Projection Mapping in Surgery

Group 10

Members:

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Mentors:

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Objective

The goal of this project is to develop a projection mapping prototype that projects patient data (eg. CT/MRI scan model) onto patient body in realtime.

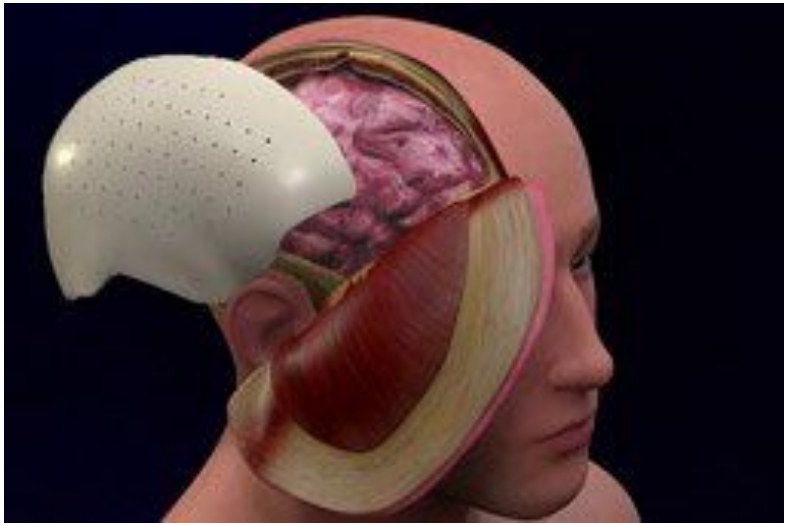
RGB image
Point cloud data

Projection

Application

Cranioplasty

- Surgical repair of bone defect in skull after operation or injury



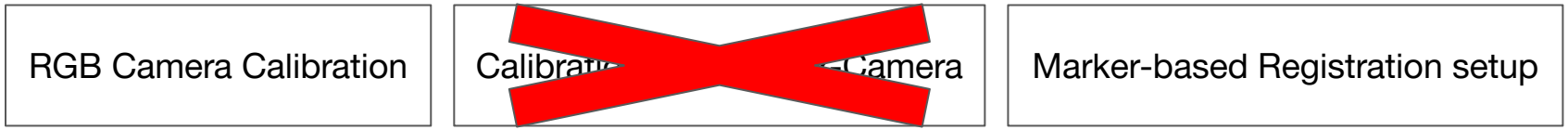
https://www.parashospitals.com/india/treatments-and-procedures/cranioplasty-craniotomy-delhi-gurgaon-patna-darbhanga/

Summary of Changes

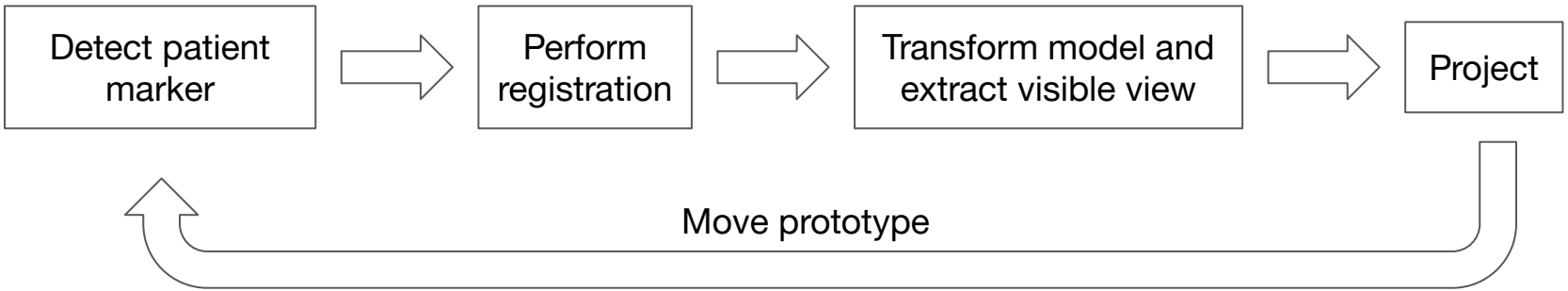
- Not handling projector hardware
- ArUco marker pose estimation was worse than anticipated, leading to delays
- Factoring in time for accuracy evaluations for each step

