Projection Mapping in Surgery

Computer Integrated Surgery II

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Introduction

This semester, I developed parts of a projection mapping prototype consisting of an Intel Realsense RGBD camera, tracking camera, and portable projector.

In this first draft of a prototype, I …

- Used OpenCV to perform AR marker pose estimation and implemented geometric filter to improve accuracy
- Developed ROS nodes to perform pivot calibration and allow user to record points on skull
- Performed registration between user-recorded points and point cloud data from skull STL model

With this prototype, we hope to increase the ease and accuracy of the skull implant design process.

The Problem

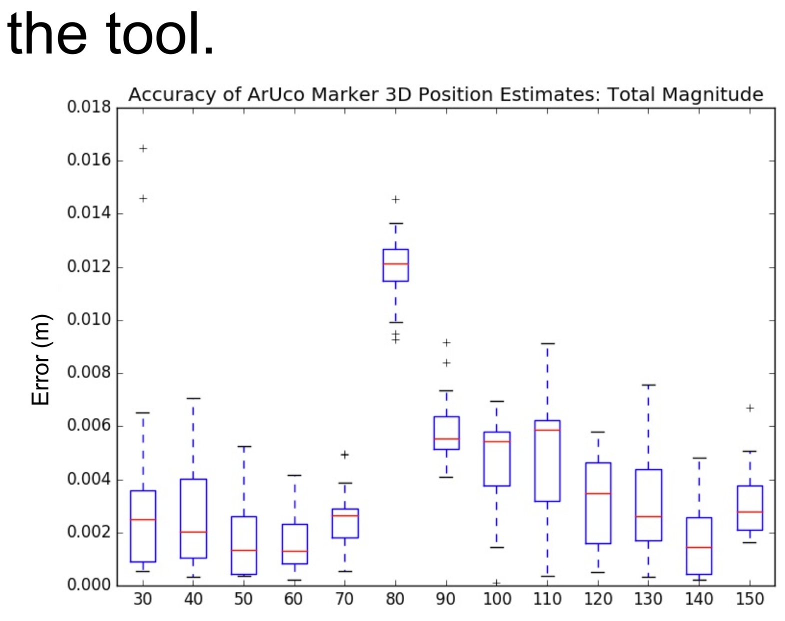
In cranioplasty, to design a skull implant, a surgeon shapes the implant's stock material relying only on what they can see. As a result, the implant design process relies on trial-and-error and is a strenuous process.

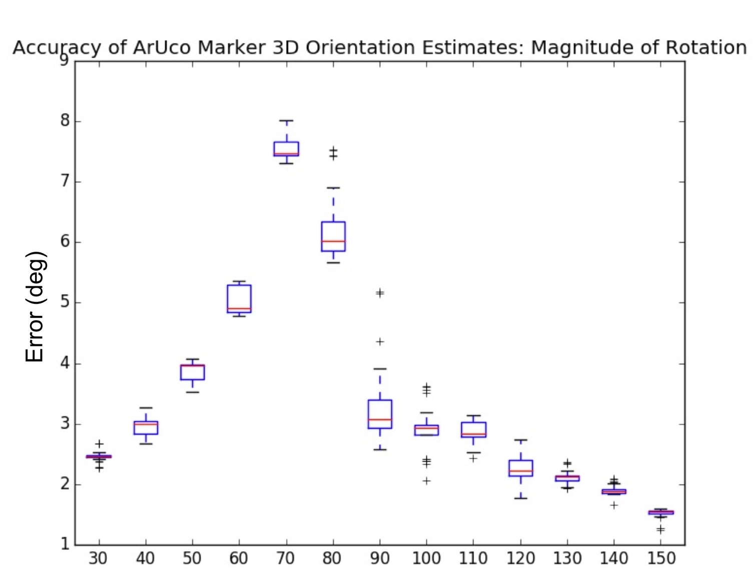
Ideally, our prototype will project skull CT scans and the implant onto the patient's skull to display the appropriate orientation and position of the implant. The point cloud data gathered by the RGBD camera of that same scene will determine the shape of the defect and therefore the shape of the implant.

