Projection Mapping in Surgery

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Group 10

Members:

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Mentors:

Professor Armand

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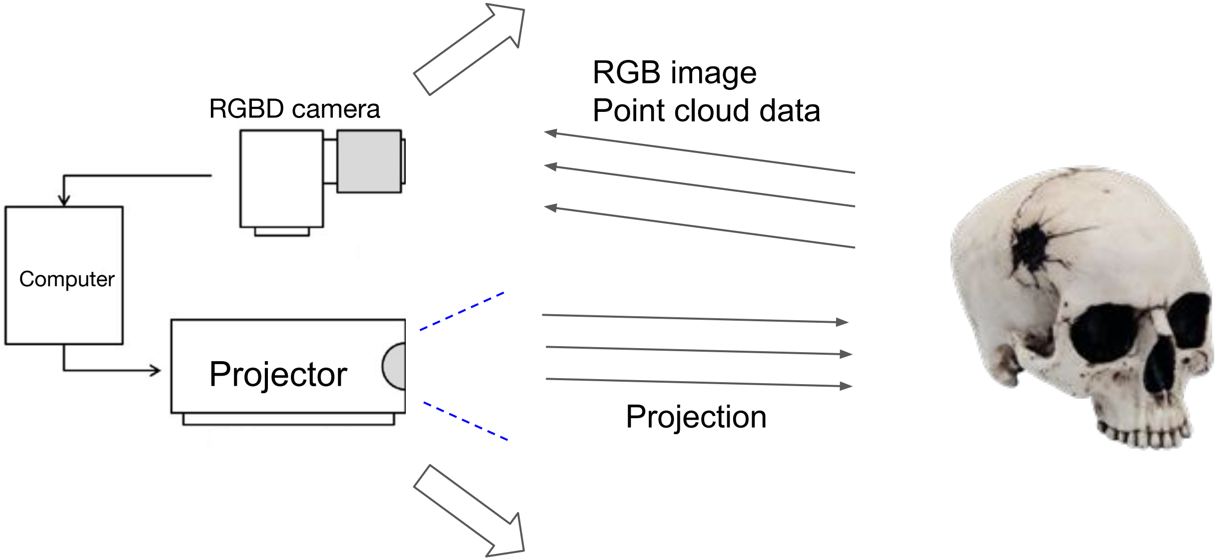
Objective

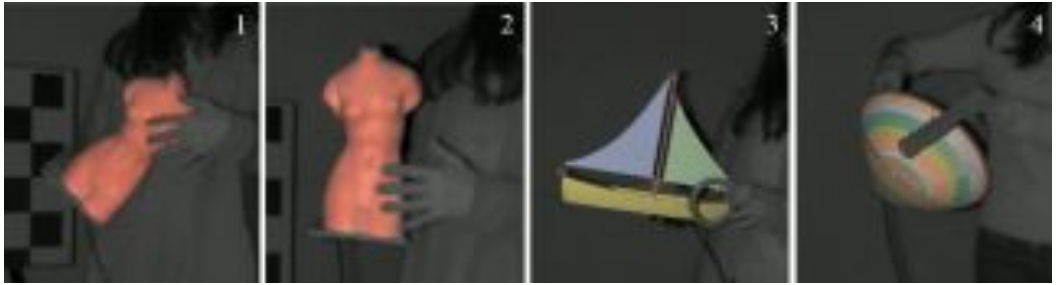
The goal of this project is to develop a projection mapping prototype that projects patient data (eg. CT/MRI scan model) onto patient body in realtime.