Technical Approach - Workflow

Before Operation



During Operation (marker-based)



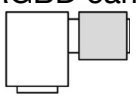
Technical Approach - Marker-based Registration

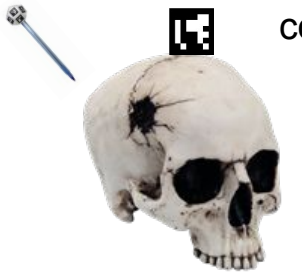
Steps

1. Detect markers ✓
2. Pivot calibration ✓
3. Touch anatomical landmarks with tool ✓
4. Record location of each landmark relative to camera ✓
5. Perform initial registration with CT model — IP
6. Calculate location of landmarks relative to patient marker for future registration

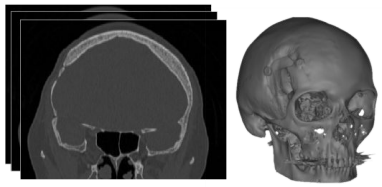
Given: RGBD data
IMU camera data

RGBD camera





Given: CT scan of skull and model of implant in same coordinate frame



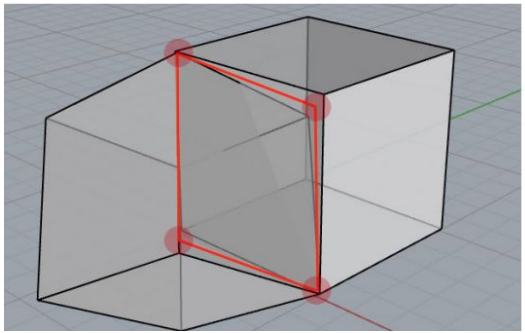
Camera - https://www.researchgate.net/figure/The-hardware-configuration-of-real-time-projection-mapping-system_fig6_276415839
Skull with hole - https://www.pinterest.com/pin/415949715559685977/?lp=true
2D and 3D model of skull - https://www.3dside.eu/en/cranial-implant-1
Marker pen - https://research.fb.com/wp-content/uploads/2017/09/uist2017_pen.pdf

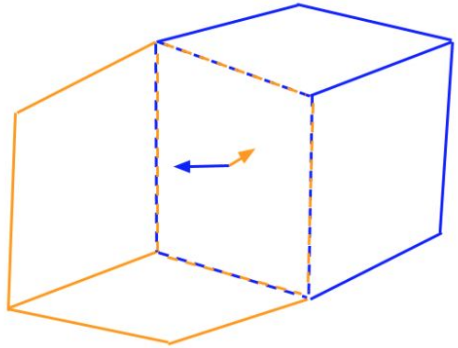
Technical Difficulty - Marker-based Detection

Difficulty: Marker Pose Estimation

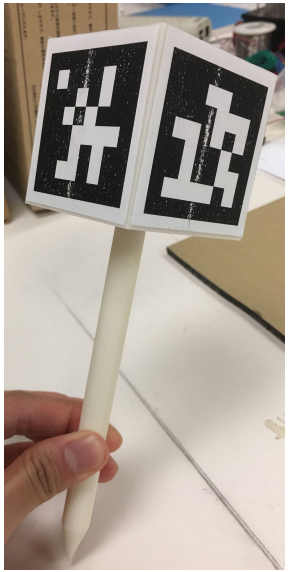
Reason: Pose Ambiguity

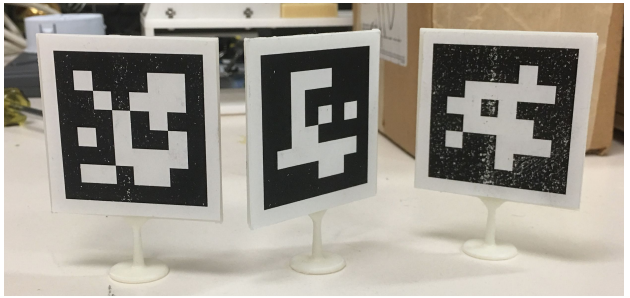
- Using min number of points with solvePnP





