Software for an Intra-Operative “Kinect” with a Flexible Endoscope

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Relevance

- “Depth cameras” have spurred the popularity and approachability of real-time 3D reconstruction
- 3D reconstruction based on images captured by endoscope
- Small laser allows for structured light approach with endoscope

http://www.zaghimd.com/sleep-endoscopy
http://jiakaizhang.com/project/real-time-3d-reconstruction/
Technical Approach

1) Calibration of laser-camera setup
   a. Rigidly affix laser to camera
   b. Obtain laser pattern template from manufacturer OR calibrate on flat surface
   c. Calculate disparity/depth maps of simple objects

2) 3D reconstruction of objects
   a. Reconstruction of simple objects (cubes, spheres)
   b. Reconstruction of complex objects (model of head with CT ground truth)

3) Camera tracking and reconstruction
   a. Track motion of camera relative to assumed static scene

Data collection, testing, and code review

Future work with endoscopes and real patients...

(using SLAM algorithm)
Technical Approach - Calibration

● Training
  ○ Collect “training” images of laser pattern on normal plane at known distances ranging from 12cm to 19cm
  ○ Identify each laser point in all training images
  ○ Determine how center point and radius of each laser point varies with distance of plane

● Testing
  ○ For new “test” images, identify each laser point then consider center point location and radius to estimate distance (linearly interpolate between training image distances)
Mechanical Fixation

Current Setup

Final Setup
Camera Calibration & Distortion Correction

Original

Distortion Corrected
Segmenting Laser Points

Original

Labeled Laser Points
Matching Laser Points

15cm

12cm
Initial Results for X Coordinate

\[ y = -11.929x + 1125.1 \]
\[ R^2 = 0.9359 \]

\[ y = -13.857x + 969.54 \]
\[ R^2 = 0.94553 \]

\[ y = -13.857x + 753.04 \]
\[ R^2 = 0.91381 \]
Initial Results for Y Coordinate

\[ y = 3.8452x + 660.27 \]
\[ R^2 = 0.91476 \]

\[ y = 1.7262x + 497.12 \]
\[ R^2 = 0.94185 \]

\[ y = 1.5357x + 295.07 \]
\[ R^2 = 0.72368 \]
Calibration Testing Plan

- Collect “test” images at known distances and verify that our distance estimate is correct for:
  - Normal plane
  - Irregular surface
  - In varying lighting conditions
  - Against red background
Planned Approach for 3D Reconstruction

- Need to move camera to collect images for 3D reconstruction
  - Need many images because of sparse laser pattern
- SLAM (simultaneous localization and mapping)
  - BreezySLAM for MATLAB
- Test on simple and complex objects
Updated Deliverables

- **Minimum**
  - Rigid fixation method of camera to laser
  - Template for laser pattern in appropriate coordinates relative to camera
  - Code to compute depth map for camera’s field of view**

- **Expected**
  - Code to create 3D reconstruction of simple objects and track camera movement relative to static scene**

- **Maximum**
  - Code to create 3D reconstruction of complex objects and track camera movement relative to static scene**

**Includes testing to verify mm accuracy
Updated Timeline

- Rigid Fixation of Camera and Laser
- Develop Calibration Code
- Collect Laser Pattern Data
- Create Testing Setup for Calibration
- Develop Testing Scripts for Calibration Code
- Collect Data to Test Calibration Accuracy
- Develop 3D Reconstruction Code
- Plan Testing for 3D Reconstruction
- Collect Data to Test Reconstruction Accuracy
- Develop Camera Tracking Code
- Create Testing Setup for Camera Tracking
- Collect Data to Test Camera Tracking
Obstacles

- Positioning of laser relative to camera and camera parameter settings
  - → Resolved
- Laser pattern dots detected are not always unique
  - Need efficient way to determine if MSER regions are overlapping significantly
- Matching laser pattern dots
  - Sparse laser pattern precludes window matching, need to match individual laser points
  - Radius varies with distance so cross-correlation ineffective
  - → Identify laser pattern dot by position relative to rest of pattern
## Dependencies

<table>
<thead>
<tr>
<th>Dependency</th>
<th>Plan for Resolving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtaining Tae Soo Kim’s prior work</td>
<td>Resolved</td>
</tr>
<tr>
<td>Obtaining calibration code</td>
<td>Not needed</td>
</tr>
<tr>
<td>Reliable fixation method for camera and laser</td>
<td>Will be resolved by 4/12</td>
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<tr>
<td>SLAM depends on calibration</td>
<td>Calibration code almost complete</td>
</tr>
<tr>
<td>Development of testing setup</td>
<td>Work with Dr. Taylor</td>
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</tbody>
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Questions?