DVRK stereo camera calibration and model registration

-Checkpoint Presentation-

Group 12: Peter Ahn and Mengze Xu
Mentors: Preetham Chalasani and Anton Deguet
April 6, 2017
Background

• Goal: Register surfaces to the robot (Patient Side Manipulator, PSM)

• Current Method: Move robot to touch the surface

• What we want to do: Using calibrated stereo camera to substitute touching
Background

- Complete Hand-Eye Calibration
- Detect and register phantom surface to PSM
- Desired accuracy in several millimeters
Current Deliverables

Minimum
- Hand-Eye Calibration and Accuracy Test
- [Completed on March 31]

Expected
- Predefined Surface Detection and Accuracy Test
- [In Progress]

Maximum
- Unknown Surface Detection and Accuracy Test
- [Not Started]
Progress – Hand Eye Calibration

• A: Marker pose to camera frame (ArUco package)

• X: Marker pose to end effector

• B: End effector pose to PSM base (DVRK API)

• Z: Camera Pose to PSM Base
Progress – Hand Eye Calibration Setup

AX = ZB
Progress – Data Collection Process

1. Wait for dVRK to be ready
2. Collect N set of Data from current pose
3. Check Data Variance
   - If $\text{std} < e$, Save Average Value of the Data
   - If $\text{std} > e$, Discard Data
4. Move to a new pose

In practice, $e$ is a key parameter.
Calibration Consistency

<table>
<thead>
<tr>
<th>Consistency of Same X and Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX/rad</td>
</tr>
<tr>
<td>e = 0.01</td>
</tr>
<tr>
<td>e = 0.001</td>
</tr>
</tbody>
</table>

- Result of e = 0.001 is not bad, but it’s very hard to collect data
- e = 0.003 is used later
- Convenience vs. Better Accuracy
Calibration Consistency

<table>
<thead>
<tr>
<th>Consistency of Same X with different Y</th>
<th>Error</th>
<th>RX/rad</th>
<th>tX/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>e = 0.003</td>
<td>0.054</td>
<td>10.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consistency of Same Y with different X</th>
<th>Error</th>
<th>RY/rad</th>
<th>tY/mm</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>e = 0.003</td>
<td>0.025</td>
<td>3.1</td>
</tr>
</tbody>
</table>
• For the case of same Y, we move the adapter (X) for about 12mm and the change of tX is 12.7 mm
Calibration Accuracy

- error = [-0.4, 2.8, -1.3] mm
- $||\text{error}|| = 3.1$ mm
Phantom Detection Accuracy (via Touching)

- $\text{error} = [34.6, 55.7, -13.7]$ mm
- $|| \text{error} || = 67$ mm
- Mainly due to the poor result of depth information
Result of Edge Detection
Result of Edge Detection

RGB Image
Result of Edge Detection

HSV Image (color threshold to eliminate background)
Result of Edge Detection

Converted back to RGB Image
Result of Edge Detection

Sectioned Binary Image
Result of Edge Detection

Edge Image (Sobel Filter)
Result of Edge Detection

Line Image (Hough Transform)
Technical Approach Changed

**Expected Deliverable**

- Detect the edge of phantom with single stereo camera and register with model
- Set up two R200 RealSense camera to build a stereo camera system and detect edge points

**Maximum Deliverable**

- Find correspond surface points in two camera
Future Work

• Set up two calibrated camera systems

• Complete ICP algorithm for detected edge points and test for accuracy

• Complete algorithm to find correspond points to estimate point cloud of unknown surface
# Updated Dependencies

<table>
<thead>
<tr>
<th>Dependencies</th>
<th>How to Resolve</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>dVRK System</td>
<td>Access to LCSR Lab</td>
<td>Resolved</td>
</tr>
<tr>
<td>Stereo / Depth Camera</td>
<td>Access to LCSR Lab</td>
<td>Resolved</td>
</tr>
<tr>
<td>Two R200 Realsense Cameras</td>
<td>Find a way to connect two stereo cameras into one USB hub</td>
<td>Pending</td>
</tr>
<tr>
<td>3D Printer</td>
<td>Access to 3D Printer Room</td>
<td>Resolved (Peter)</td>
</tr>
<tr>
<td>Opaque Phantom</td>
<td>Develop another phantom with different coloring dye</td>
<td>Pending [Not immediate concern]</td>
</tr>
<tr>
<td>ROS</td>
<td>Open source codes</td>
<td>Resolved</td>
</tr>
<tr>
<td>ArUco / OpenCV Package</td>
<td>Open source codes</td>
<td>Resolved</td>
</tr>
<tr>
<td>Solidworks (CAD)</td>
<td>WSE IT website</td>
<td>Resolved (Peter)</td>
</tr>
<tr>
<td>MATLAB</td>
<td>WSE IT website</td>
<td>Resolved</td>
</tr>
</tbody>
</table>
### Updated Timeline

