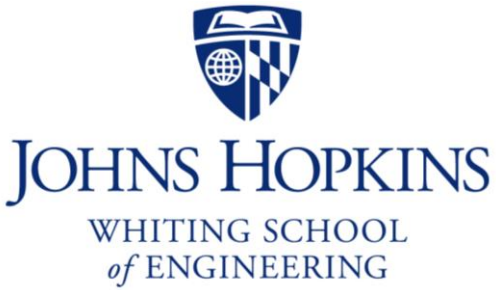
NSF Engineering Research Center
for Computer Integrated Surgical
Systems and Technology

3D Tool Tracking in the Presence of Microscope Motion

Checkpoint Presentation



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Mentors:

Dr. Austin Reiter,

Dr. Russell Taylor

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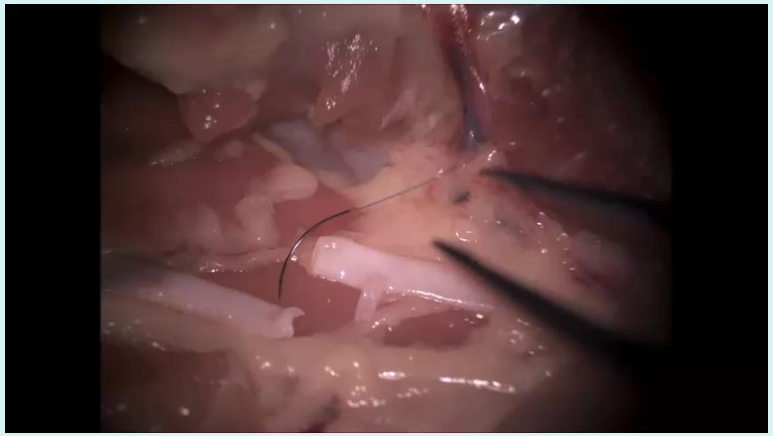
Project Summary

Motivation

[1]



Project Goals

Camera Motion Tracking → **Video Tool Tracking** → **Frequency Analysis**

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Key Progress and Changes

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	Original Plan	Updates
Implement Optical Tool Tracking	•Attach optical marker to tool •Record stereo video of tool •Compute marker position •Perform frequency analysis of tool motion	• Stopped, time consuming and not as important • Stereo video of suturing and validation video recorded
Camera Motion Tracking	•Extract background feature points from left and right frame •Stereo matching •Triangulate background 3D point cloud •Perform ICP to find 3D camera motion between frames	• Implemented • Validation: compare tracking results against known motions
Video Tool Tracking	•Implement tool tracking •Frequency analysis •Test against ground truth results	• Initial test of color segmentation unsuccessful • Track painted tool
Frequency Analysis	•Compare frequency analysis from optical tool tracking and video tool tracking-> Can ground truth tremor be recovered from imperfect video tracking? •Compare frequency analysis of hand-held tools and robot-held tools	• No comparison of optical tracking and microscope tracking results

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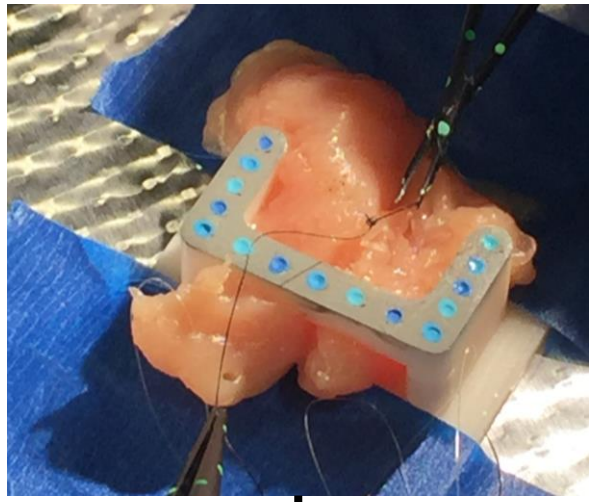
Updated Technical Approach



