LABORATORY FOR Computational Sensing + Robotics

JOHNS HOPKINS WHITING SCHOOL of ENGINEERING

Seminar Presentation

Software for an “Intraoperative Kinect”

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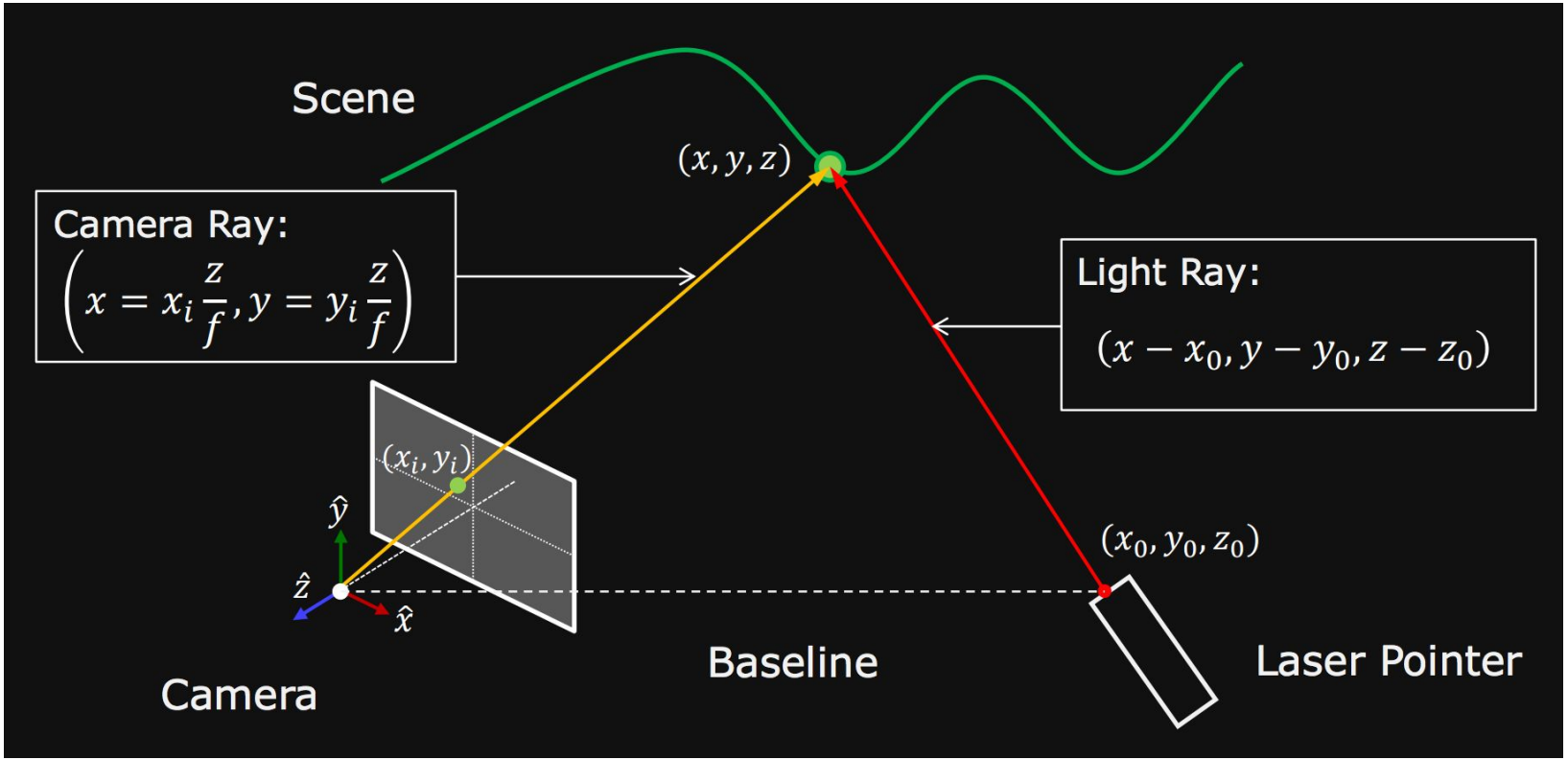
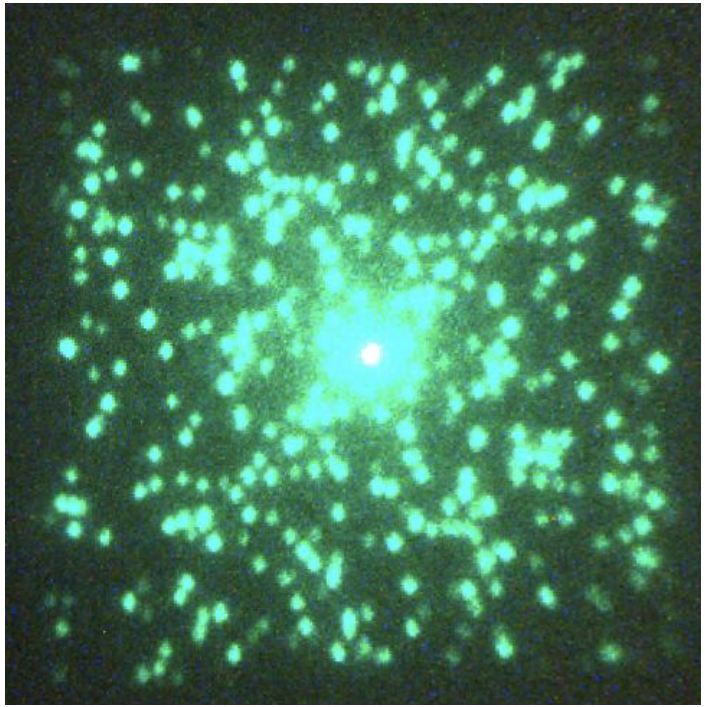
3D Reconstruction for Endoscopy