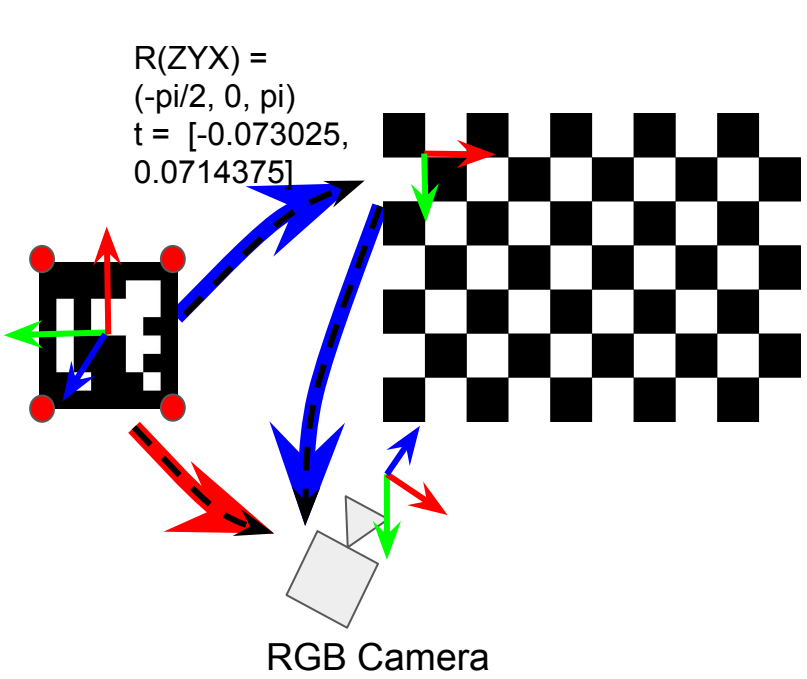
Jin, Pengju. Uncertainty Adaptation in Robot Perception and Learning. Dec 2017. CMU.

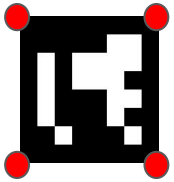




Technical Solution - Marker Pose Estimation

Solution: Geometry-based Filter





Center = [0.1444625,
-0.1857375]

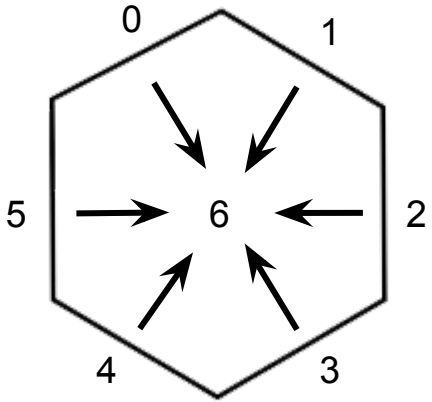
In reality, the chessboard is 4 x 3.
Each side is length 2.6 cm.

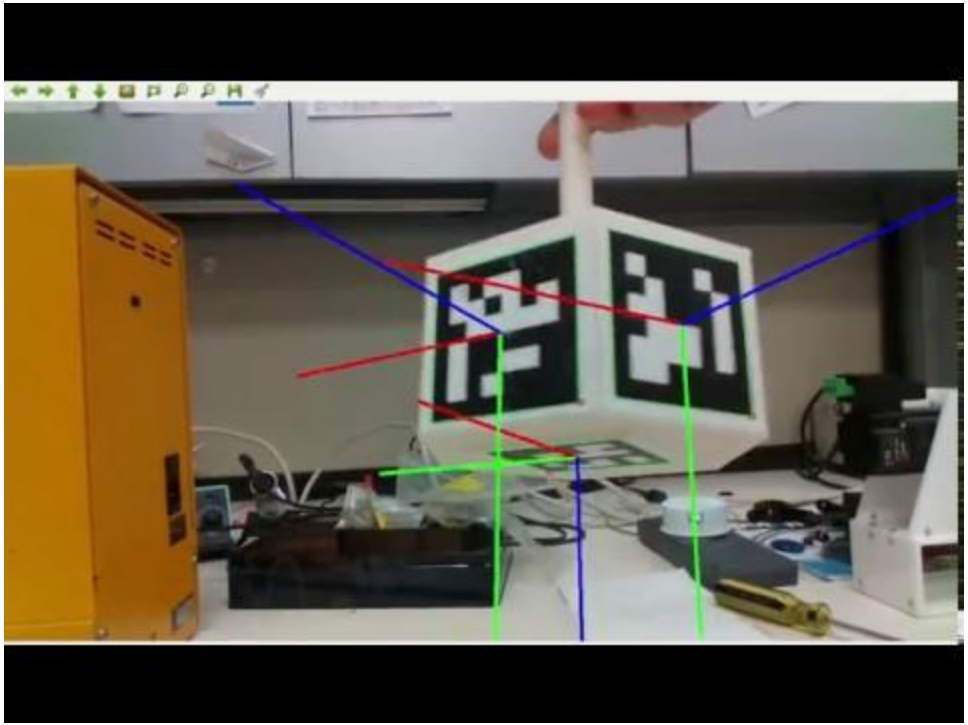
Other potential solutions: two markers per panel side, custom function to extract all corners on marker, printed markers on workspace, IPPE package + depth map