Color Blob Detection

Camera Motion Tracking
- input: feature points
- Output: 3D Transform from current image to previous image

Tool Tracking
- Input: feature points
- Output: 3D tool point locations

Frequency Analysis
- Input: Camera movement between frames, tool point locations
- Output: tool frequency analysis

*Photos by Abhinav Goyal

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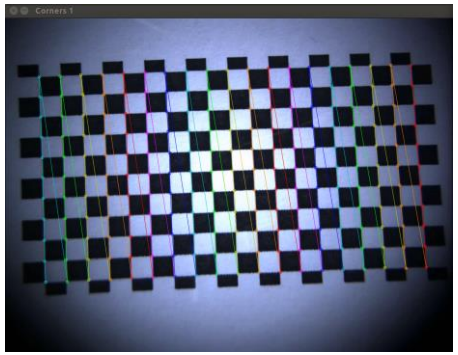
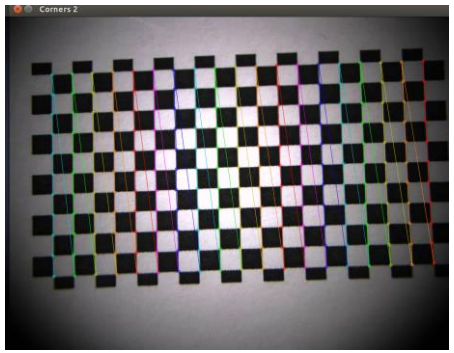
Camera Movement Tracking

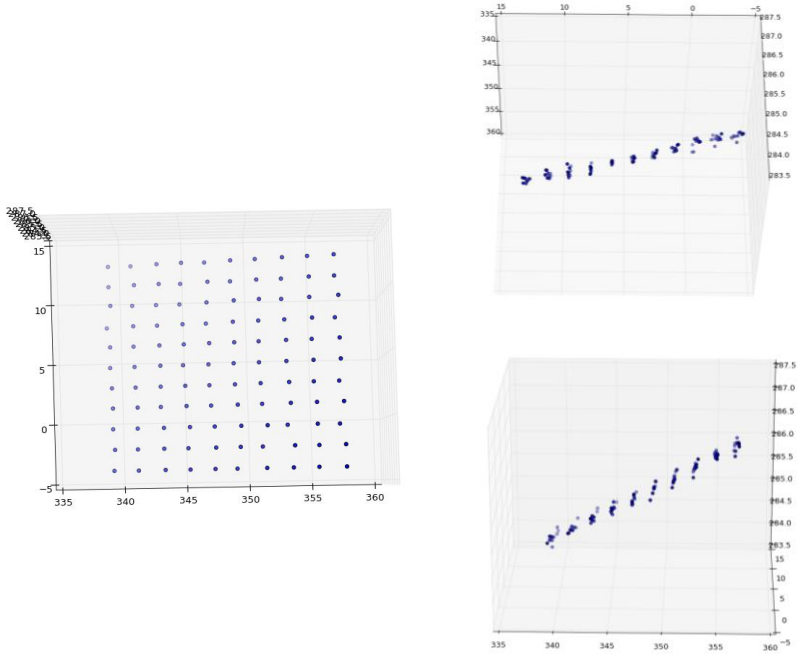
- Camera Calibration
- Triangulate 3D points

