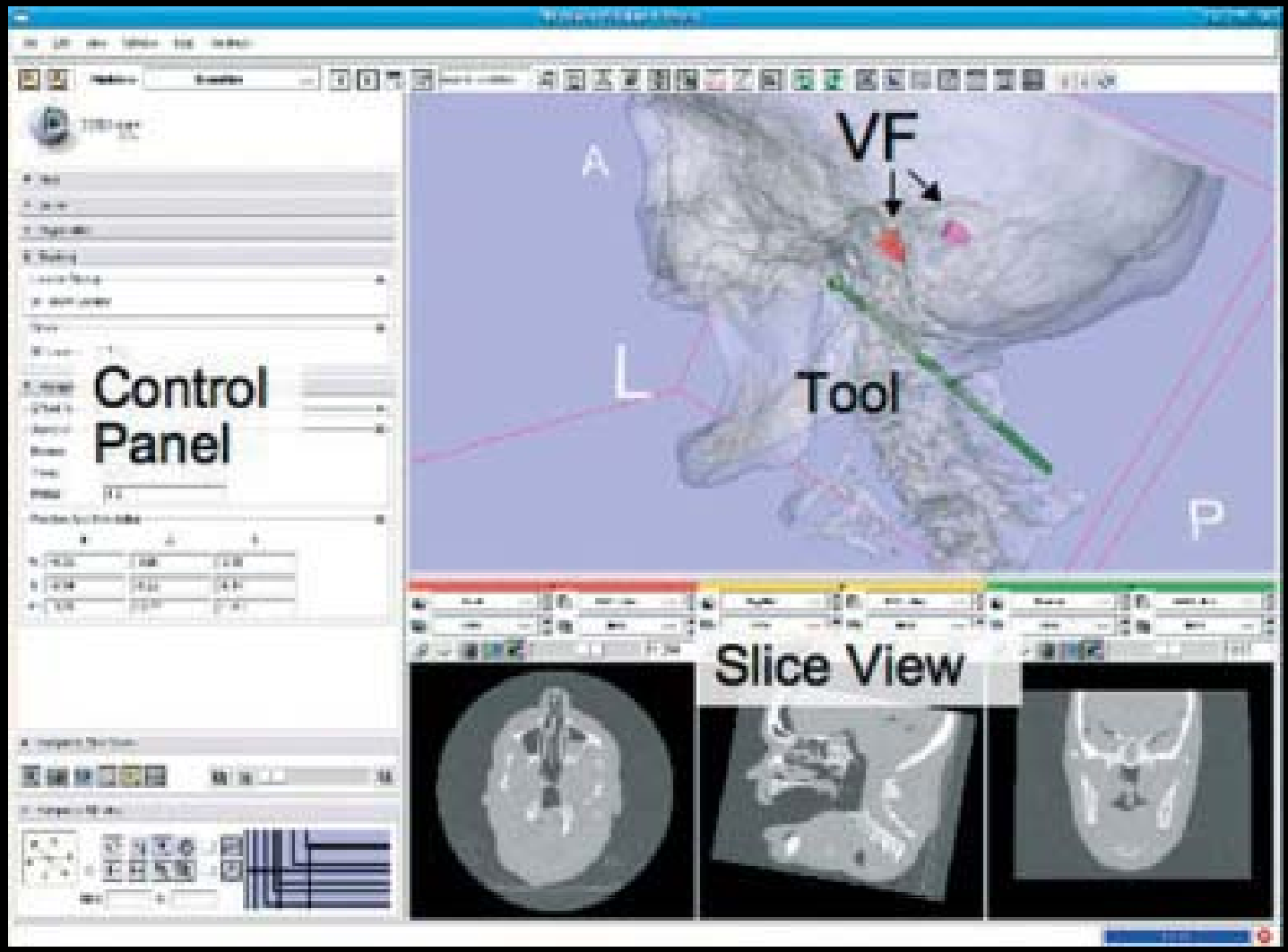
3D Slicer



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