Technical Approach - Marker Setup

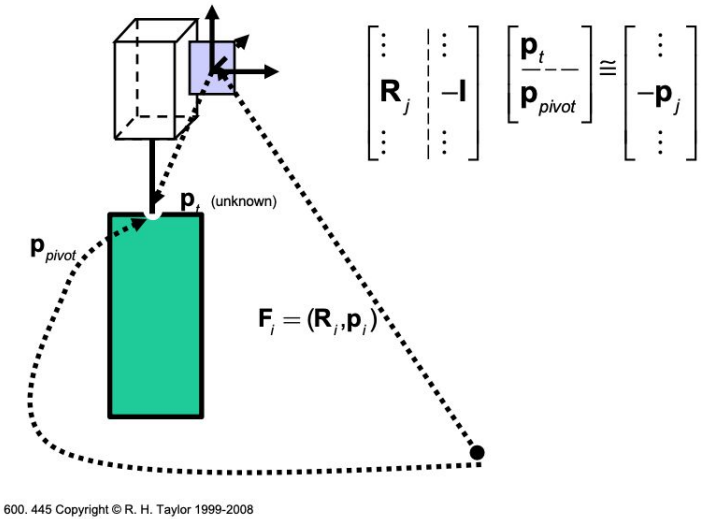
For example, 6-sided marker tool:

Top view





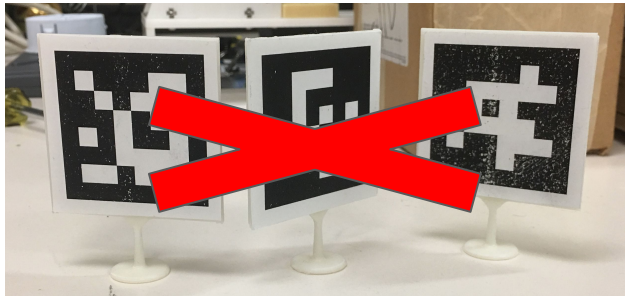
Technical Approach - Pivot Calibration

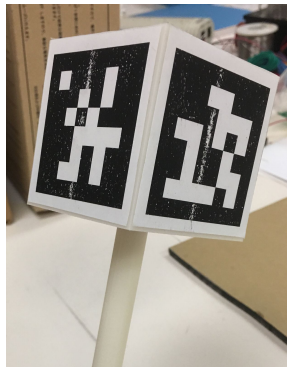


Ground truth: [0, 0, -0.210]
Measured: [0.00812451, -0.00558087, -0.21730515]

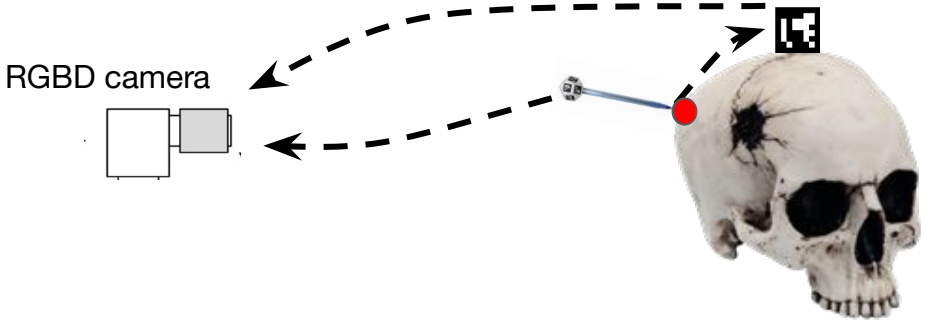
Technical Approach - Realtime Registration

1.