Sample Stereo Image Pair

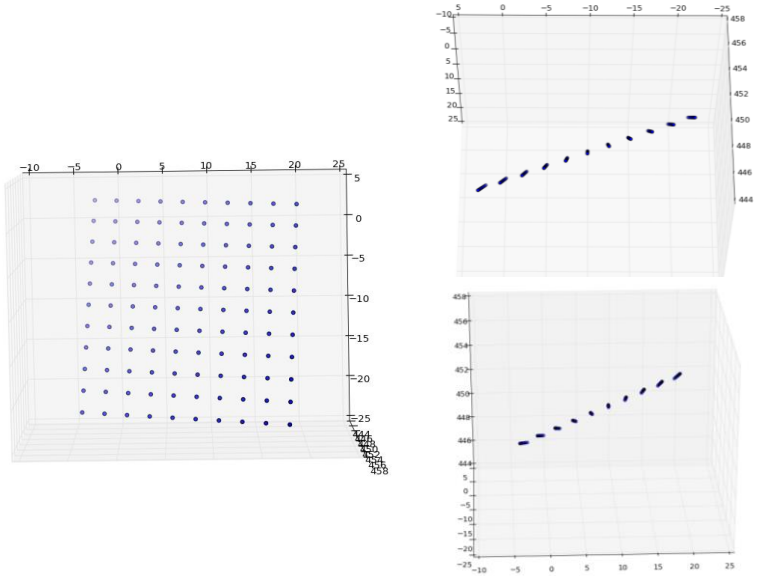




Triangulated Points



Ground Truth Points



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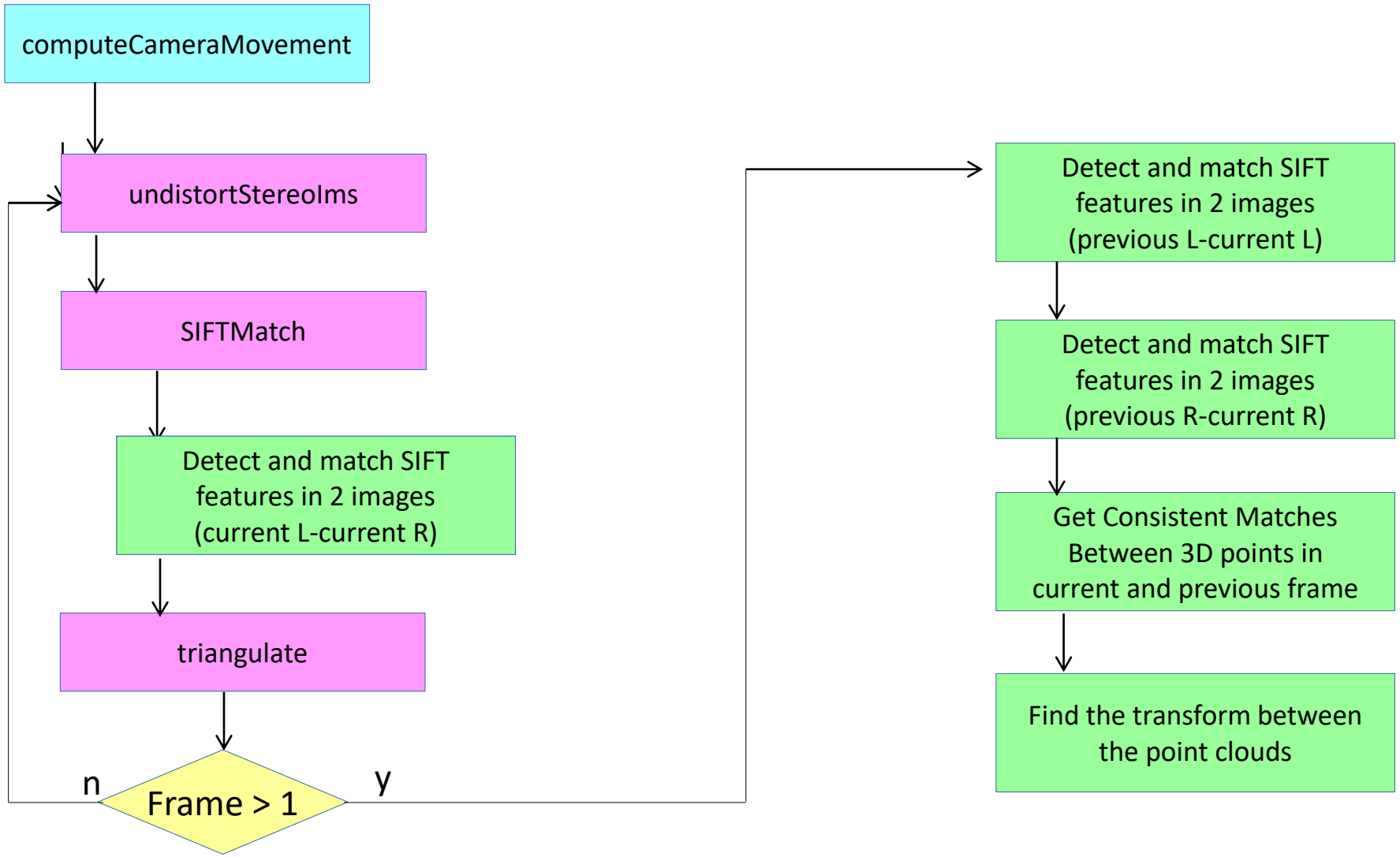
Camera Movement Tracking



