Software for an Intra-Operative "Kinect"

Computer Integrated Surgery II

Spring 2017

Shohini Ghosh and Elli Tian

Mentors: Dr. Austin Reiter and Dr. Russell Taylor

Laboratory for Computational Sensing + Robotics

Johns Hopkins University

Introduction

- We have developed portable software to do 3D reconstruction based on a structured light approach, using a color USB camera and a laser fiber that generates a pseudo-random pattern of green dots.
- This software can eventually be adapted to work with the laser fiber inserted down the working channel of a flexible endoscope, and can assist with visualization in the tight spaces imaged during an endoscopy.

The Problem

- Endoscopy is normally limited by the geometrically distorted view of the operating site that a surgeon is able to see with traditional imaging techniques.
- A structured light approach to 3D reconstruction similar to that used by the Microsoft Kinect can address this issue. A projected light pattern can create feature points on tissue where there were previously no distinguishable features.

The Solution

- Camera used: Chameleon 1.3 MP Color USB 2.0 with a Fujinon varifocal lens.
- Laser: manufactured by 3Dintegrated; emits a 520nm (green) light at 50mW w/ approx. 4 dots/cm^2.
- Camera calibration: checkerboard calibration
- Camera-laser calibration: lookup table built relating (x,y) coordinates of dots detected with MSER across images of varying distances
- 3D reconstruction: computed (x,y,z) coordinates for detected dots using lookup table, distance, focal length, and principal point
- Finding dots in realistic setting: evaluated precision and accuracy of SIFT and MSER by counting true positives, false positives, and false negatives projected onto simulated setting (ham)

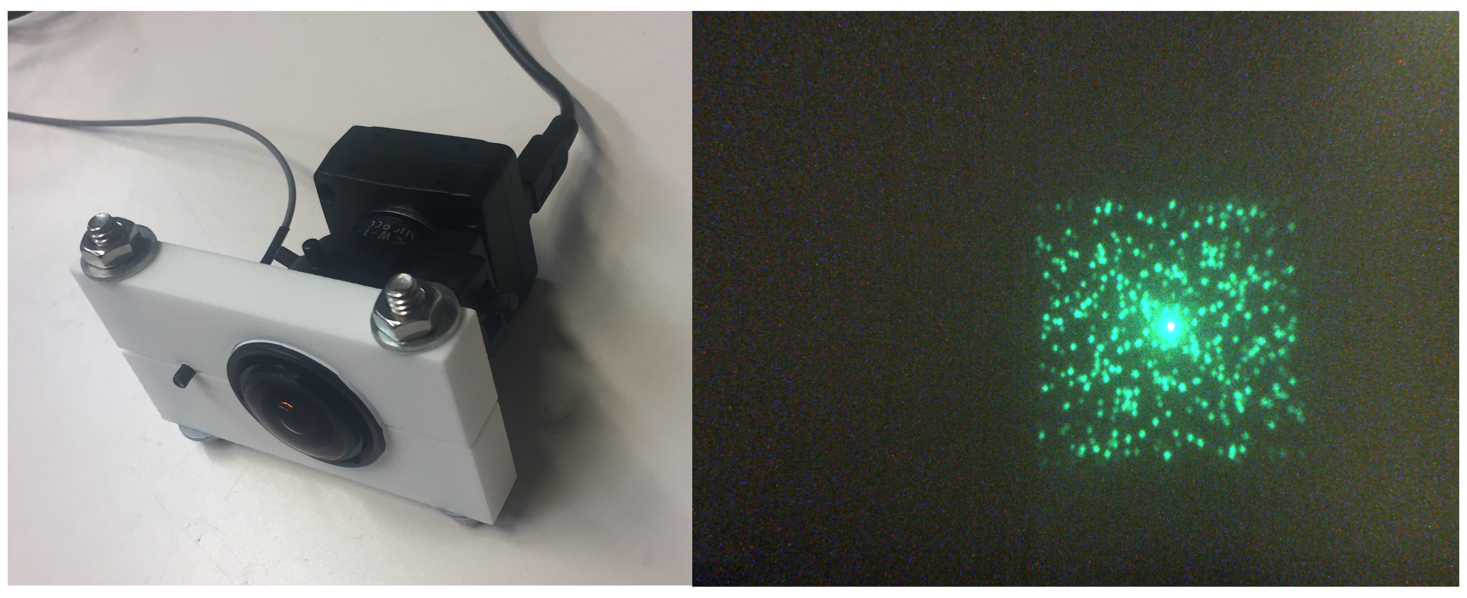

Figure 2. The physical camera-laser setup (left) and the laser pattern projected onto a flat surface 141mm from focal point of the camera (right).

