High-Precision Drill Guide Placement with the UR5

Computer Integrated Surgery II

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Introduction

- Pedicle screw placement procedures involve the insertion of screws into the pedicles of vertebrae for a variety of medical purposes such as re-alignment
- To improve this procedure, we aimed to adapt the UR5 robotic arm to place a drill guide along a patient's body surface to assist physicians with the procedure
- Our goal is to provide a noninvasive method to minimize pedicle screw placement error thereby minimizing risks associated with the procedure

The Problem

- The current standard of care involves free-hand placement of screws into pedicle corridors by physicians
- Given that the procedure has a small acceptance window, the risks associated with the procedure can be as severe as spinal cord breaches and damage to vascular structures
- Thus, the risks involved with the current standard of care warrant a means of maximizing screw placement precision to improve patient outcomes

The Solution

- We integrate an optical tracking system to relate the position of the UR5 to that of a patient's body (rigid spine model in experimental setup) via an AX=XB calibration and fiducial registration.
- A custom drill guide tool was developed as part of the optical tracking setup
    - The tool was pivot/axis calibrated for the setup
- Target-placement planning was performed in a "pre-operative" CT volume of the physical spine model which was related to the optical tracker by means of a 16-point fiducial registration
- UR5 Robotic control was accomplished using an open-source, python-based library—URX.

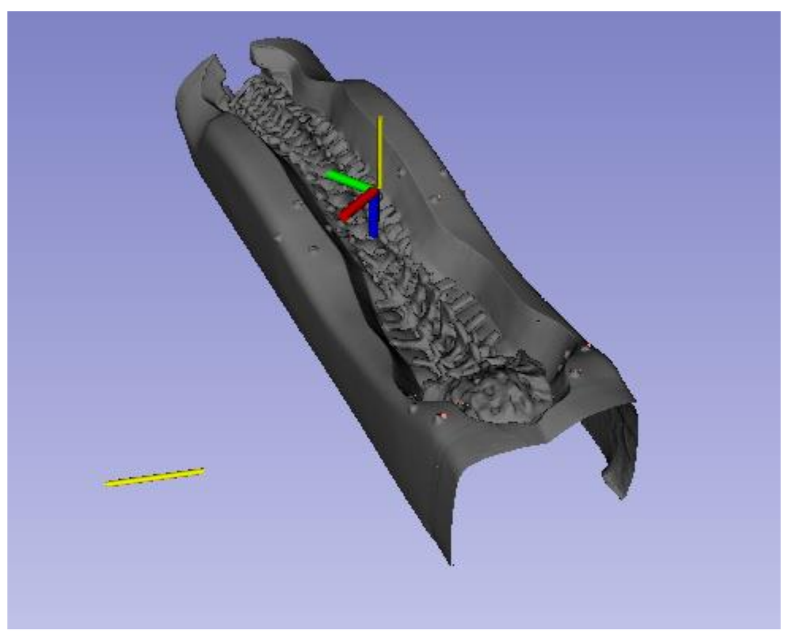

Figure 1: 3DSlicer view of the optical tracking setup

Figure 2: The custom drill guide tool used in the setup

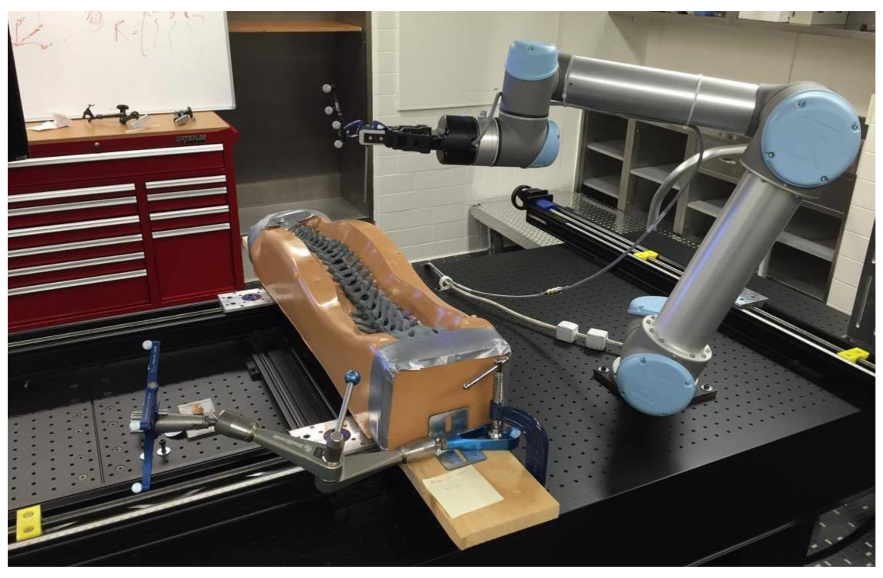

Figure 3: Physical setup (tracker not shown)