Background

Projection Mapping

- turn objects into a display surface for video projection
- 2D/3D object is spatially mapped onto real environment
- PMOMO
  - projection mapping on movable 3D object

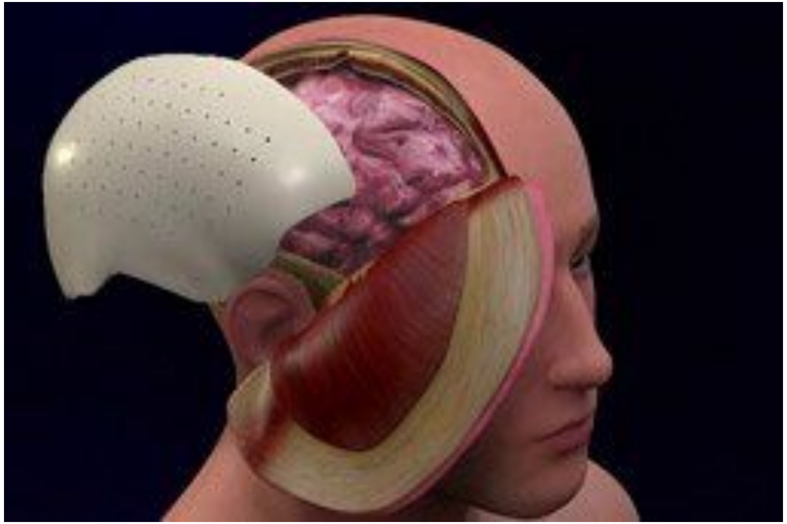


1. Yi Zhou, Shuangjiu Xiao, Ning Tang, Zhiyong Wei, and Xu Chen. 2016. **Pmomo: Projection Mapping on Movable 3D Object**. *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). ACM, New York, NY, USA, 781-790.* DOI: https://doi.org/10.1145/2858036.2858329

Application

Cranioplasty

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

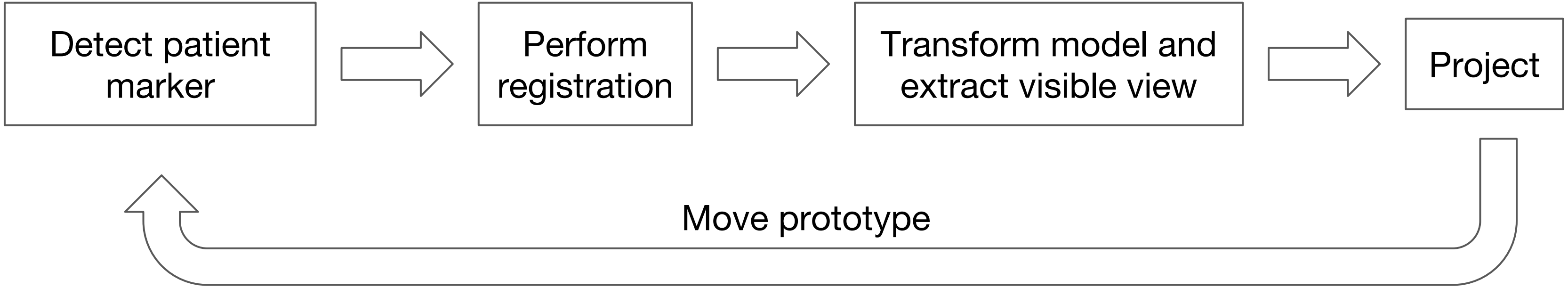


Technical Approach - Workflow

Before Operation

- Calibration of Projector-Camera
- Marker-based Registration setup

During Operation (marker-based)



