Robot Calibration

Niharika Arora

10.08.2016
Overview
Robot Calibration

- Robot calibration is the process of determining the actual values of kinematic parameters of an industrial robot.
- Why does it matter?
  - Design tolerances
  - Variances in assembly
  - Other imperfections
Camera Calibration

Intrinsic Calibration:
- Estimating focal length, optical center.

Extrinsic Calibration:
- Estimation of rotation and translation of the camera in the world
Robot Sensor - Joint Calibration

- Calibration of the sensors and the kinematic chains
Existing Systems

Challenges of existing calibration systems:
• An inability to generalize across sensor and platforms.
• Slow calibration times.
• Lack of robustness.
**fetch calibration**

- **fetch calibration** is a hand-eye calibration system.
- Advantages
  - Fast, less than 3 minutes
  - Repeatable results
  - Robust
Robot calibration

Two phases:
1. Capture phase:
   • Capture data about calibration targets
2. Calibration phase:
   • Optimizing parameters of the system
Capture

- The robot moves through a set of predefined poses.
- We have three finders available in the package:
  - Led finder
  - Checkerboard finder
  - Ground plane finder
Led Finder

- Looks for the four calibration LEDs
- Simple thresholding algorithm
Checkerboard Finder

- Detects the position of each of the corner points in the checkerboard.
Ground Plane Finder

- Finds the ‘ground’.
- Calibrate the the pitch of camera mounted on a freight.
Optimization

- Use CERES optimizer
  - solve the re-projection error minimization problem.
- CERES
  - problem
  - free parameters
  - error blocks
Residuals for the finders

- **LED detector** - led points reprojected into the base link
- **Checkerboard calibration** - more points
- **Ground plane method** - only Z
## Results

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>FETCH1</th>
<th>FETCH2</th>
<th>FETCH3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Pan Joint</td>
<td>5.0320e-06</td>
<td>5.2546e-05</td>
<td>7.8241e-06</td>
</tr>
<tr>
<td>Shoulder Lift Joint</td>
<td>1.3376e-07</td>
<td>1.5427e-04</td>
<td>1.0073e-07</td>
</tr>
<tr>
<td>Upperarm Roll Joint</td>
<td>6.7229e-08</td>
<td>3.3959e-05</td>
<td>1.2355e-07</td>
</tr>
<tr>
<td>Elbow flex Joint</td>
<td>2.8776e-08</td>
<td>1.4416e-05</td>
<td>3.7454e-08</td>
</tr>
<tr>
<td>Forearm Roll Joint</td>
<td>2.6495e-07</td>
<td>5.2288e-07</td>
<td>1.5986e-07</td>
</tr>
<tr>
<td>Wrist Flex Joint</td>
<td>2.5105e-08</td>
<td>3.7200e-05</td>
<td>5.1110e-08</td>
</tr>
<tr>
<td>Wrist Roll Joint</td>
<td>9.1720e-07</td>
<td>2.9987e-06</td>
<td>1.1503e-06</td>
</tr>
<tr>
<td>Head Tilt Joint</td>
<td>1.8179e-07</td>
<td>2.3881e-05</td>
<td>2.0002e-07</td>
</tr>
<tr>
<td>Focal Length fx</td>
<td>2.2515e-05</td>
<td>6.8372e-04</td>
<td>2.1232e-05</td>
</tr>
<tr>
<td>Focal Length fy</td>
<td>2.6757e-05</td>
<td>8.6287e-04</td>
<td>2.0084e-05</td>
</tr>
<tr>
<td>Center cx</td>
<td>1.8679e-06</td>
<td>5.6485e-06</td>
<td>1.4719e-06</td>
</tr>
<tr>
<td>Center cy</td>
<td>1.4155e-05</td>
<td>8.7725e-05</td>
<td>1.7352e-05</td>
</tr>
<tr>
<td>Z scaling</td>
<td>8.6054e-06</td>
<td>1.9849e-07</td>
<td>1.5411e-06</td>
</tr>
<tr>
<td>Z offset</td>
<td>2.8598e-07</td>
<td>6.9011e-06</td>
<td>9.3637e-06</td>
</tr>
<tr>
<td>Camera joint x</td>
<td>9.4526e-06</td>
<td>6.5708e-05</td>
<td>7.6847e-06</td>
</tr>
<tr>
<td>Camera joint y</td>
<td>1.7924e-07</td>
<td>6.5242e-07</td>
<td>3.4685e-08</td>
</tr>
<tr>
<td>Camera joint z</td>
<td>3.6800e-07</td>
<td>7.5355e-08</td>
<td>5.6251e-07</td>
</tr>
<tr>
<td>Camera joint a</td>
<td>5.3193e-07</td>
<td>9.7933e-06</td>
<td>4.4715e-07</td>
</tr>
<tr>
<td>Camera joint b</td>
<td>1.0078e-07</td>
<td>2.8095e-05</td>
<td>1.4035e-07</td>
</tr>
<tr>
<td>Camera joint c</td>
<td>5.8759e-07</td>
<td>1.5675e-06</td>
<td>5.4968e-07</td>
</tr>
<tr>
<td>head pan joint x</td>
<td>1.0595e-08</td>
<td>6.0103e-06</td>
<td>9.9500e-09</td>
</tr>
<tr>
<td>head pan joint y</td>
<td>7.6362e-08</td>
<td>8.2762e-08</td>
<td>1.3644e-07</td>
</tr>
<tr>
<td>head pan joint z</td>
<td>1.2288e-08</td>
<td>1.1491e-05</td>
<td>2.1953e-08</td>
</tr>
<tr>
<td>head pan joint a</td>
<td>1.4428e-08</td>
<td>1.0040e-07</td>
<td>5.4682e-08</td>
</tr>
<tr>
<td>head pan joint b</td>
<td>7.2910e-08</td>
<td>3.5083e-07</td>
<td>1.6987e-08</td>
</tr>
<tr>
<td>head pan joint c</td>
<td>3.3001e-06</td>
<td>1.6960e-05</td>
<td>9.5201e-06</td>
</tr>
</tbody>
</table>
Result of Calibration
Calibrating the Freight!!

- Time of flight camera
- Calibrate the pitch of the camera
- Ground Plane finder
Final Remarks

- *fetch* calibration is awesome.

Links

- https://github.com/fetchrobotics/fetch_ros
- https://github.com/mikeferguson/robot_calibration
- http://docs.fetchrobotics.com
Questions?