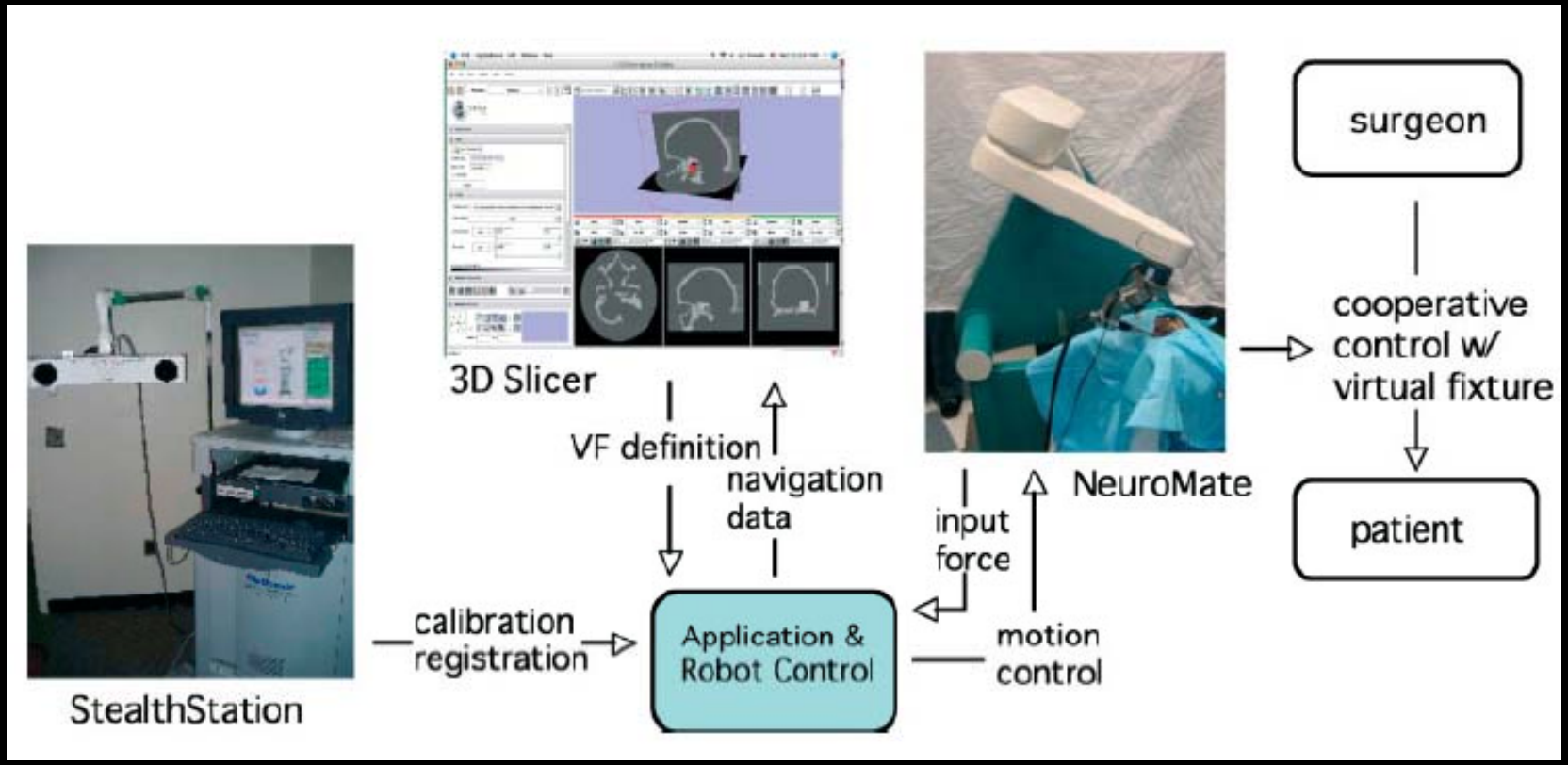
Major Components