2. Recording points



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Skull with hole - https://www.pinterest.com/pin/415949715559685977/?lp=true
Marker pen - https://research.fb.com/wp-content/uploads/2017/09/uist2017_pen.pdf

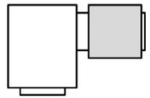
Technical Approach - Markerless Registration

Ideas

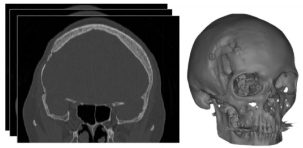
1. Collect high density of points around unique anatomical feature to do registration
2. Do registration with raw Realsense point cloud data

Given: RGBD data
IMU camera data

RGBD camera



Given: CT scan/model of skull
Model of implant



Camera - https://www.researchgate.net/figure/The-hardware-configuration-of-real-time-projection-mapping-system_fig6_276415839
Skull with hole - https://www.pinterest.com/pin/415949715559685977/?lp=true
2D and 3D model of skull - https://www.3dside.eu/en/cranial-implant-1
Implant - http://balticimplants.eu/patient-specific-medical-devices/cranial-implants/

Deliverables

Minimum:

- Video showing ArUco markers are detected and output of their 3D location
- Accuracy evaluation of marker pose estimation
- Video of marker setup procedure and pivot calibration

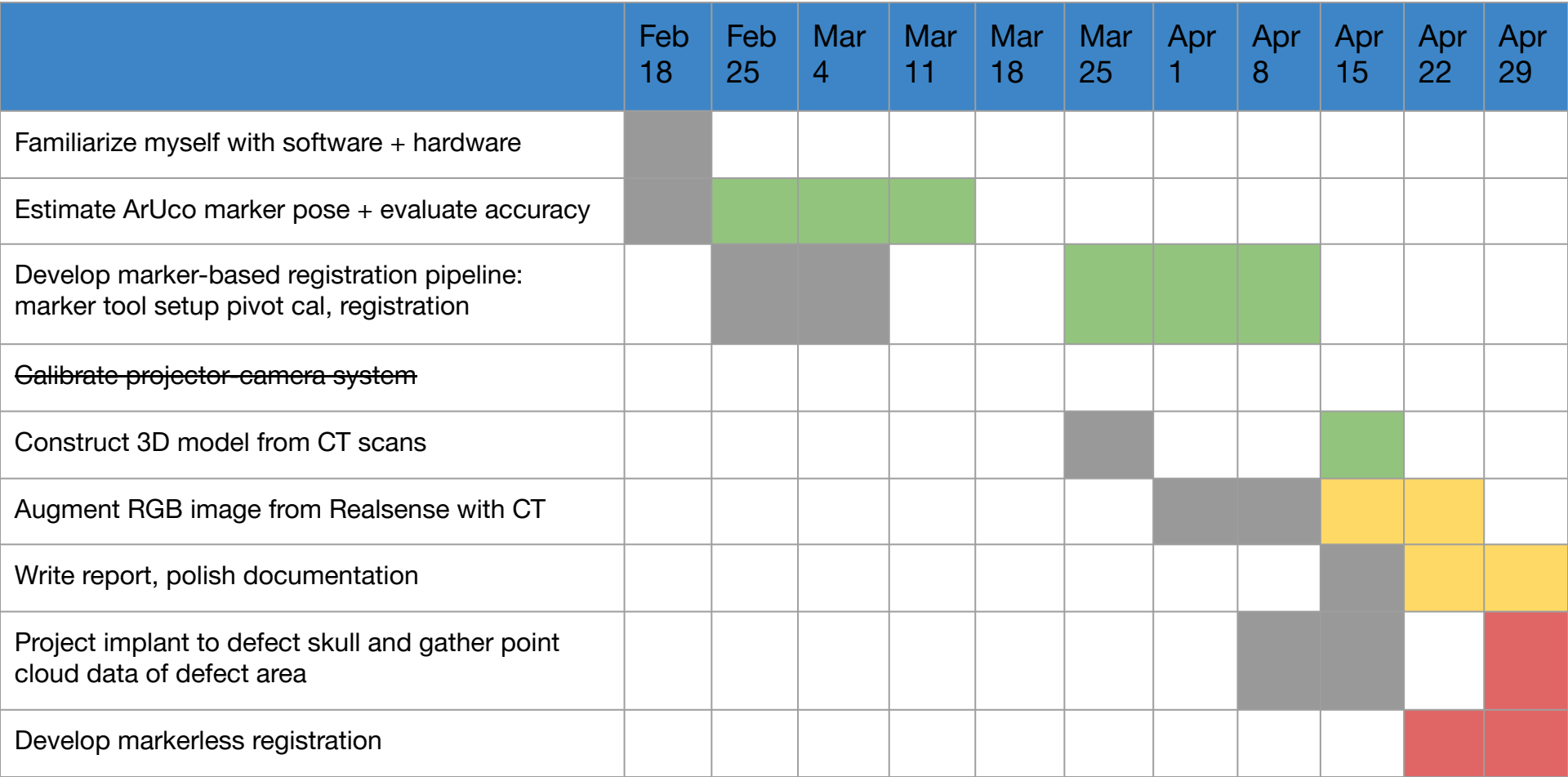
Expected:

- Python/C++ source code and documentation
- Window display of aligned points with marker-based registration and text file with output stream of computed transformations
- Window display of defect skull augmented with CT model

Maximum:

- Same deliverable as marker-based registration but with markerless procedure
- Accuracy evaluation of marker-based and markerless procedure with comparison
- Video of projection mapping also projecting oversize implant on defect skull

Updated Activity Schedule



Dependencies

Dependencies	Solution	Expected Date	Needed by
Computer	Personal laptop	Done	
Access to BIGGS Lab	Asking Professor Armand	Done	
Access to Intel RealSense SDK 2.0	Downloaded from website	Done	
Access to Intel RealSense Camera	Bought	Done - Joshua	
Access to Open3D library and OpenCV	Installed	Done	
Access to projector	Bought	Done - Joshua	
Holding mechanism for projector and camera	Built by Joshua	Done	

Dependencies

Dependencies	Solution	Expected Date	Needed by
Construct ArUco marker panels and marker tool	3D-printed	2/21	2/22
Construct ArUco marker fixture	3D-printed	4/17	4/17
CT scan reconstruction software (eg 3D slicer)	Seek advice from Professor Armand and lab mates	4/15	4/21
Obtain data (scans/models of skulls)	Currently have molds, need corresponding scans. Currently using heart model and 3D-reconstructed scan from structure sensor	~~3/10~~ 4/17 - Joshua	~~3/15~~ 4/21
~~Interface with projector~~	~~Online research~~	~~3/10~~	~~3/25~~

Milestones

3/3 - Python script to estimate ArUco marker pose

3/16 - Accuracy evaluation report for marker pose estimation

3/29 - Python script to calculate transformation between markers on marker tool

4/1 - Python script to execute pivot calibration

4/8 - Python script that allows user to interactively pick points in point cloud

3/17 4/11 - Python script for complete working marker-based registration

3/31 4/17 - compilation of 3D models of CT scans of skulls

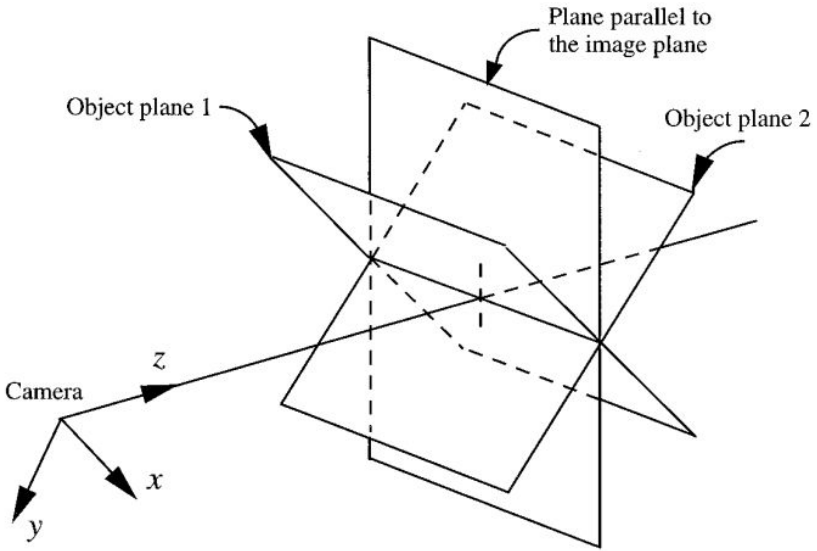
4/14 4/29 - Video of RGB Realsense image overlaid with appropriately transformed CT model