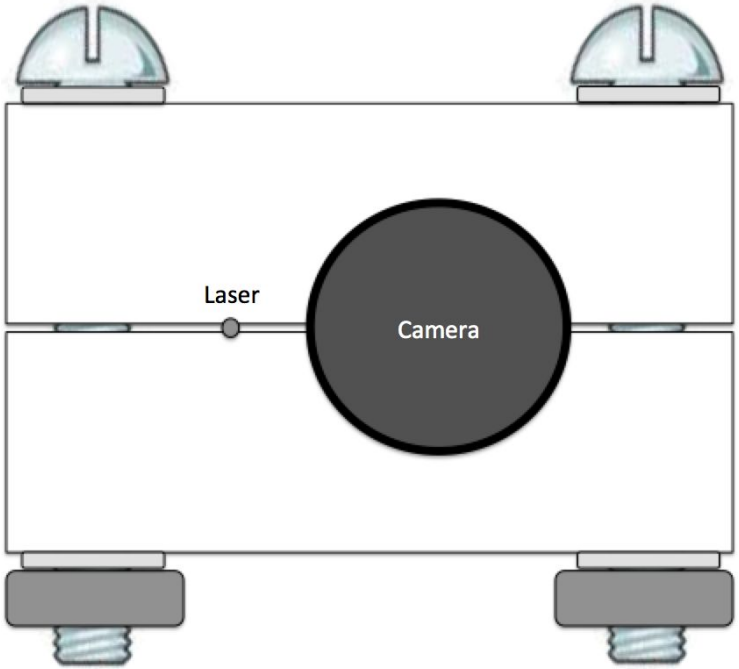
- Surgeons lack 3D depth perception when looking at 2D image from endoscope
- 3D reconstruction can guide surgery and diagnosis
- Stereo reconstruction less effective on featureless tissue
- Structured light can create features by projecting light pattern on tissue!