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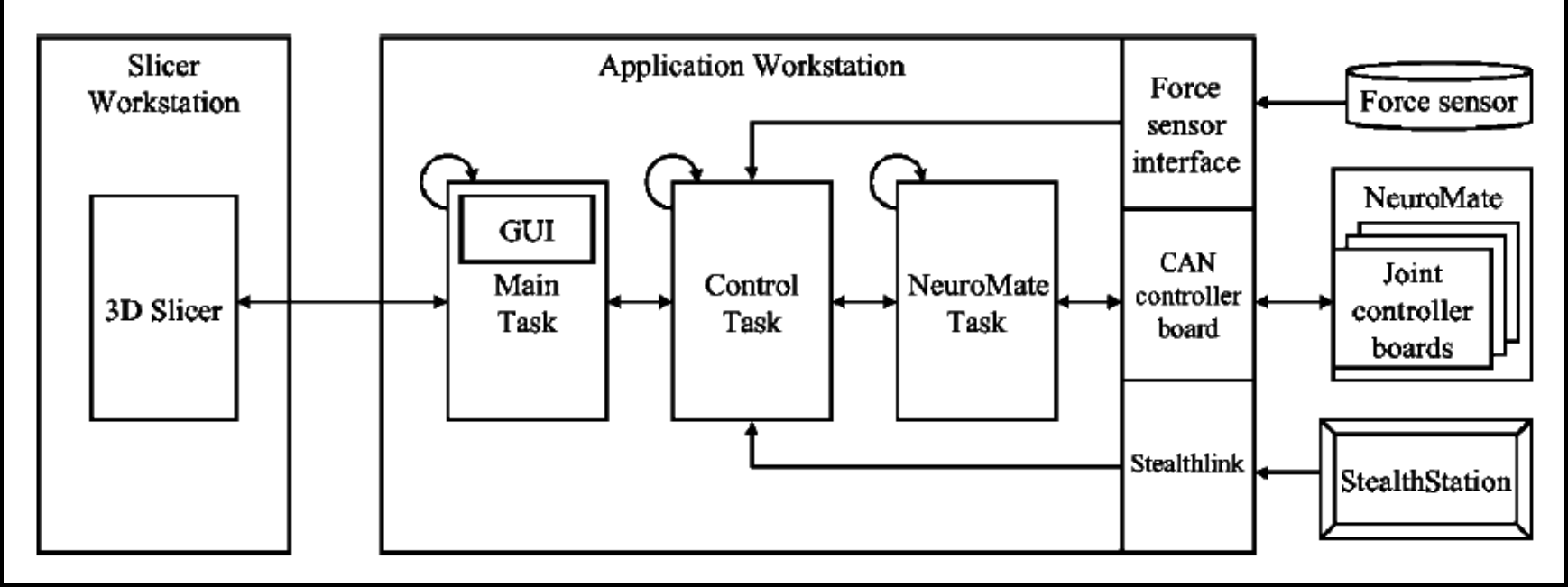
System Block diagram



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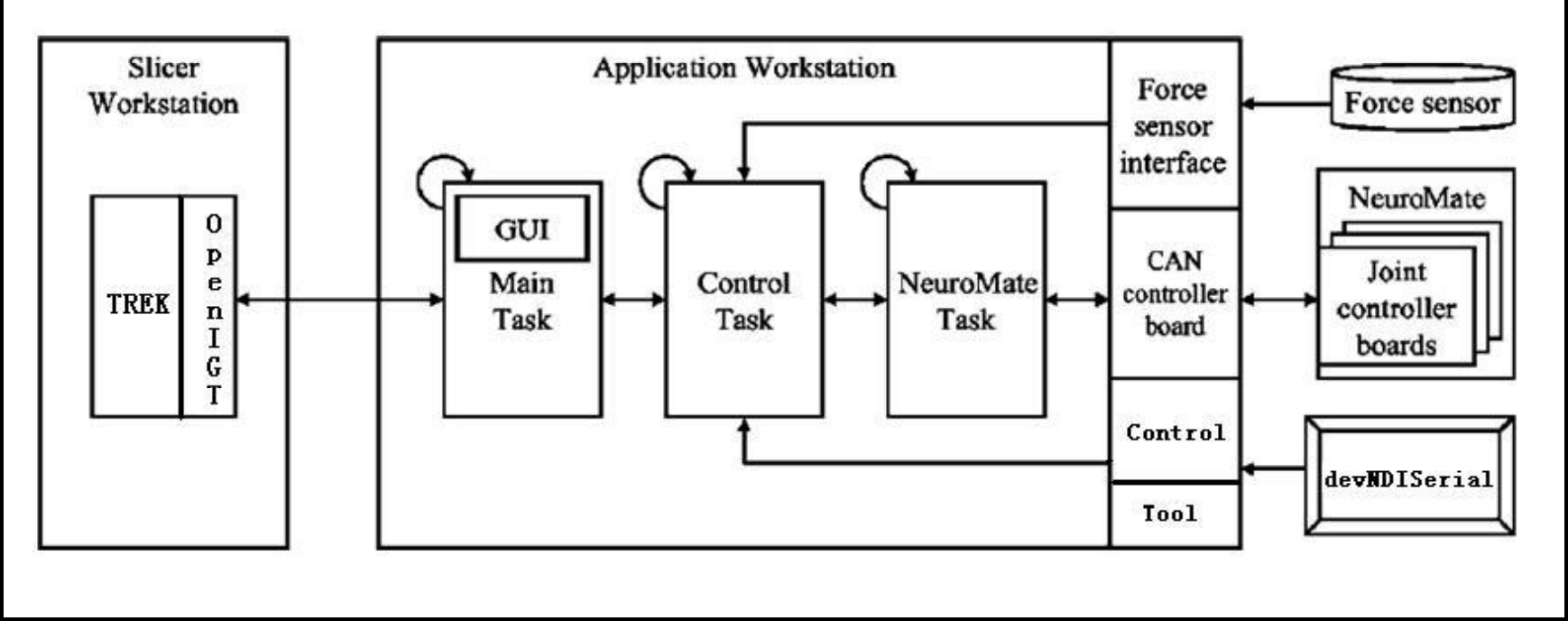
System Block diagram