Technical Approach - Camera-Projector Calibration

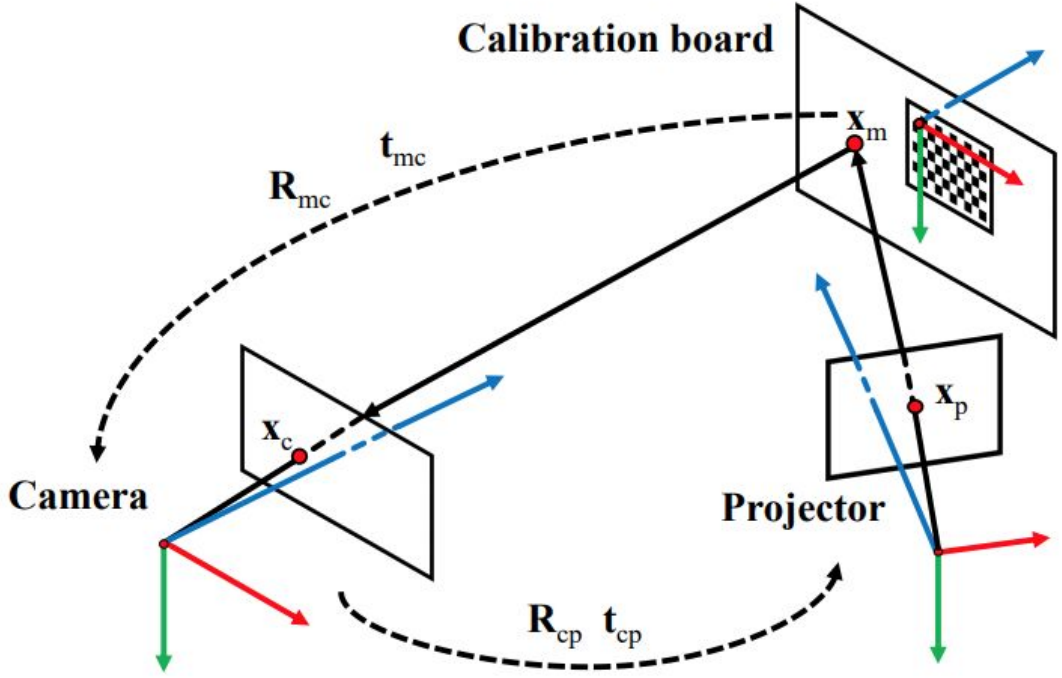
Steps

1. Camera calibration using checkerboard

2. Calculate homography between calibration board pose and camera image plane

3. Undistort structured light nodes and transform to calibration board model space

4. Camera calibration for projector



Bingyao Huang, Samed Ozdemir, Ying Tang, Chunyuan Liao, and Haibin Ling. **A Single-shot-per-pose Camera-Projector Calibration System for Imperfect Planar Targets**. In *Adjunct Proceedings of the IEE International Symposium for Mixed and Augmented Reality.* 2018.

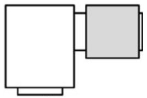
Technical Approach - Marker-based Registration

Steps

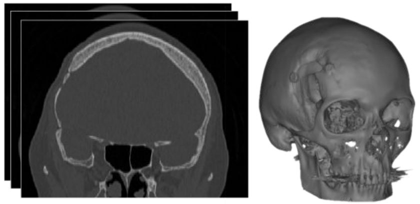
1. Detect markers
2. Pivot calibration
3. Touch anatomical landmarks with pen
4. Record location of each landmark relative to camera
5. Perform initial registration with CT model
6. Calculate location of landmarks relative to patient marker for future registration

Given: RGBD data
IMU camera data

RGBD camera



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



Technical Approach - Markerless Registration

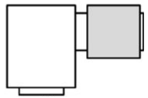
Ideas

1. Register subset of point cloud data with subset of 3D model without any filtering or downsampling

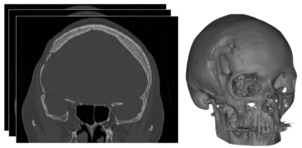
2. Use object tracking with bounding box to constrain depth data to be registered

Given: RGBD data
IMU camera data

RGBD camera



Given: CT scan/model of skull
Model of implant



Deliverables

Minimum:

- Video showing ArUco markers are detected and output of their 3D location
- Window display of aligned points with marker-based registration and text file with output stream of computed transformations

Expected:

- Window display of defect skull augmented with CT model
- Python/C++ source code and documentation along with report of future work and recommendations

Maximum:

- Video of projection mapping also projecting oversize implant on defect skull
- Visualization of point cloud data of defect area overlaid on CT skull model
- Window display of aligned points with markerless registration and text file with output stream of computed transformations