Structured Light



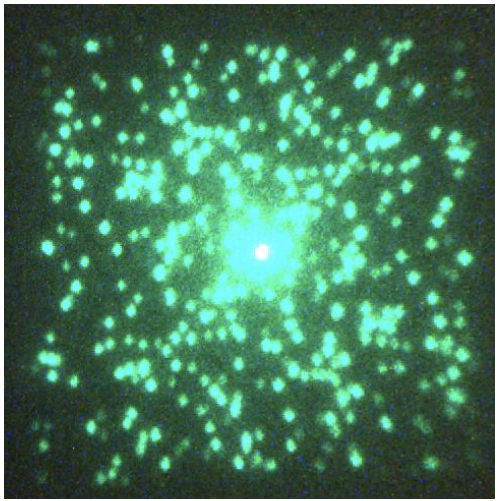
Our Project



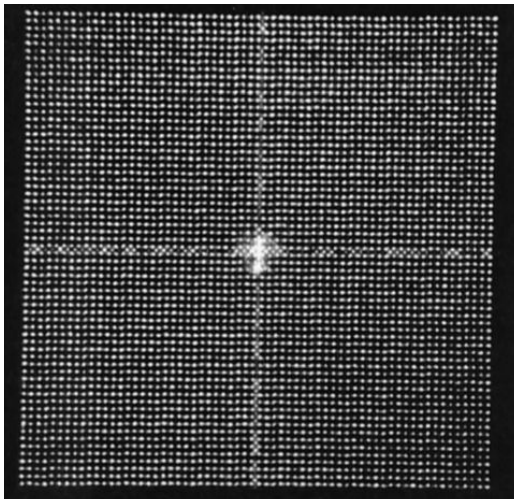


Paper Selection

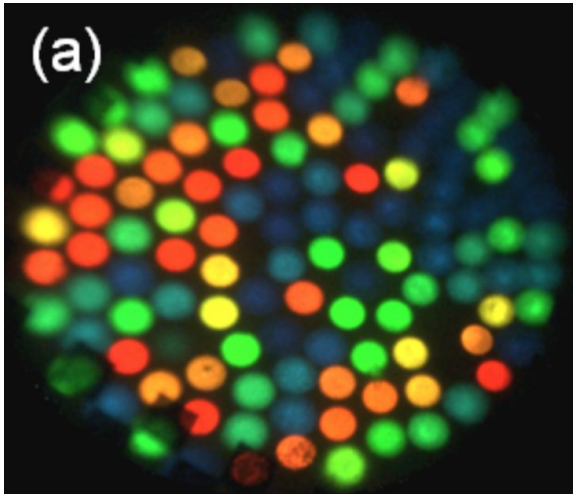
- Both papers describe systems for 3D reconstruction in endoscopy and present results on accuracy of reconstruction
- Similar laser patterns to ours



Ours



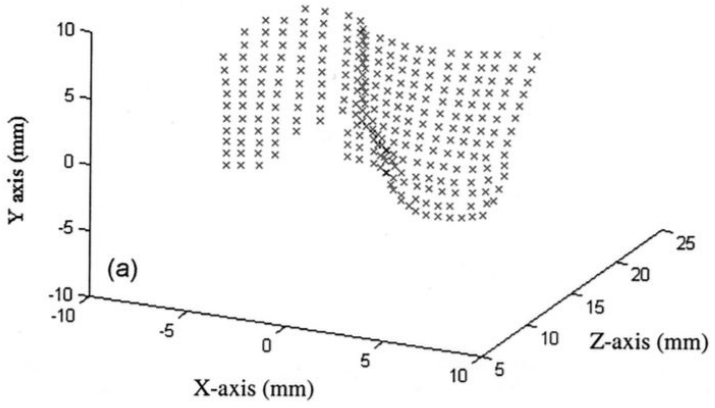
Paper 1

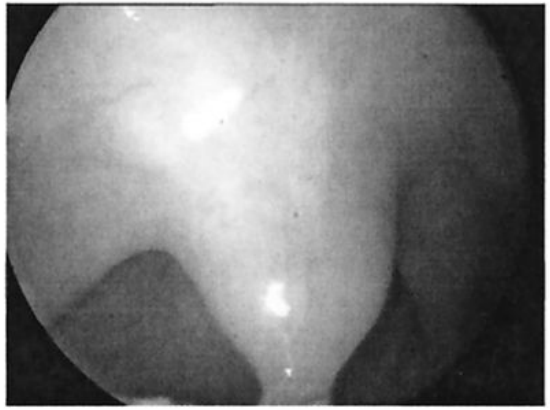


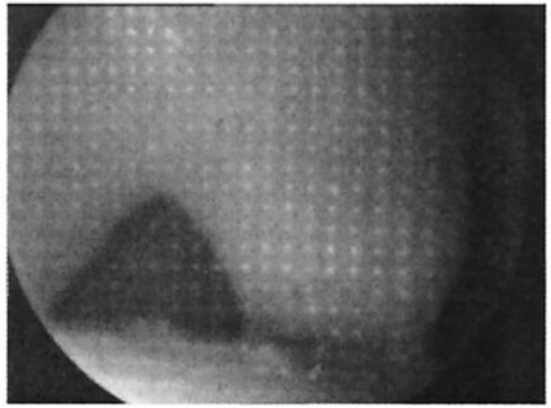
Paper 2

Miniaturized three-dimensional endoscopic imaging system based on active stereovision