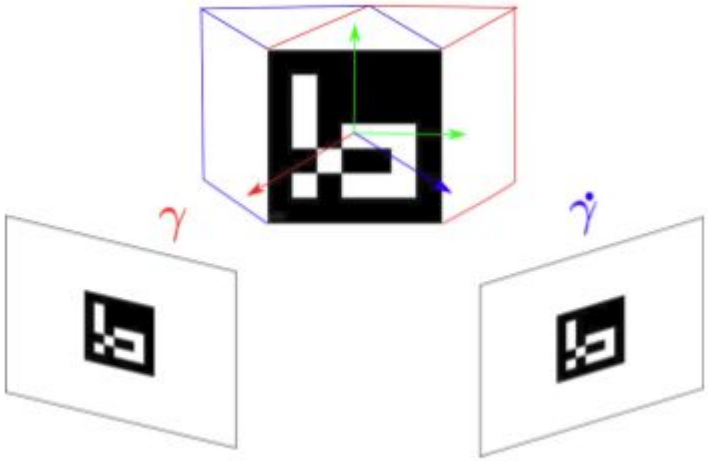
5/3 - Python script for complete working markerless registration

5/5 - Final report written and code review by Joshua

Any Questions?

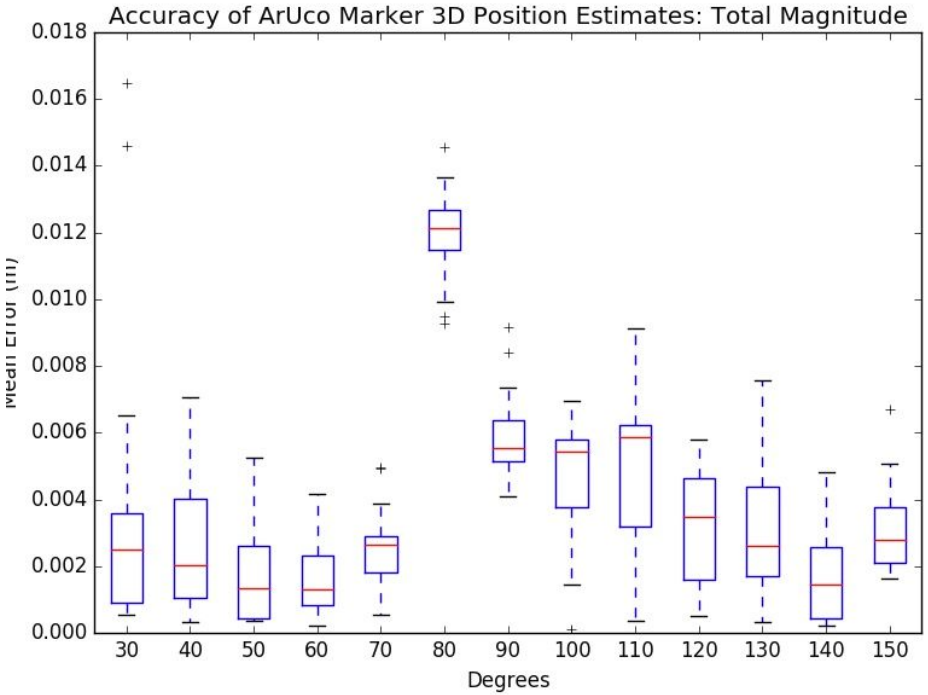
Additional Pose Ambiguity Explanation