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Camera Movement Tracking

- **Pipeline**: Match 3D feature points across frames

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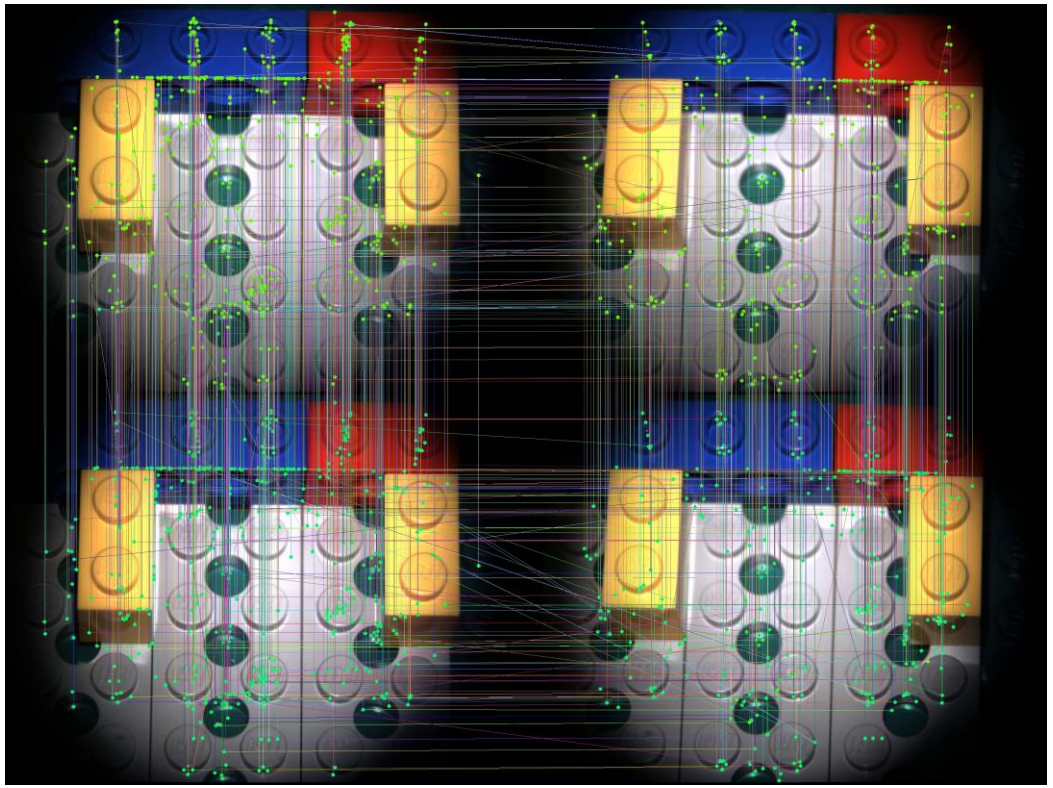
All Matches