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	Currently have one, may upgrade	Done - Joshua	
Holding mechanism for projector and camera	Built by Joshua	Done	

Dependencies

Dependencies	Solution	Expected Date	Needed by
Construct ArUco markers and marker tool	Build our own using sticker paper and 3D printer from Makerspace (need to be trained)	2/21 - Austin	2/22
CT scan reconstruction software (eg 3D slicer)	Seek advice from Professor Armand and lab mates	2/22 - Austin	3/15
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 - Joshua	3/15
Interface with projector	Online research	3/10 - Austin	3/25

Activity Schedule

	Feb 18	Feb 25	Mar 4	Mar 11	Mar 18	Mar 25	Apr 1	Apr 8	Apr 15	Apr 22	Apr 29
Familiarize myself with software + hardware											
Develop and detect ArUco markers and locations											
Conduct marker-based registration with image data from RealSense camera											
Calibrate projector-camera system											
Construct 3D model from CT scans											
Augment RGB image from Realsense with CT											
Write report, polish documentation											
Project implant to defect skull and gather point cloud data of defect area											
Develop markerless registration											

Milestones

2/24 - Python script to run ArUco marker detection with RealSense

3/10 - Python script for marker-based registration with RealSense and code review by Joshua

3/31 - 3D skull models reconstructed from CT scans

4/14 - Video of projection mapping done on skull model and code review by Joshua

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

Management Plan

- Code stored in GitHub
- Scans/models stored in OneDrive
- Weekly meetings with Professor Armand and Joshua (Tues 10:30 am)
- Additional meetings with Joshua when necessary
  - Or corresponding by email

Reading List

1. Yi Zhou, Shuangjiu Xiao, Ning Tang, Zhiyong Wei, and Xu Chen. 2016. **Pmomo: Projection Mapping on Movable 3D Object.** *In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). ACM, New York, NY, USA, 781-790.* DOI: https://doi.org/10.1145/2858036.2858329
2. Thuong Hoang, Martin, Reinoso, Zaher Joukhadar, Frank Vetere, and David Kelly, 2017. **Augmented Studio: Projection Mapping on Moving Body for Physiotherapy Education.** In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). ACM, New York, NY, USA, 1419-1430*. DOI: https://doi.org/10.1145/3025453.3025860
3. Yuki Morikubo and Naoki Hashimoto. **Marker-less real-time tracking of texture-less 3D objects from a monocular image**. In *Proceedings of SIGGRAPH Asia 2017 Posters (SA '17). ACM, New York, NY, USA.* DOI: https://doi.org/10.1145/3145690.3145695
4. Yuki Morikubo, Eugene San Lorenzo, Daiki Miyazaki, and Naoki Hashimoto. **Tangible projection mapping: dynamic appearance augmenting of objects in hands**. In *Proceedings of SIGGRAPH Asia 2018 Emerging Technologies (SA '18). ACM, New York, NY, USA.* DOI: https://doi.org/10.1145/3275476.3275494
5. J.-P. Tardif, S. Roy, and J. Meunier. **Projector-Based Augmented Reality in Surgery without Calibration**. In *Proceedings of the 25th Annual International Conference of the IEE EMBS (Sept 2003), Cancun, Mexico, 548-551*.
6. Christoph Bichlmeier, Felix Wimmer, Sandro Michael Heining, and Nassir Navab. **Contextual Anatomic Mimesis: Hybrid In-Situ Visualization Method for Improving Multi-Sensory Depth Perception in Medical Augmented Reality**. In *Proc. ISMAR '07. 129-138*.
7. Bingyao Huang, Samed Ozdemir, Ying Tang, Chunyuan Liao, and Haibin Ling. **A Single-shot-per-pose Camera-Projector Calibration System for Imperfect Planar Targets**. In *Adjunct Proceedings of the IEE International Symposium for Mixed and Augmented Reality.* 2018.

Any Questions?