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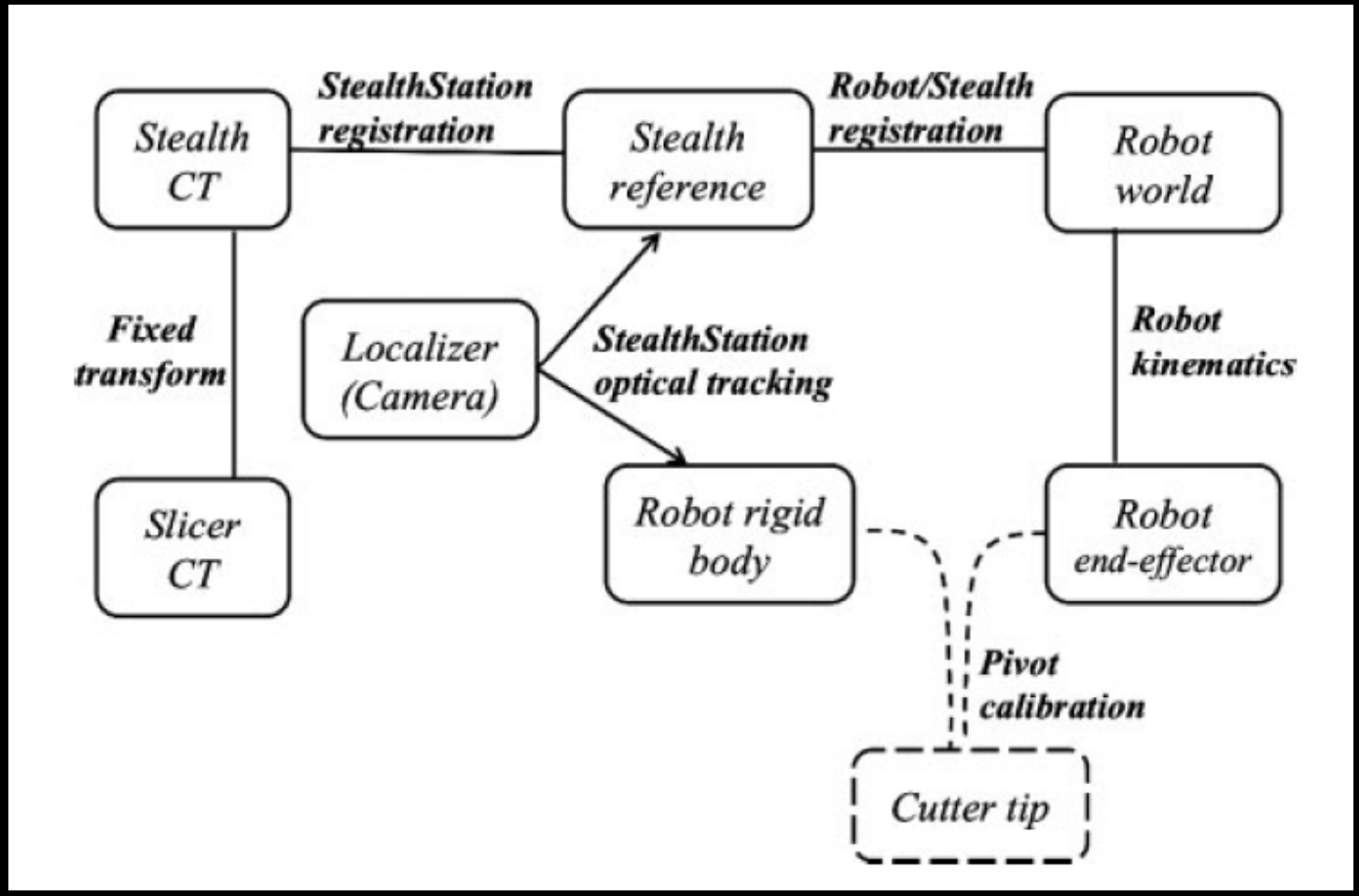
Registration and calibration



