

Integration of Cone Beam CT and a Skull Base Drilling Robot

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Introduction

- During this project, we
- Obtained CBCT images before, during and after robot-assisted surgical procedure
- Achieved sub-millimeter accuracy in registering CBCT images to pre-opera CT, tracker and robot
- Performed target-pointing and foam ablation experiments with effective virtual fixture (VF) constraint and real-time visualization

We aim at introducing intra-operative imaging as update to image-guided robotics, helping it better provide precise mechanical assistance and safety constraints.

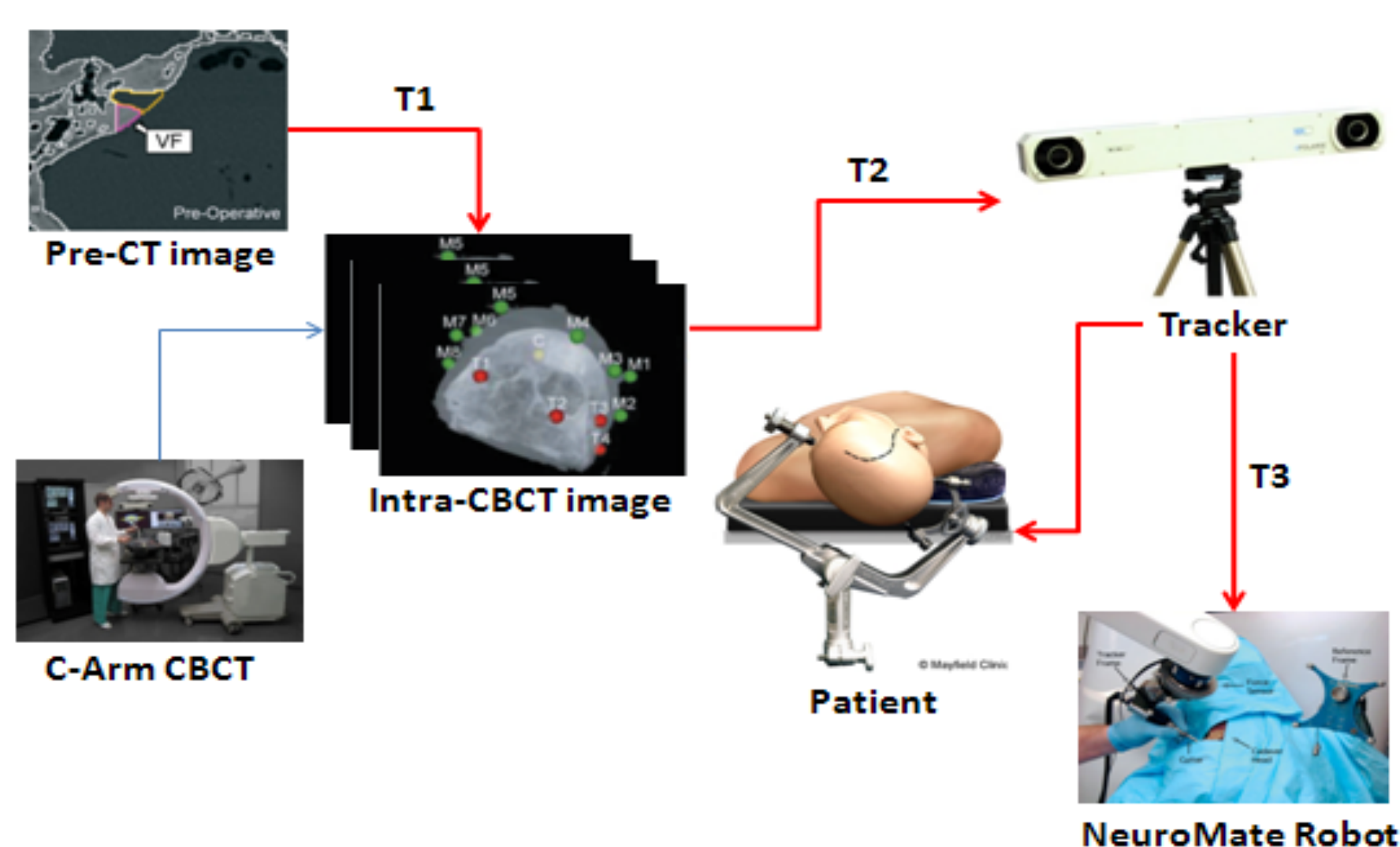
The Problem

- Neurosurgery, especially skull base surgery, requires high accuracy in localizing anatomical structures.
- Previous robot system starts with small pre-opera registration error but ends with cut out of VF in cadaver studies, and navigates only on pre-opera CT images.

The Solution

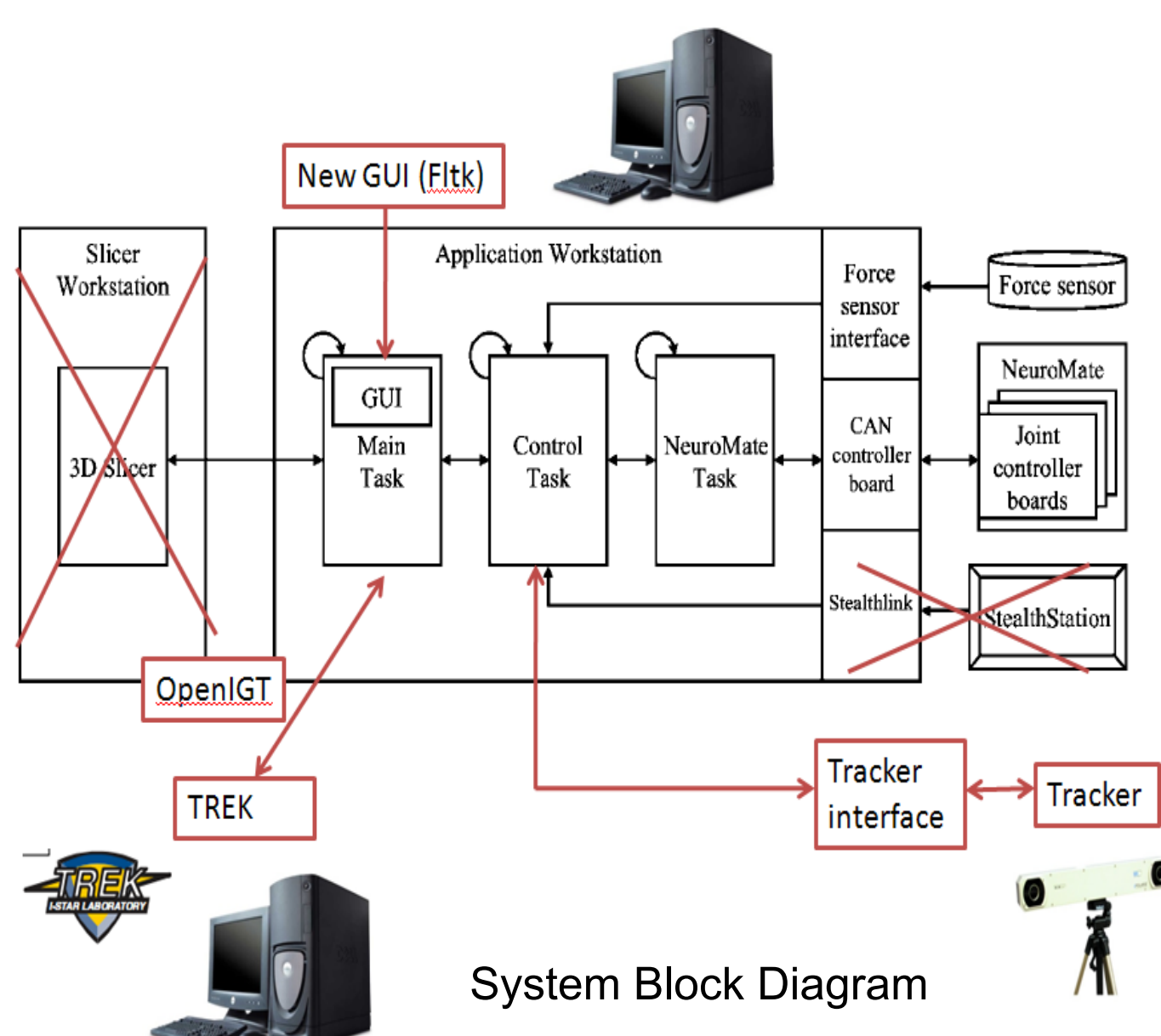
Intra-operative Cone Beam CT imaging is integrated into current skull base robot system to update registration, deformation, and ultimately virtual fixture.