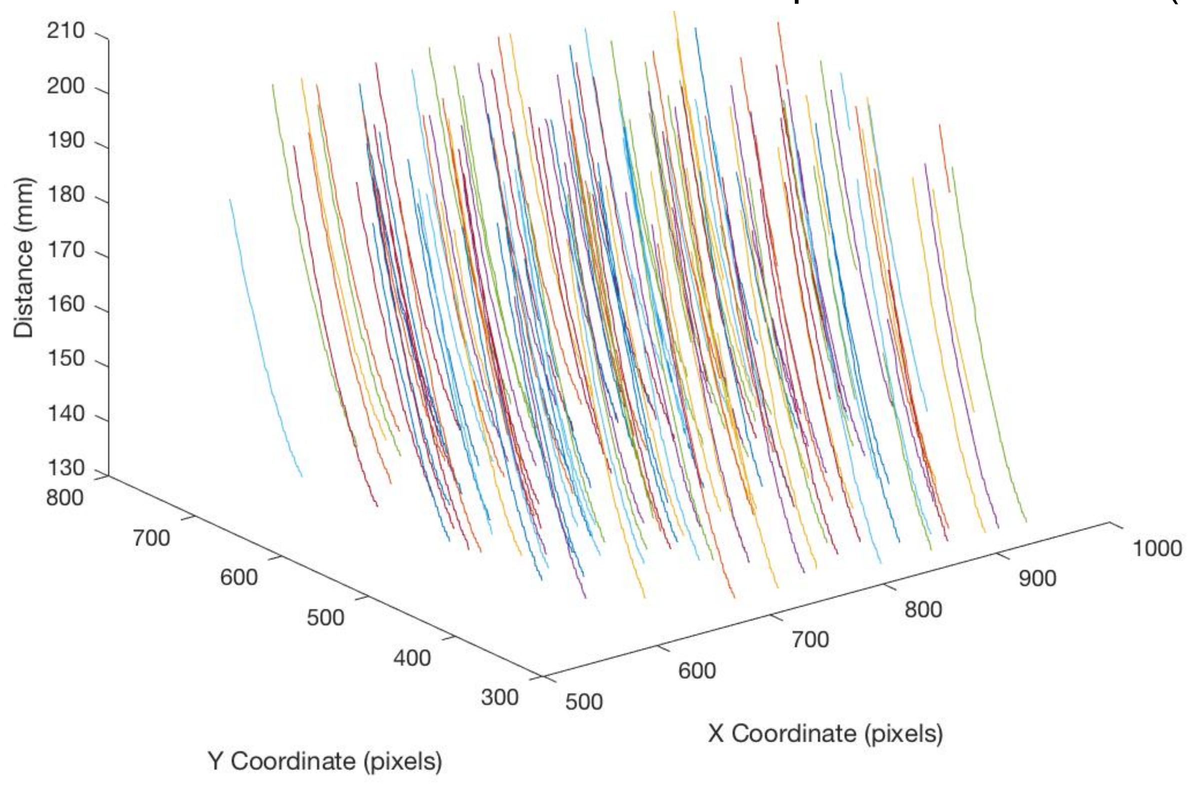

Figure 3. Plot of (x,y) pixel coordinates and distance for training data obtained from one data set. Each line represents single dot in laser pattern.