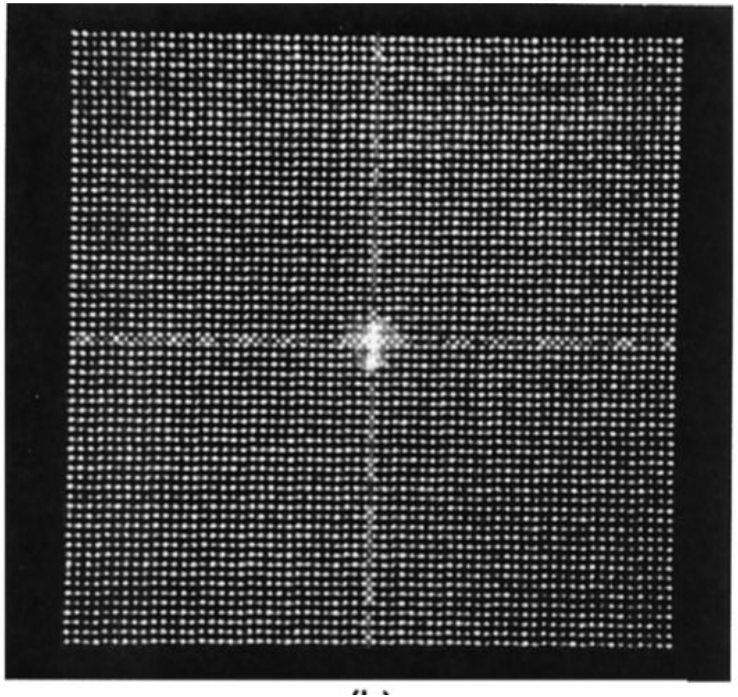
Manhong Chan, Wumei lin, Changhe Zhou, and Jianan Y. Qu







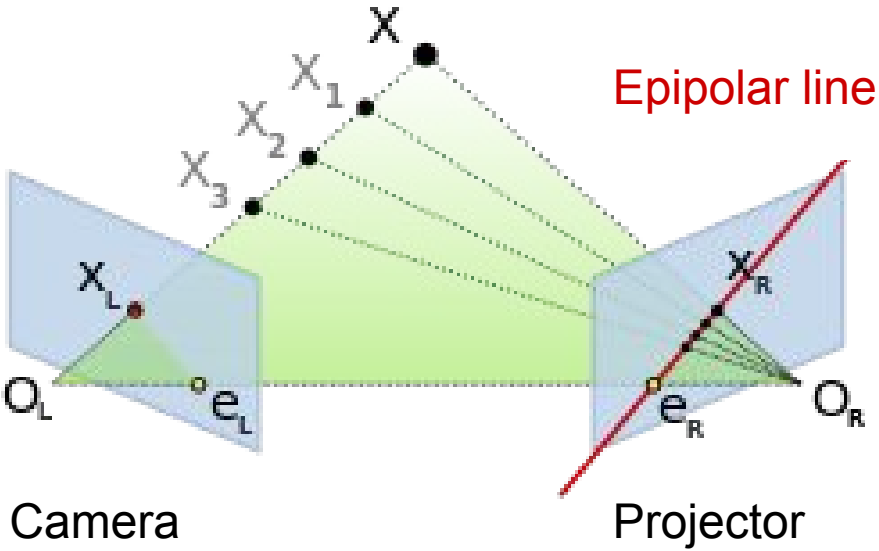
Technical Approach - Imaging System & Calibration



- Dual-channel rigid endoscope with one imaging channel, one laser projection channel, known baseline
- Use quarter of 64x64 grating pattern to avoid zero-order beam
- Checkerboard calibration based on pinhole camera model for camera
- Project channel calibration parameters same as camera