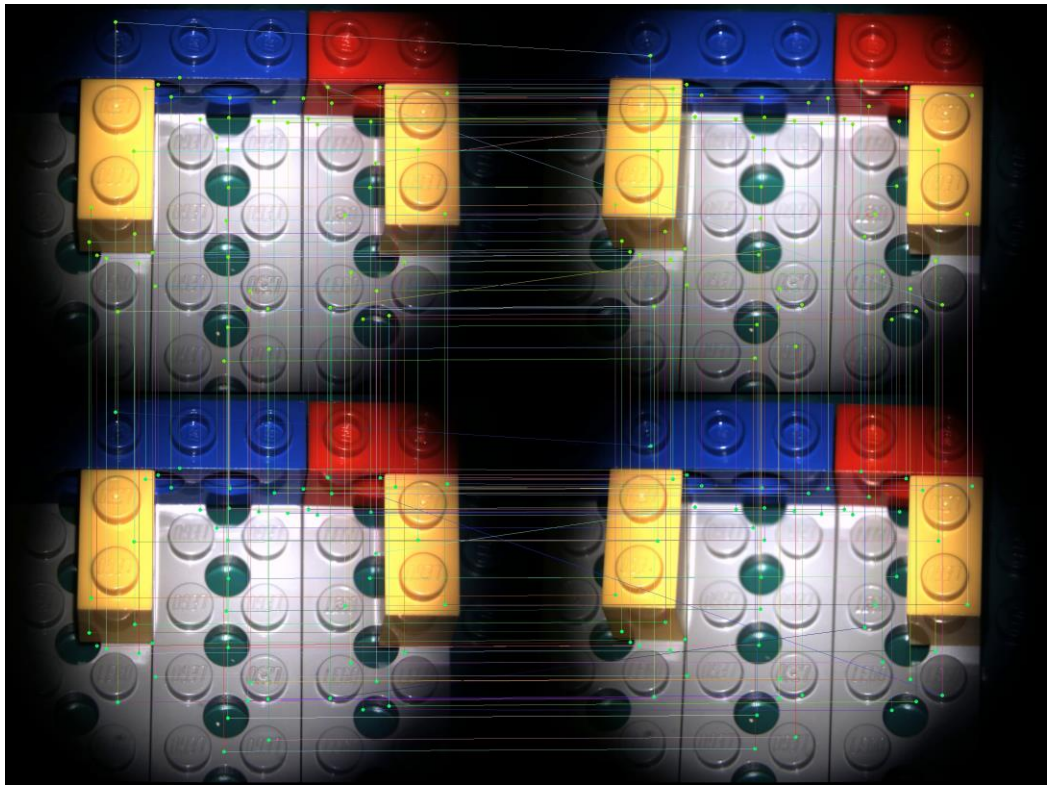
Frame1 L Frame1 R



Frame 2 L Frame 2 R

Good Matches

Frame1 L Frame1 R



Frame 2 L Frame 2 R

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