Design New Registration Workflow



Creation

- Tracker interface
- TREK interface
- Tracker GUI

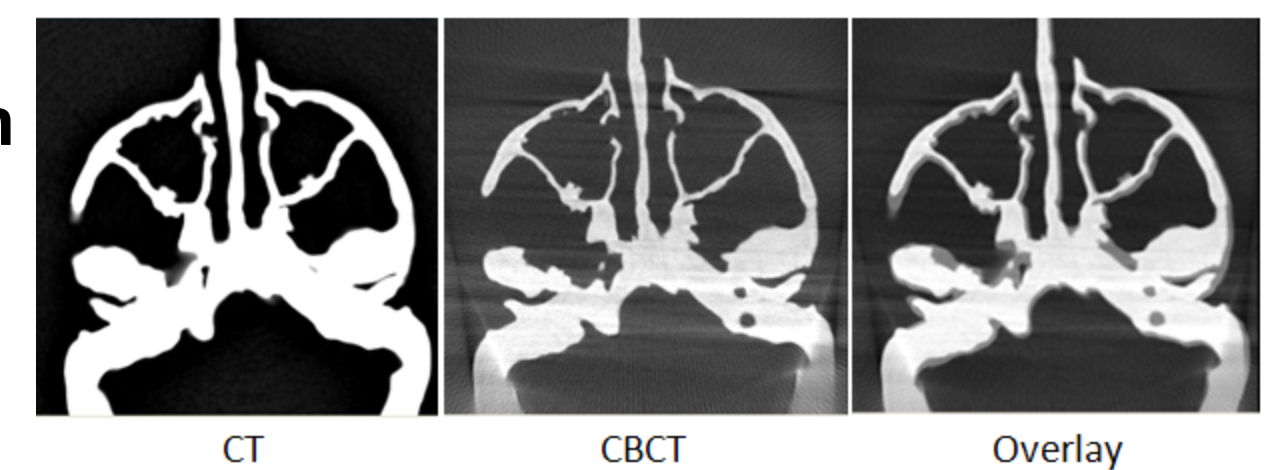


Outcomes and Results

CBCT-CT Registration

Mean FRE: ~0.8 mm

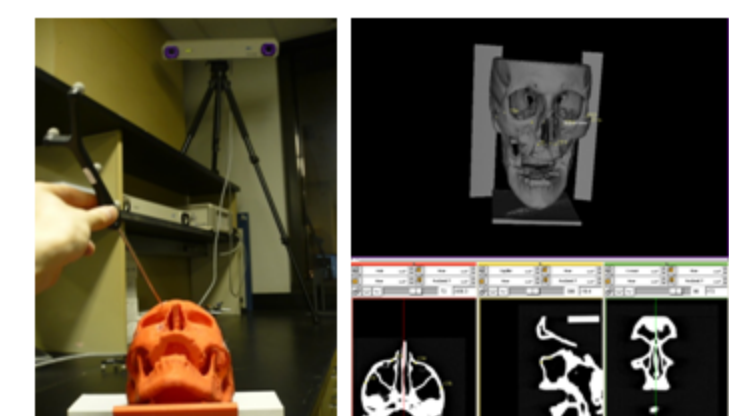
Mean TRE: ~1mm



CBCT-Tracker Registration

Mean FRE: 0.5~0.8 mm

Mean TRE: <1mm



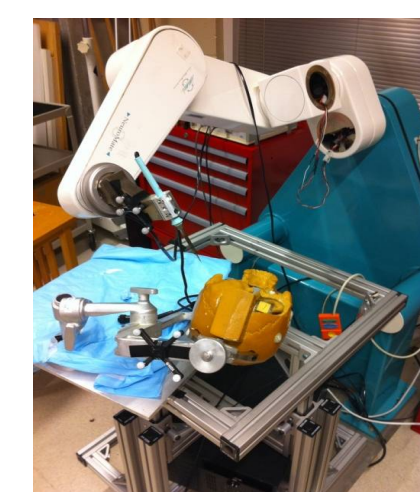
Tracker-Robot Registration

Pivot calibration error

Robot end effector: 0.43mm

Robot rigid body: 0.64mm

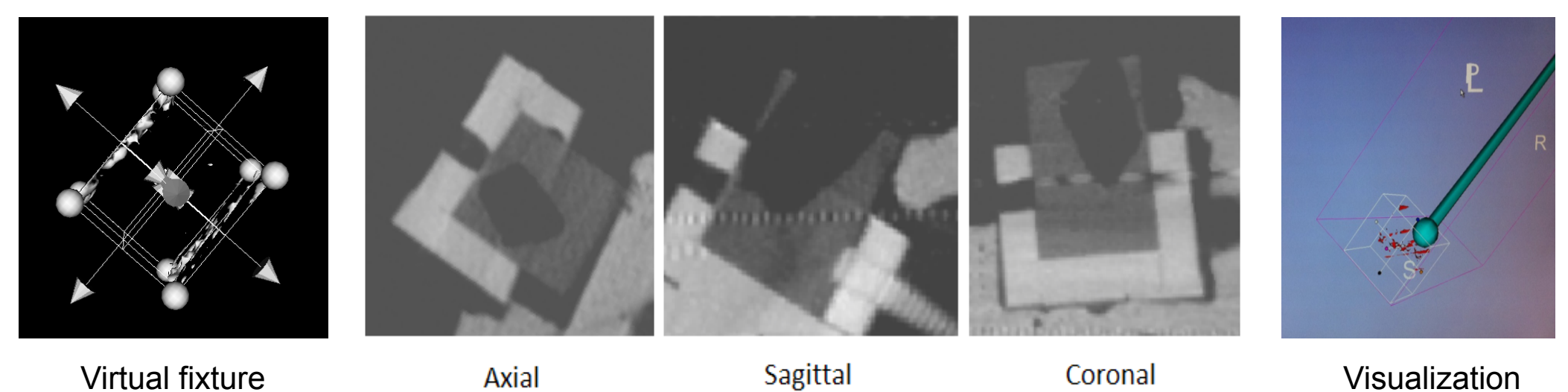
Registration error: 0.65 mm



Target-pointing Experiment (unit: mm)

	Point 1 in Robot world (Estimate)	Point 1 in Robot world (Truth)	Point1 Error (Absolute)	Point 2 in Robot world (Estimate)	Point 2 in Robot world (Truth)	Point 2 Error (Absolute)
X	-230.09	-230.83	0.74	-192.32	-191.72	0.60
Y	625.73	625.60	0.13	554.53	555.55	1.02
Z	-192.18	-190.86	1.32	-214.07	-215.76	1.69

Foam Ablation Experiment



Future Work

- Cadaver experiment
- Deformable CT-CBCT registration

Lessons Learned

- Accuracy control and system integration are of much important

Credits

- Hao: CBCT-CT and CBCT-Tracker registration
- Zihan: Tracker-Robot registration and visualization

Support by and Acknowledgements

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