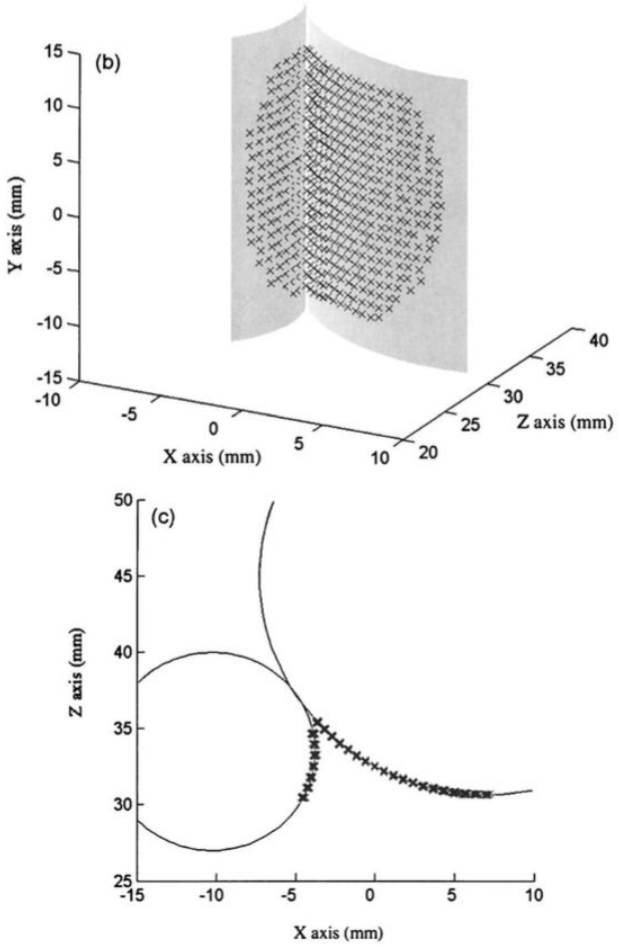
Technical Approach - 3D Reconstruction

- Dot Extraction
- Dot Correspondences
  - Use camera ray through dot in image to identify epipolar line in projection channel image plane
  - Use dot in known laser pattern closest to epipolar line as potential correspondence
- Intersect camera and projection rays to find 3D coordinate



Results

- Simple Objects → 2-3% error
  - Rigid plane
  - Step target
  - Curved object made from two cylinders
- Tissue
  - Skin placed against glass plate → similar error to simple objects
  - Finger tips → sizes consistent with caliper measurements
  - Oral cavity → visual confirmation