<table>
<thead>
<tr>
<th>Plan Date</th>
<th>Progress</th>
<th>Actual Complete Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/18</td>
<td>Finish proposal and presentation</td>
<td>2/18</td>
</tr>
<tr>
<td>2/25</td>
<td>Prepare hardware and environment</td>
<td>3/05</td>
</tr>
<tr>
<td>3/11</td>
<td>Complete codes for hand-eye calibration</td>
<td>3/14</td>
</tr>
<tr>
<td>3/18</td>
<td>Test codes and estimate accuracy</td>
<td>3/31</td>
</tr>
<tr>
<td>4/01</td>
<td>Complete contour detection</td>
<td>3/25</td>
</tr>
<tr>
<td>4/08</td>
<td>Set up 2 camera system and calibrate</td>
<td></td>
</tr>
<tr>
<td>4/11</td>
<td>Test codes and estimate accuracy for expected deliverables</td>
<td></td>
</tr>
<tr>
<td>4/15</td>
<td>Complete codes for finding correspond points</td>
<td></td>
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<tr>
<td>4/22</td>
<td>Test codes and estimate accuracy for expected deliverables</td>
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<tr>
<td></td>
<td>Leave time for other methods</td>
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<tr>
<td>Minimum</td>
<td>12-Feb</td>
<td>19-Feb</td>
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*Final Reports*

*Final Presentations*
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<td>* Extracting usable depth information from the 3D camera</td>
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<td>* Installing/Using ROS packages for dVRK and RealSense Camera</td>
<td>* Detecting the boundaries of the surface</td>
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<td>* Developing Camera Mount</td>
<td>* Detecting the features of the surface</td>
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### Activity Details

- **12-Feb**: Preparing Closed Proposal and Presentation
- **19-Feb**: Preparing programming and hardware environment
- **26-Feb**: * Installing/Using ROS packages for dVRK and RealSense Camera
- **5-Mar**: * Developing Camera Mount
- **12-Mar**: Preparing ArUco Marker and Marker Adaptor
- **19-Mar**: * Measuring and developing the CAD model of the Adaptor
- **26-Mar**: * 3D Printing the Marker Adaptor
- **2-Apr**: Coding and testing (with ArUco Marker)
- **9-Apr**: Developing and testing Hand-Eye Calibration Codes
- **16-Apr**: Expected
- **23-Apr**: Expected
- **30-Apr**: Expected
- **7-May**: Expected
- **14-May**: Expected

### Timeline

- **Minimum**
  - 12-Feb: Preparing Closed Proposal and Presentation
  - 19-Feb: Preparing programming and hardware environment
  - 26-Feb: Installing/Using ROS packages for dVRK and RealSense Camera
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  - 2-Apr: Coding and testing (with ArUco Marker)
  - 9-Apr: Developing and testing Hand-Eye Calibration Codes

- **Expected**
  - 12-Feb: Researching methods for estimating contour of a surface
  - 19-Feb: Coding using existing libraries (MATLAB)
  - 26-Feb: Detecting the boundaries of the surface
  - 5-Mar: Detecting the features of the surface
  - 12-Mar: Testing the codes with the given phantom
  - 19-Mar: Modifying the codes

- **Maximum**
  - 12-Feb: Exploring algorithms to detect unknown surfaces
  - 19-Feb: Extracting usable depth information from the 3D camera
  - 26-Feb: Testing the codes with the given phantom

### Final Reports
- 16-Apr
- 30-Apr
- 7-May
- 14-May

### Final Presentations
- 16-Apr
- 30-Apr
- 7-May
- 14-May
### Updated Timeline

#### Minimum

- Preparing Closed Proposal and Presentation
- Preparing programming and hardware environment
- * Installing/Using ROS packages for dVRK and RealSense Camera
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- Coding and testing (with ArUco Marker)
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#### Expected

- Researching methods for estimating contour of a surface
- Coding using existing libraries (MATLAB)
- * Detecting the boundaries of the surface
- * Detecting the features of the surface
- Testing the codes with the given phantom
- Modifying the codes

#### Maximum

- Exploring algorithms to detect unknown surfaces
- * Extracting usable depth information from the 3D camera
- Testing the codes with the given phantom

*Final Reports*

*Final Presentations*