Projection Mapping in Surgery

Group 10

Members:
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Mentors:
Professor Armand
Joshua Liu
Objective

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

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)

- Detect patient marker
- Perform registration
- Transform model and extract visible view
- Project
- Move prototype
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

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

Given: RGBD data

IMU camera data

RGBD camera
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

- Given: CT scan/model of skull
- Model of implant

- RGBD camera
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
<table>
<thead>
<tr>
<th>Dependencies</th>
<th>Solution</th>
<th>Expected Date</th>
<th>Needed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>Personal laptop</td>
<td>Done</td>
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<tr>
<td>Access to BIGGS Lab</td>
<td>Asking Professor Armand</td>
<td>Done</td>
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<tr>
<td>Access to Intel RealSense SDK 2.0</td>
<td>Downloaded from website</td>
<td>Done</td>
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<tr>
<td>Access to Intel RealSense Camera</td>
<td>Bought</td>
<td>Done</td>
<td>Joshua</td>
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<tr>
<td>Access to Open3D library and OpenCV</td>
<td>Installed</td>
<td>Done</td>
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<tr>
<td>Access to projector</td>
<td>Currently have one, may upgrade</td>
<td>Done</td>
<td>Joshua</td>
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<tr>
<td>Holding mechanism for projector and camera</td>
<td>Built by Joshua</td>
<td>Done</td>
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<tr>
<td>Dependencies</td>
<td>Solution</td>
<td>Expected Date</td>
<td>Needed by</td>
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<tr>
<td>Construct ArUco markers and marker tool</td>
<td>Build our own using sticker paper and 3D printer from Makerspace (need to be trained)</td>
<td>2/21 - Austin</td>
<td>2/22</td>
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<tr>
<td>CT scan reconstruction software (eg 3D slicer)</td>
<td>Seek advice from Professor Armand and lab mates</td>
<td>2/22 - Austin</td>
<td>3/15</td>
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<tr>
<td>Obtain data (scans/models of skulls)</td>
<td>Currently have molds, need corresponding scans. Currently using heart model and 3D-reconstructed scan from structure sensor</td>
<td>3/10 - Joshua</td>
<td>3/15</td>
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<tr>
<td>Interface with projector</td>
<td>Online research</td>
<td>3/10 - Austin</td>
<td>3/25</td>
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<td>Activity</td>
<td>Feb 18</td>
<td>Feb 25</td>
<td>Mar 4</td>
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<tr>
<td>Familiarize myself with software + hardware</td>
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<td>Develop and detect ArUco markers and locations</td>
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<td>Conduct marker-based registration with image data from RealSense camera</td>
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<td>Calibrate projector-camera system</td>
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<tr>
<td>Construct 3D model from CT scans</td>
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<td>Augment RGB image from Realsense with CT</td>
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<td>Write report, polish documentation</td>
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<td>Project implant to defect skull and gather point cloud data of defect area</td>
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<td>Develop markerless registration</td>
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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


Any Questions?