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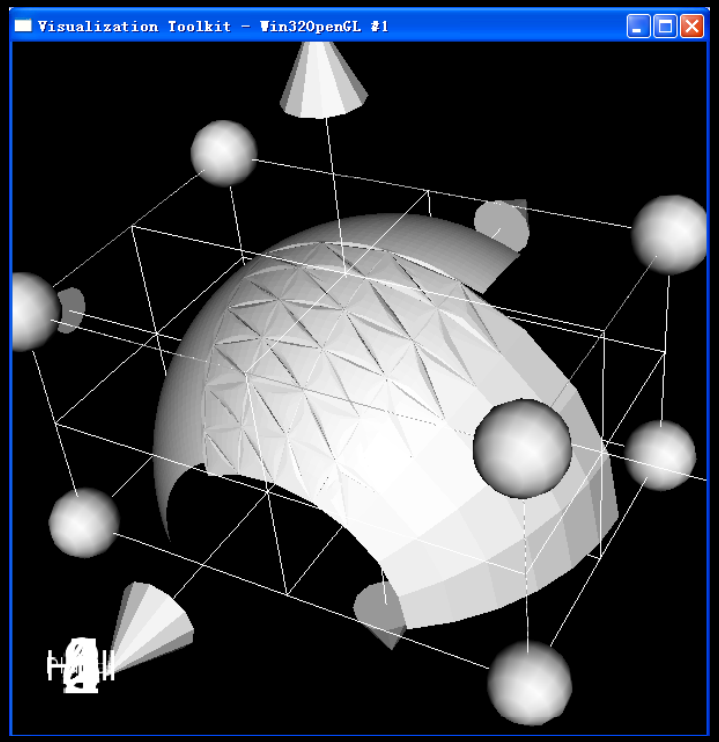
Virtual Fixture



- 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

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

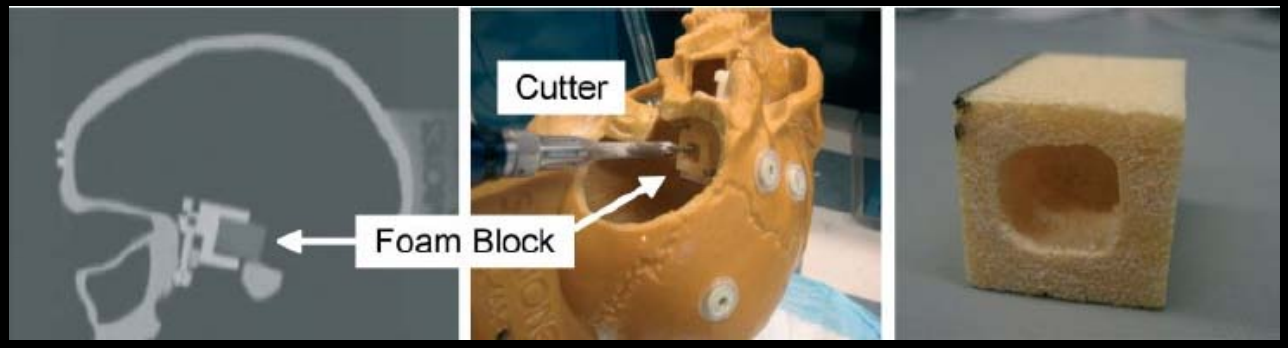
- J^{-1} inverse Jacobian
- G(f) : admittance gains
  - High speed for coarse positioning
  - Fine motion control
  - Exponential functions

