dVRK Stereo Camera Model Registration

Computer Integrated Surgery II
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Introduction

- Current method for registering unknown surface to the dVRK coordinate frame:
  - Moving the tool tip of the PSM to touch the desired surface.
- As a solution, we developed software package that processes stereo RGB images to register the phantom model to the PSM.
- New registration method will expedite the research and surgical processes that need the target surface registered to the robot.

The Problem

- Every time the phantom moves, surface registration is required
- Some cases (like organ surfaces), touching is unfeasible
- Manual manipulation of the tool tip has low accuracy especially on elastic surfaces
- Thus, a new non-tactile surface registration method is vital for the success and accuracy of the dVRK related procedure

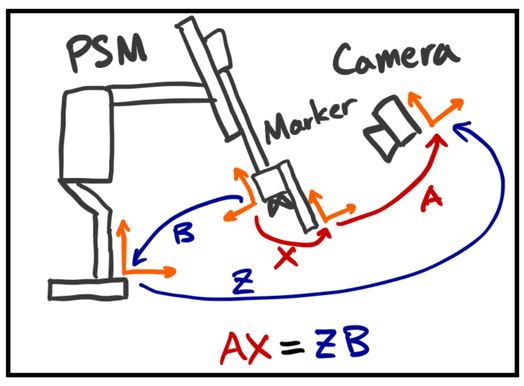

Figure 1: Simplified Representation of Setup (AX = ZB Hand-Eye Calibration)

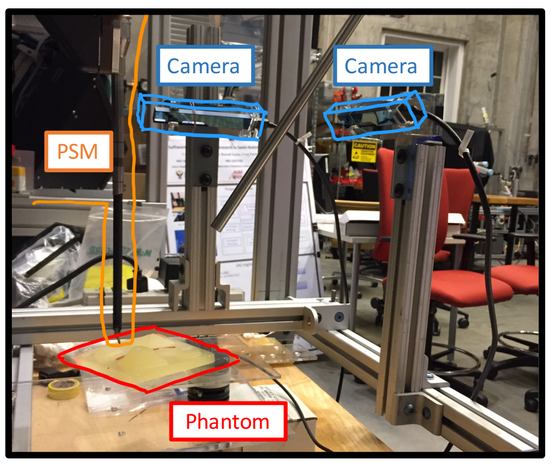

Figure 2: Physical Setup

The Solution

- Stereo camera system:
  - Two Intel RealSense cameras oriented perpendicular to each other
- Hand-Eye Calibrations (AX = ZB):
  - Register static cameras to PSM
  - Using ArUco Marker Tracking

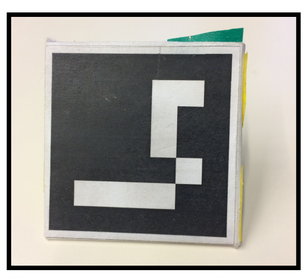

Figure 3: ArUco Marker

- Corner Detection:
  - Converted the difference between boundary point and the centroid of the surface shape into polar coordinates and used as boundary signatures
  - Local maxima of boundary signature = corner points
- Register corner point to robot frame:
  - Least square problem of linear system of camera pose and parameters and corner coordinates

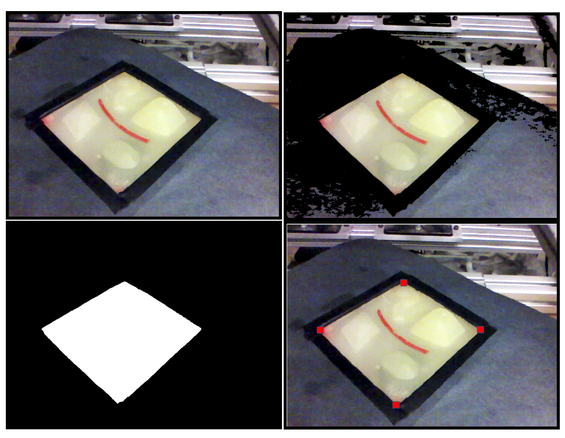

Figure 4: Phantom Corner Detection Process (Top Left: input image; top right: set surrounding background to zero; bottom left: isolate the surface boundaries; bottom right: derived four corners)

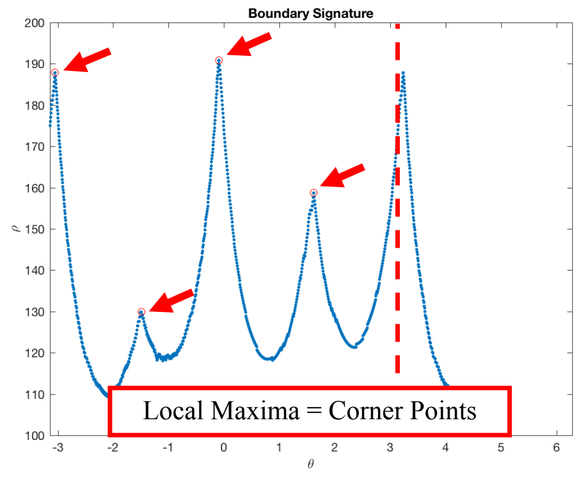

Figure 5: Boundary Signature (red arrows: corner point in polar coordinates)

Outcomes and Results

- The developed stereo camera system allows dVRK system to register objects to robot coordinate frame
  - Average Norm of Error in Hand-Eye Calibration: [Table 1]
  - Mean Error in Corner Detection = 2.5 px = 0.75 mm
  - **Average Norm of Overall Error = 5.1 mm**
- For particular camera poses, the overall error reduced significantly
  - **Average Norm of Overall Error = 2.5 mm**

	Rotation [rad]	Translation [mm]
Camera 1	0.025	2.7
Camera 2	0.023	3.1

Table 1: Hand-Eye Calibration (Average norm of error from 10 different robot poses)

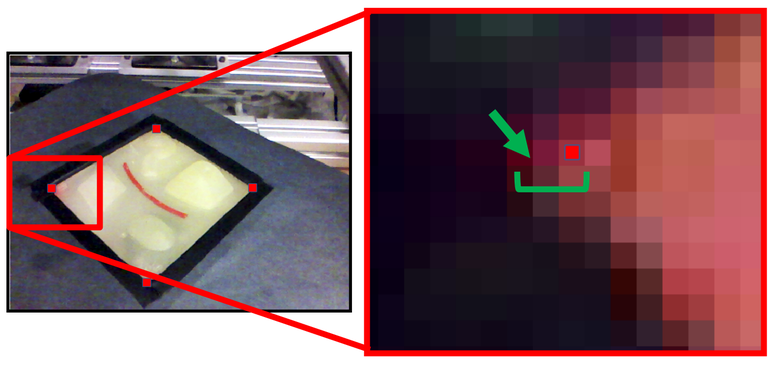

Figure 6: Example error in Corner Detection

Future Work

- Use optical marker instead of AR marker and use better camera to reduce the error to 2mm.
- Detecting the surface features of the phantom (potentially creating a 3D point cloud).
- Integrate the functions written in MATLAB into ROS package
- Develop sensor fusion for more accurate results

Lessons Learned

- Sometimes, we have to sacrifice robustness for the solution to work
- Learned how to analyze and reduce the error of a coupled system

Credits

- Joonghyun Ahn: Camera Mount Design and Development, Development of AR Marker, Corner Detection Function, Phantom Model Modifications
- Mengze Xu: Hand-Eye Calibration, Stereo Camera Calibration, Accuracy Testing & Error Evaluation

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