Outcomes and Results

- 3D reconstruction:
  - Percent of dots matched within 2mm of real distance:
    - 97% on flat plane with data set 1
    - 70% on flat plane with data set 2
    - 73% on simple step of height 12mm (data set 1)
    - 68% on cylinder with radius 80mm (data set 1)
  - Overall system performance limited by accuracy of dot detection and identification

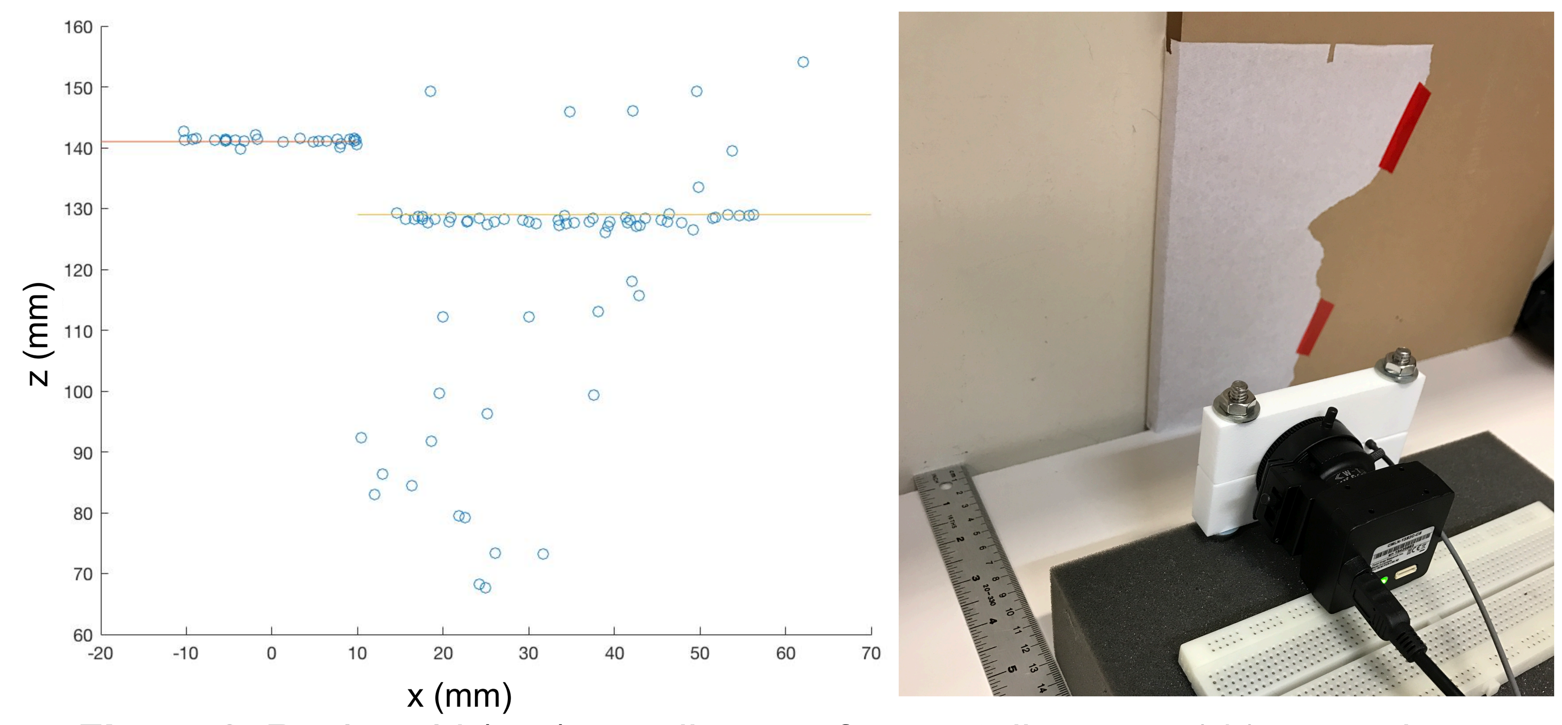

Figure 3. Real world (x, z) coordinates of step at distances 141mm and 129mm (left) and image of physical setup (right).