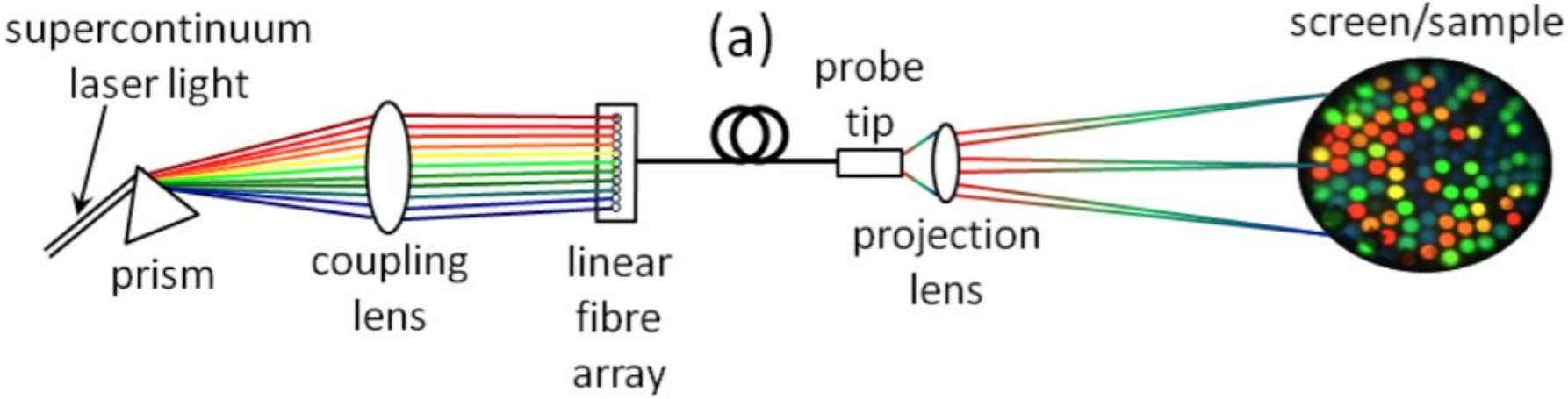


Assessment

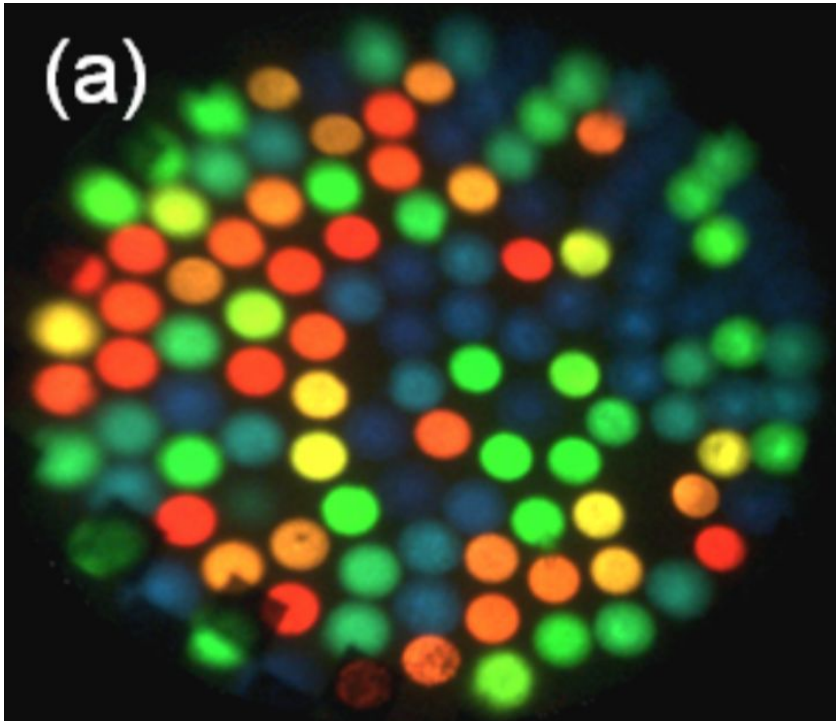
- Critique
  - Good accuracy results for simple objects
  - Interesting testing ideas
  - Lacking quantitative results in realistic setting
  - No comments on algorithm runtime
- Relevance
  - Suggests workaround for “zero-order beam”
  - Models for testing
    - Skin against glass plate
    - Curved object made from 2 cylinders

Spectrally encoded fiber-based structured lighting probe for intraoperative 3D imaging

Neil T. Clancy, Danail Stoyanov, Lena Maier-Hein, Anja Groch,
Guang-Zhong Yang, and Daniel S. Elson