The Solution

OpenCV Marker Pose Estimation

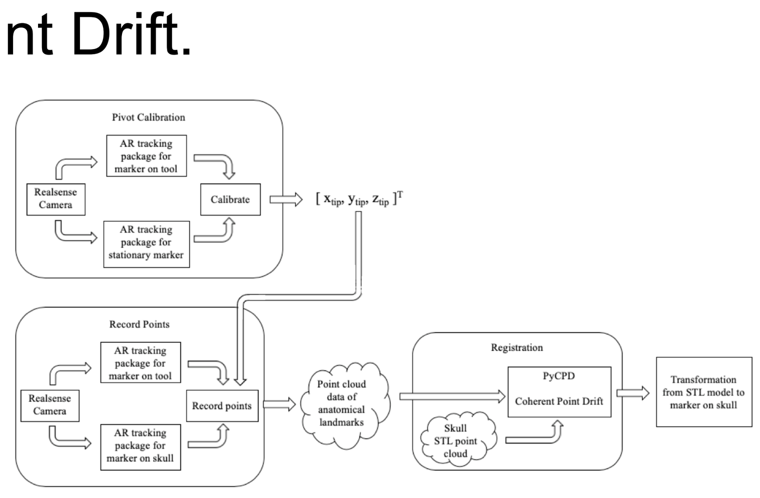
OpenCV's ArUco library was used to estimate the markers' poses. The estimated depth and orientation was not sufficiently accurate so I designed a geometric filter that relies on the known transformations between each marker on the tool.





ROS Marker Pose Estimation

Basic evaluation of ROS's AR marker pose estimation shows a stable translation error of 8-10 mm. With this estimation, the user can record points of distinct anatomical landmarks and proceed with registration, done using PyCPD. The package considers the alignment of two point sets as a probability density function using an algorithm called Coherent Point Drift.



ROS network of nodes: pivot calibration, record points, registration

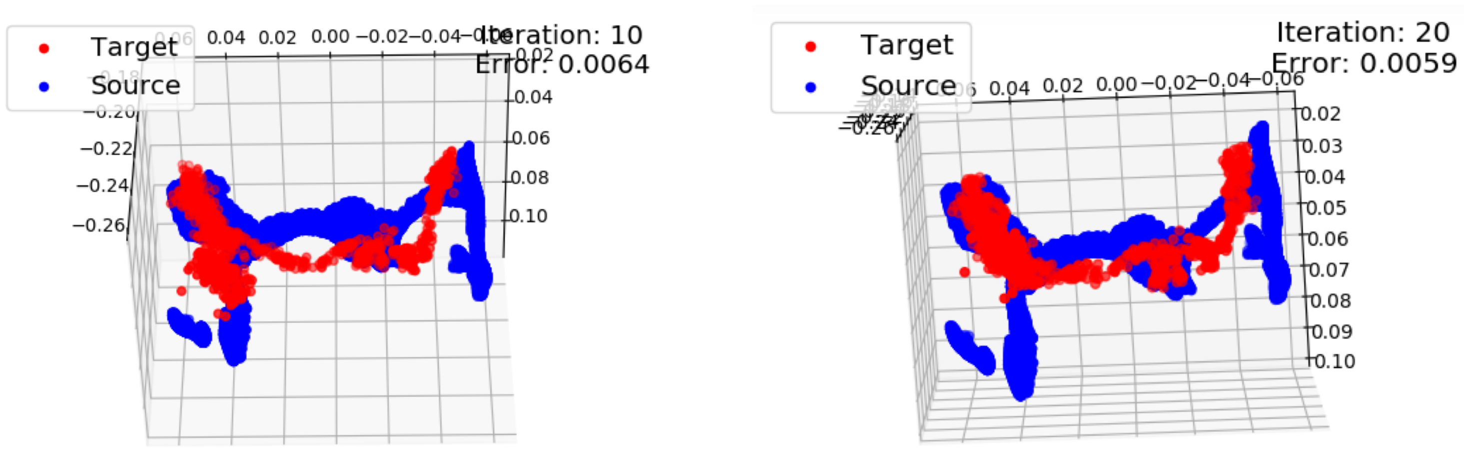
Outcomes and Results

Pivot Calibration

Due to the high amount of error in marker pose estimation, there is also an error of 8-10 mm in the results of our pivot calibration procedure.