- 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

	Placement		Dimensional		Depth
Foam	*X*	*Y*	*X*	*Y*	*Z*
1	0.17	1.12	0.54	0.25	1.16
2	0.04	1.08	0.50	0.20	1.06
3	0.49	0.96	0.25	0.05	1.19
Mean1	0.23	1.05	0.43	0.17	1.14
SD1	0.23	0.09	0.16	0.10	0.07
3	0.49	0.96	0.25	0.05	1.19
4	1.28	1.11	0.70	0.33	0.51
5	−0.44	0.79	0.99	0.35	1.39
6	1.04	−0.62	0.54	0.10	1.85
Mean2	0.59	0.56	0.62	0.21	1.23
SD2	0.76	0.80	0.31	0.15	0.56



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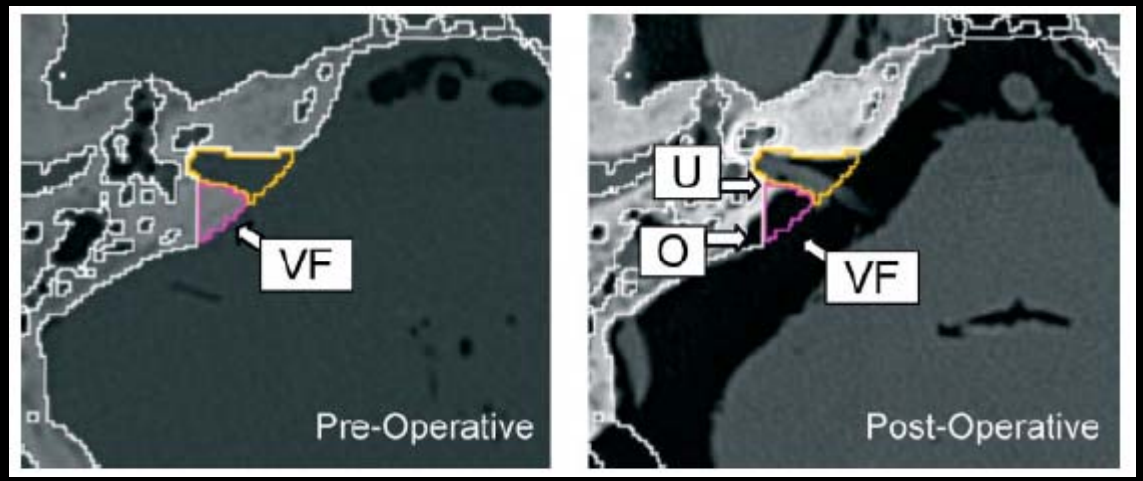
Experiment: Cadaver

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

Table 2. Registration residual errors in cadaver experiments

Trial No.	Cadaver	Procedure	StealthStation-to-CT residual error (mm)	StealthStation-to-robot residual error (mm)
1	A	Left porus	0.61	0.36
2	B	Right porus	0.86	0.48
3	B	Left porus	0.94	0.33



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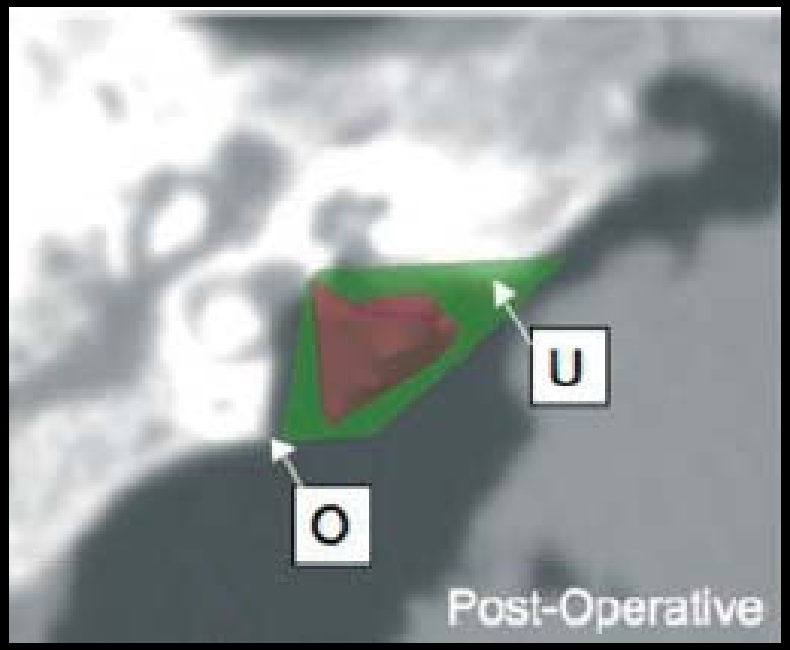
Experiment: Cadaver

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



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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