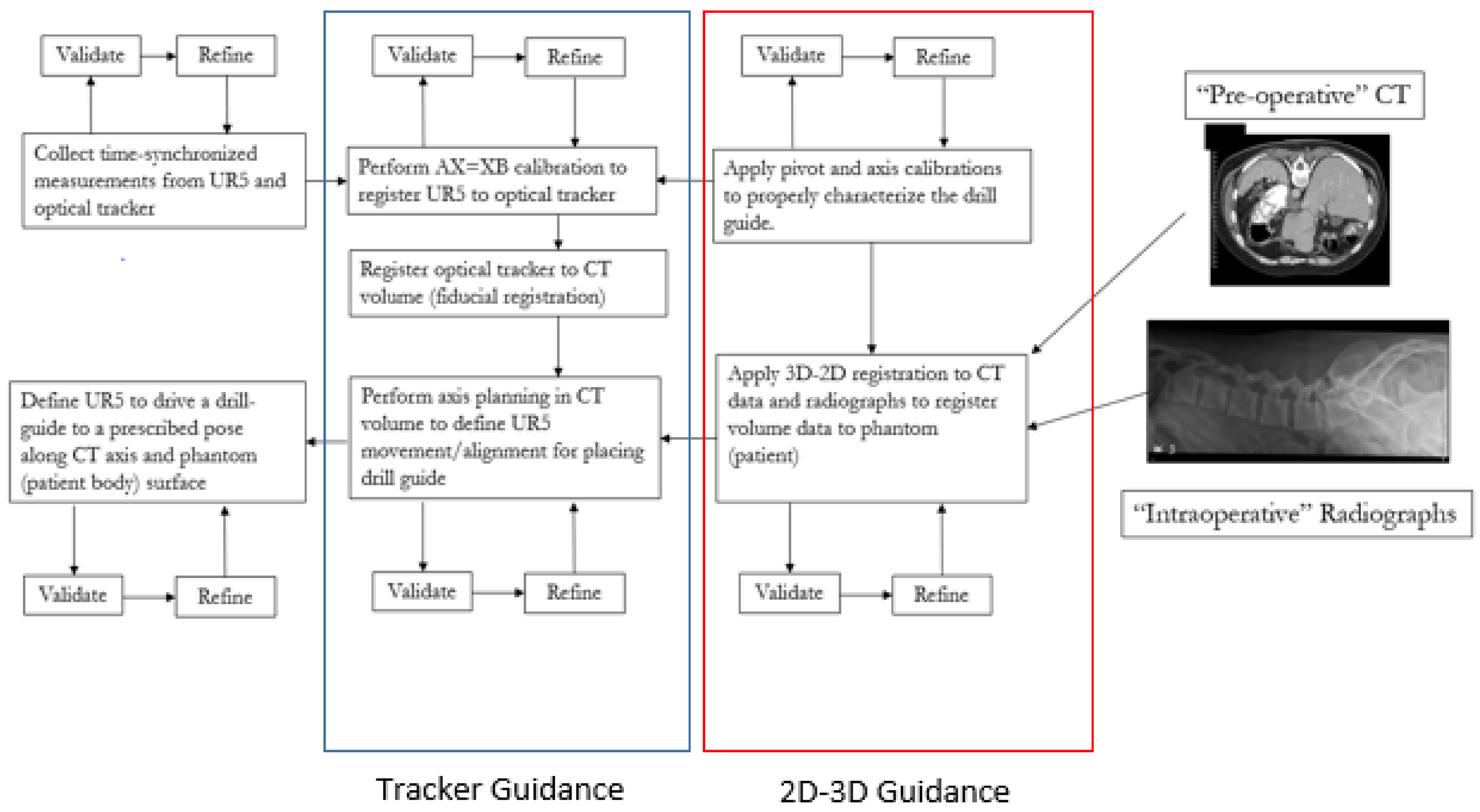

Figure 4: Technical Approach

Outcomes and Results

- Developed workflow for defining a 6-DOF pose in CT space and driving the UR5 to position the drill guide along that target pose
- Streamlined tracker-robot calibration and statistical processing methods
- TRE computed based upon a "leave-one-out" method where target poses were defined by fiducial points that were left out of the registration one at a time
- Average TRE of 5.07 mm

Future Work

- Refine intermediate calibrations/registrations in order to minimize error associated with optical tracking solution
- Move towards a 2D-3D registration approach, eliminating the need for an optical tracker
- Assess ability of solution to work with a cadaver setup involving more deformable anatomy

Lessons Learned

- Processes involved in bringing multiple systems and objects together to relate different coordinate systems
- Fundamentals underlying known software builds and mathematical validation

Credits

- We worked together for the majority of tasks, including the tracker and phantom registrations as well as development of the custom drill guide
- Vignesh performed mathematical validations/analyses throughout the course of the project
- Thomas implemented UR5-driven processes in a custom TREK module

Support by and Acknowledgements

- I-STAR Lab
- We extend our thanks to our CIS II peers who offered valuable critiques during the course of the semester