Point Recording and Registration

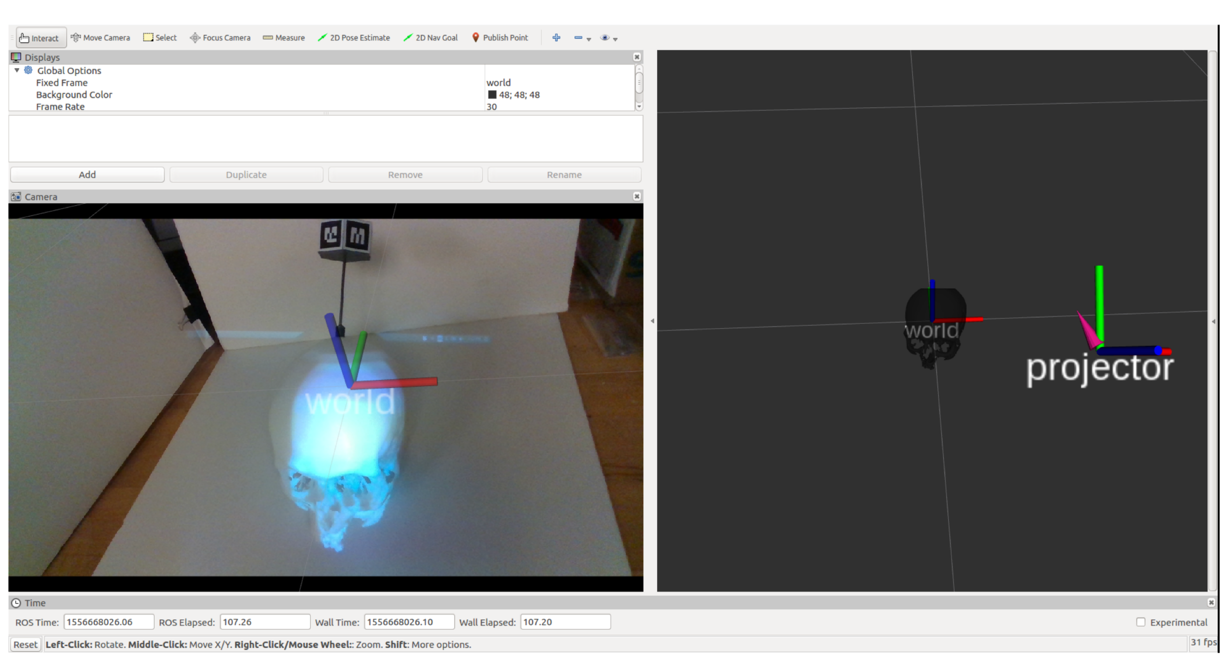
Using the 3D-printed marker tools, the user can record points of distinct anatomical features of the patient's skull and see visualizations of the registration procedure.



Registration of user-recorded points and STL skull model. Points represent area around eyebrows. Error value is average distance (m) between each user-recorded point and closest point on STL model.

Integration with Projector Work

Using the transformation obtained from the registration procedure, the transformation from the camera to the STL coordinate frame can be calculated and helps position the projection in the correct location.



STL skull model projected onto plastic skull with rigidly fixed marker

Future Work

I will be continuing work on this project the following semester, and here are the next steps:

- Integrating the Realsense 3D point cloud data to improve AR marker pose estimation accuracy
- Developing a markerless registration procedure using the Realsense 3D point cloud data

Lessons Learned

- It is difficult to obtain high precision and accuracy in AR marker pose estimation using 2D RGB images
- The ROS communication system makes it very easy to seamlessly connect different project parts together.
- It is more efficient to build on top of as much pre-existing software as possible.

Support by and Acknowledgements

- Thank you to my mentors, Professor Armand and Joshua Liu, for providing me with advice and recommendations to difficult problems.
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