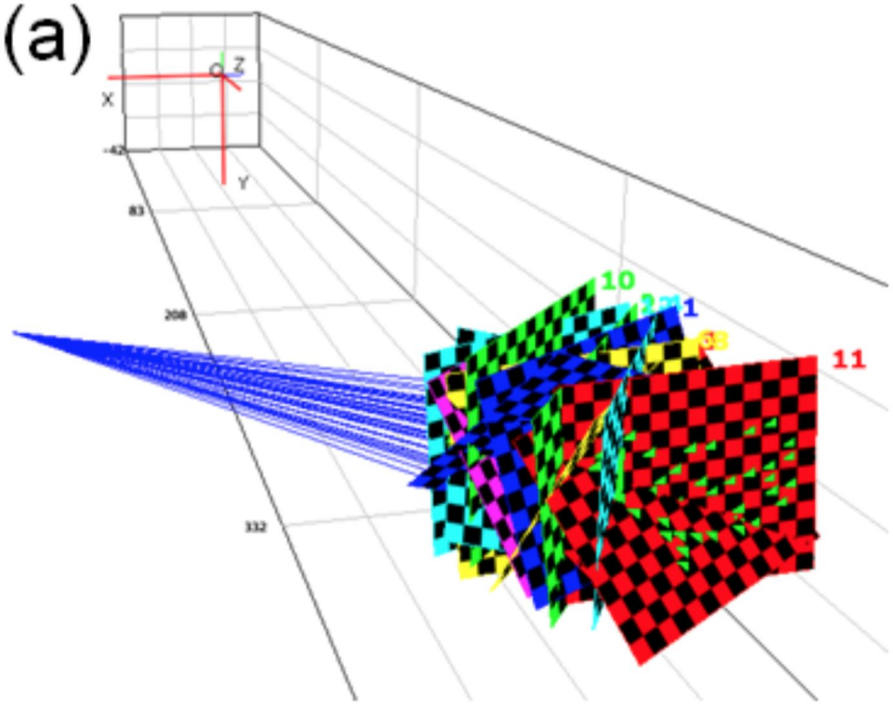
Technical Approach - Dot Identification



- Random pattern of uniquely colored dots
- Identify dots by dominant wavelength of light
- Apply region-growing algorithm then median filter to fill gaps and remove erroneous pixels for a given dot/wavelength

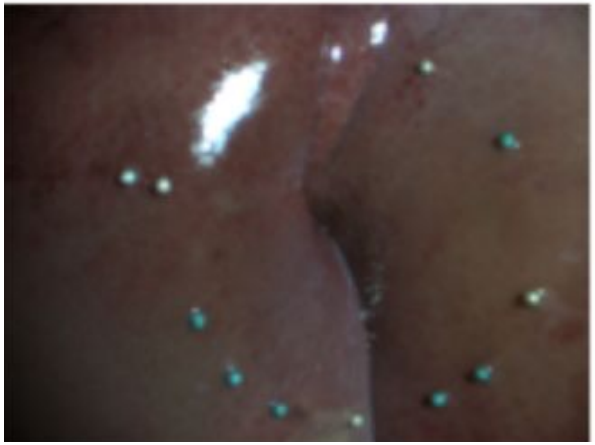
Technical Approach - Calibration & 3D Reconstruction

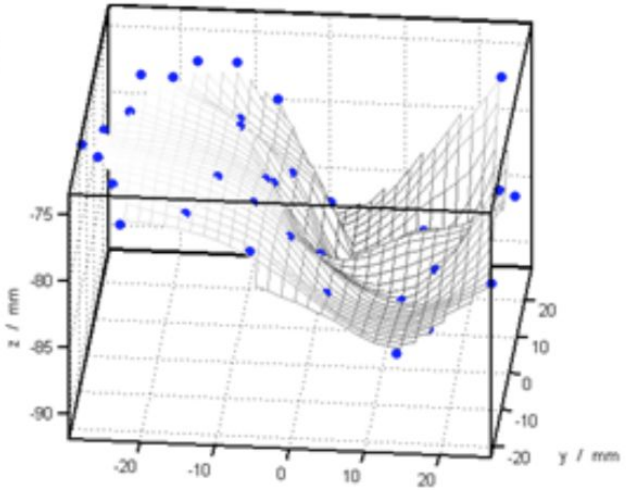
- Calibration
  - Camera - Checkerboard calibration based on pinhole camera model
  - Laser projector - Checkerboard calibration to compute rays for each dot in laser pattern relative to camera
- Intersect camera ray and projector ray to find 3D coordinates



Results

- Opaque Objects → sub-mm accuracy
  - Black binder
  - Brown cylinder
- Reconstruction evaluation
  - Fit surface to point cloud
  - Compare surface to known shape
  - Find error between point cloud and surface
- Ex-vivo Tissue → no quantitative results
  - Kidney
  - Liver
  - Fatty tissue





Assessment

- Critique
  - Interesting choice of uniquely colored dots for laser pattern
  - Lacking quantitative results in realistic setting
  - Limited number of dots in pattern, large dots
- Relevance
  - Region growing algorithm followed by median filter to get only green dots
  - Surface fitting to evaluate reconstruction

References

1. M. Chan, W. Lin, J Qu, “Miniaturized three-dimensional endoscopic imaging system based on active stereovision,” in *Applied Optics*. **42**(10), 1888-1898 (2003)

2. N. T. Clancy, D. Stoyanov, L. Maier-Hein, A. Groch, G. Yang, D. Elson, “Spectrally encoded fiber-based structured lighting probe for intraoperative 3D imaging,” in *Biomedical Optics Express*. **2**(11), 3119-3128 (2011).

Thank you!