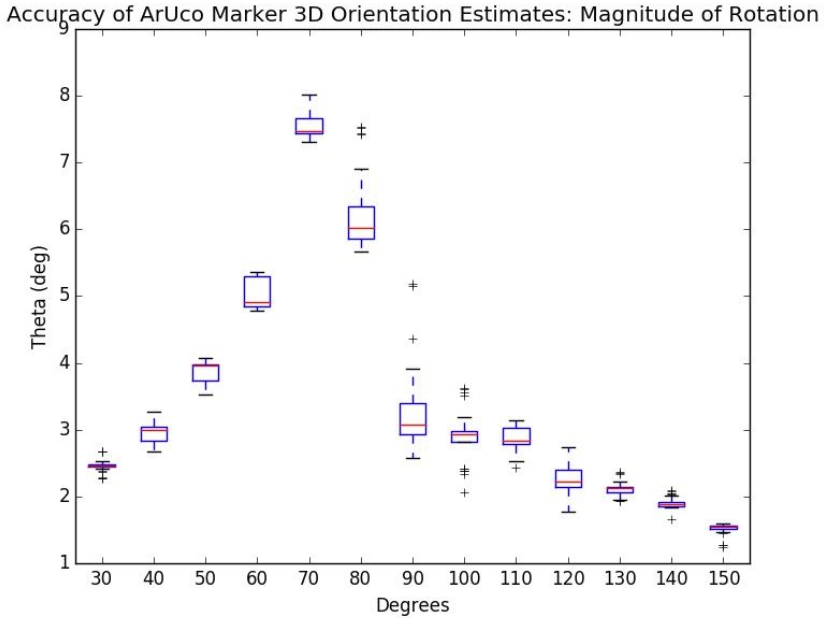




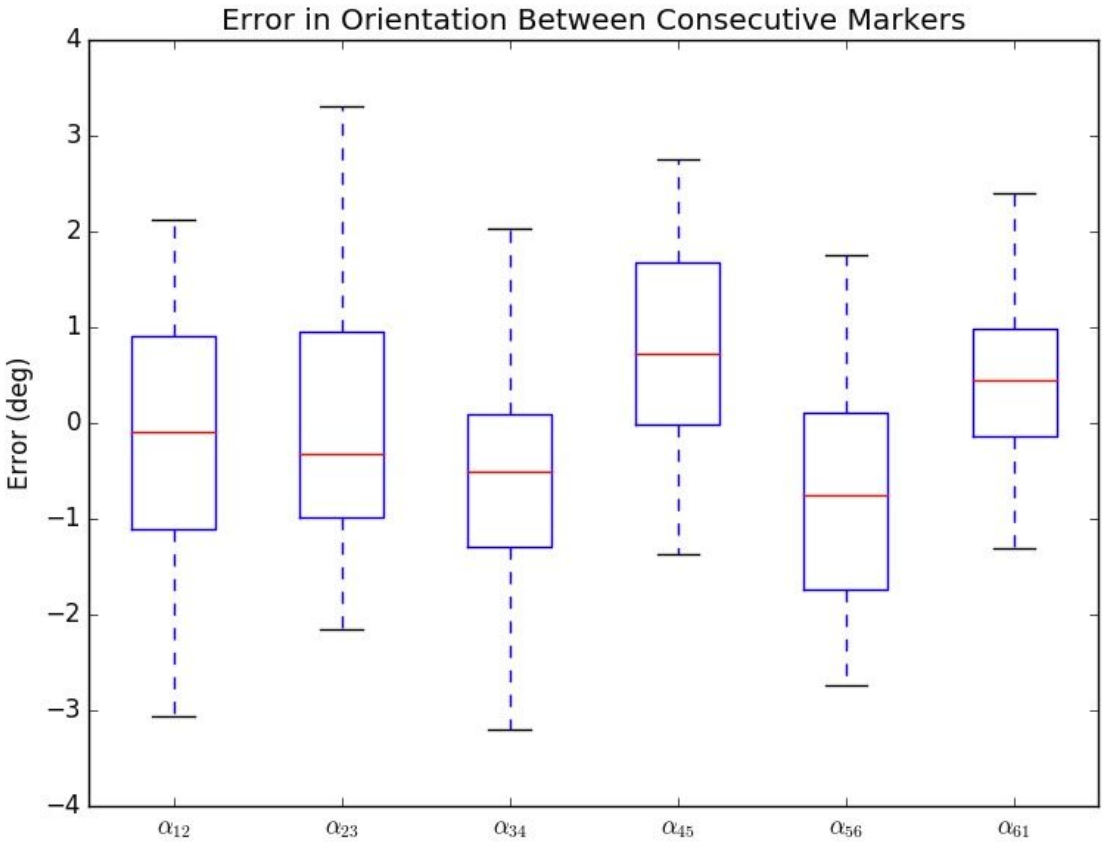
The ambiguity problem. The same marker projection could come from two poses, the two cubes shown in red and blue.

Calibration Results





Marker Tool Setup Plots



Pivot Calibration Plots