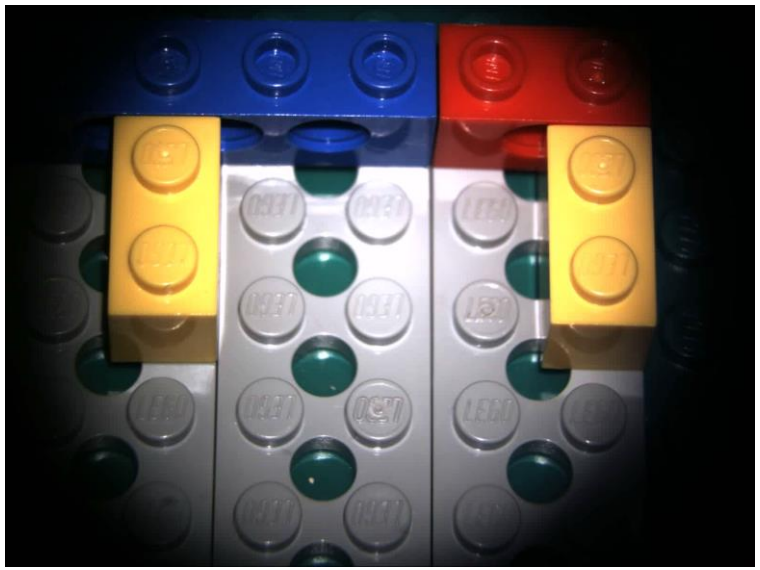
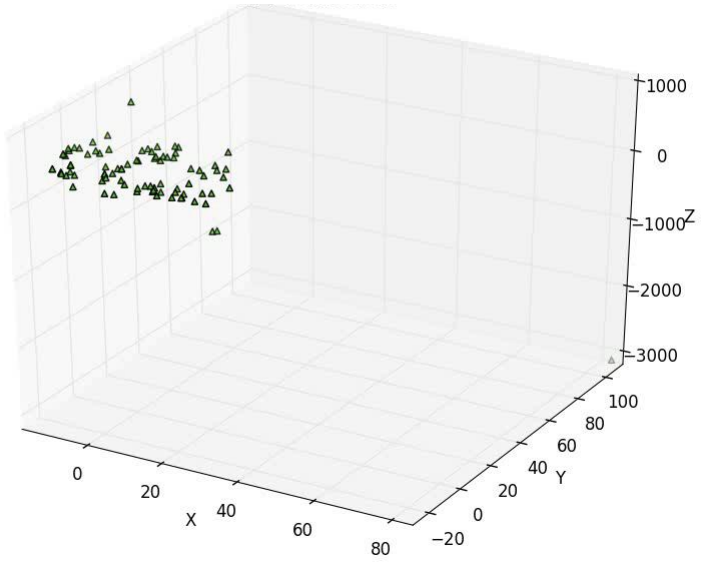
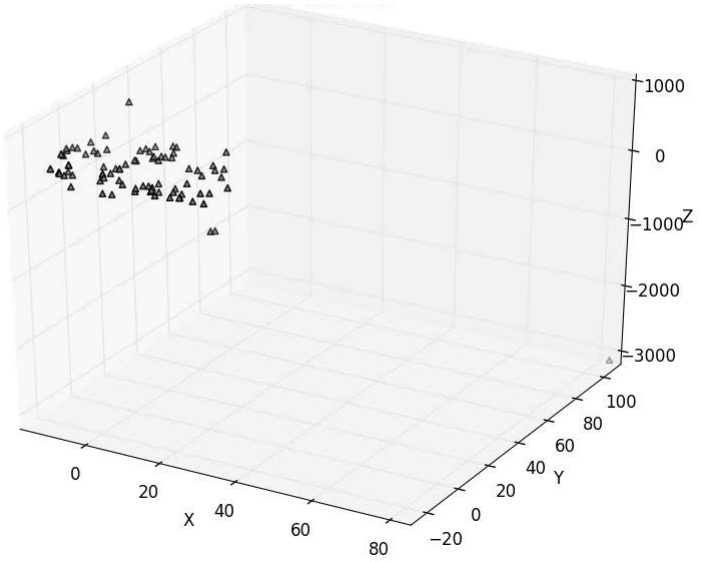
Camera Movement Tracking