- Finding dots in realistic setting:
  - MSER was effective and accurate for simple reconstructions, but with time and space optimizations SIFT would be a better choice for real-life application

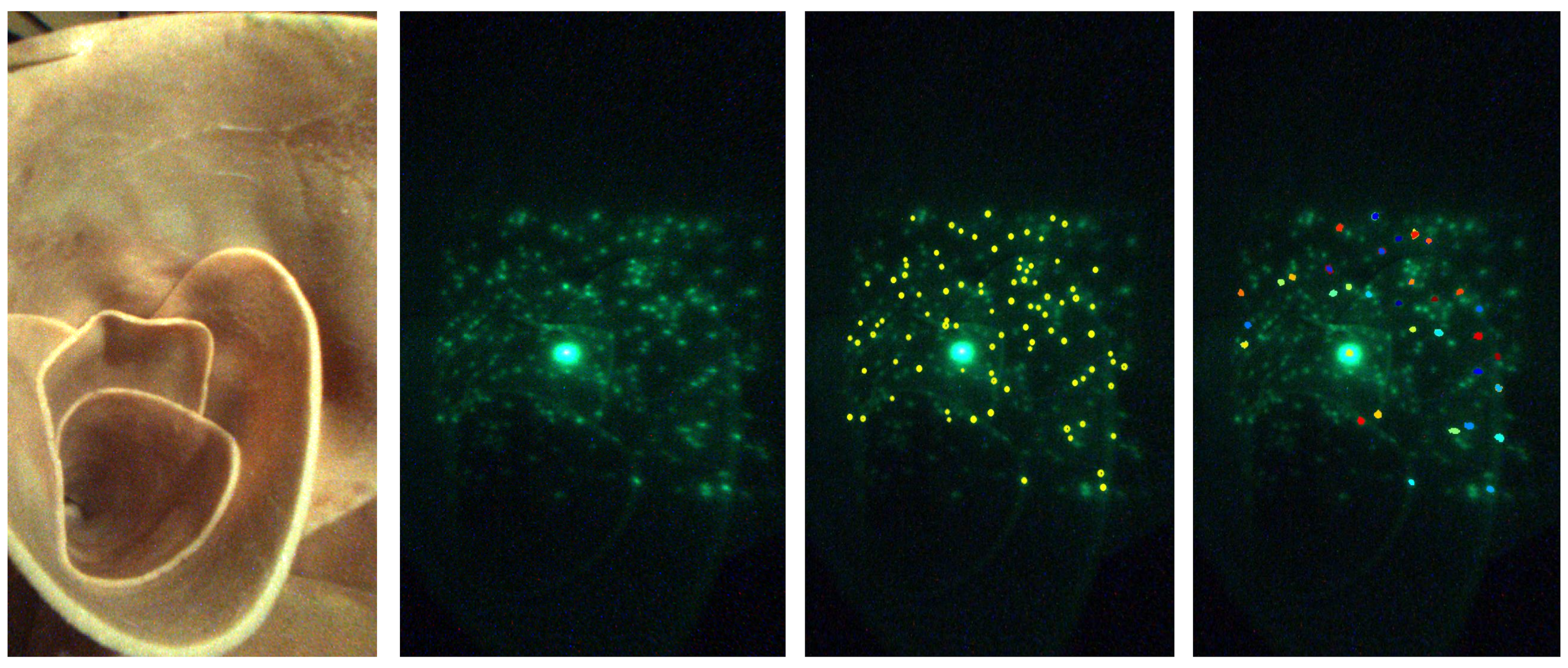

Figure 4. L to R: testing setup with ham, laser pattern on ham setup, detected SIFT features, detected MSER features. Images are cropped.

Future Work

- Increasing accuracy of dot detection algorithms with thresholding, larger range of workable distances, etc.
- Hardware adjustments (e.g. dot pattern with higher density, automatically adjusting aperture)
- Integration with SLAM for real-time reconstruction/tracking
- Adaptation to work with laser fiber down working channel of endoscope

Lessons Learned

- Accurate camera-laser calibration is crucial to accurate 3D reconstruction
- Need way to quickly determine appropriate thresholds in order to refine the results for a variety of environmental conditions

Credits

- Elli: mechanical setup, dot detection (SIFT), dynamic 3D reconstruction (SLAM)
- Shohini: mechanical setup, dot detection (MSER), static 3D reconstruction

Acknowledgements

- Thank you to Dr. Reiter, Dr. Taylor, and the LCSR for their guidance and support through this project.