Original Points



Stabilized Points



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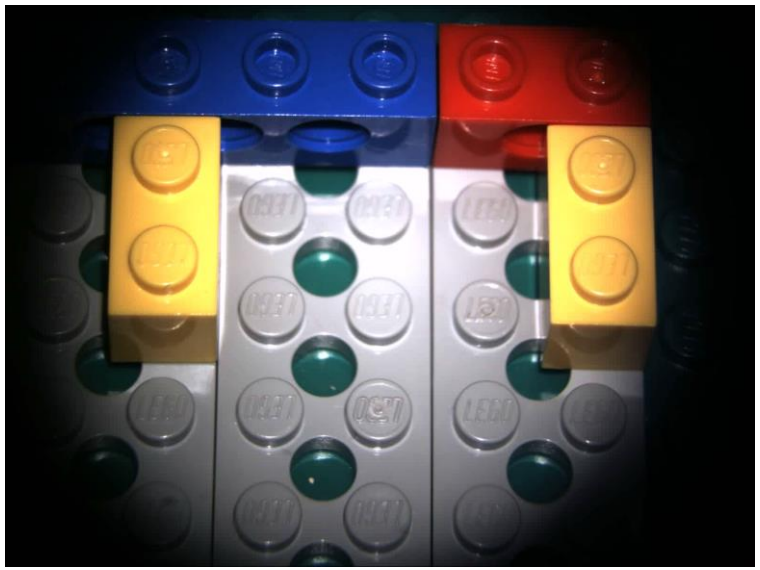
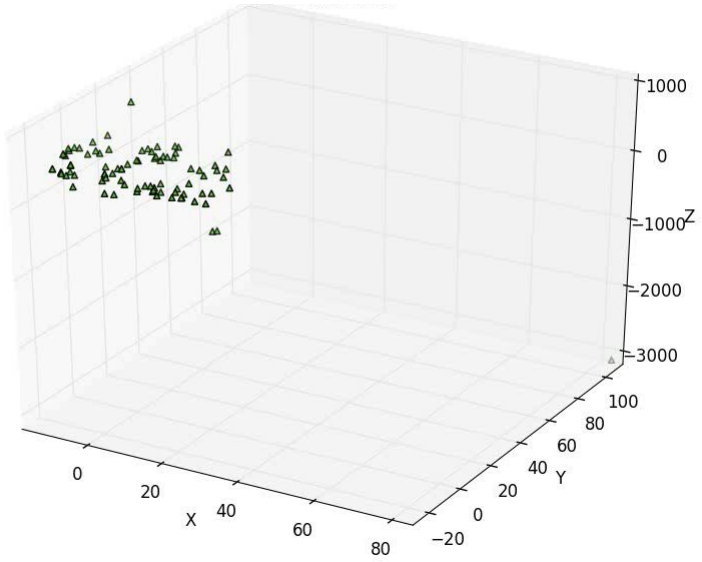
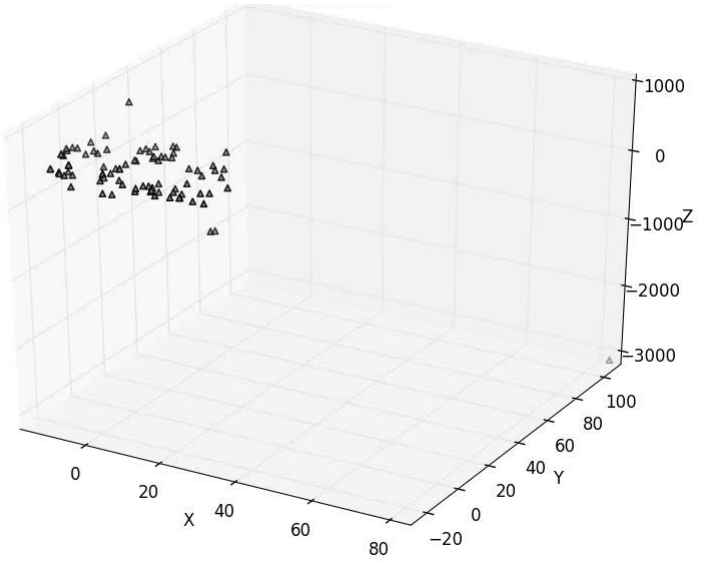
Camera Movement Tracking



Original Points



Stabilized Points



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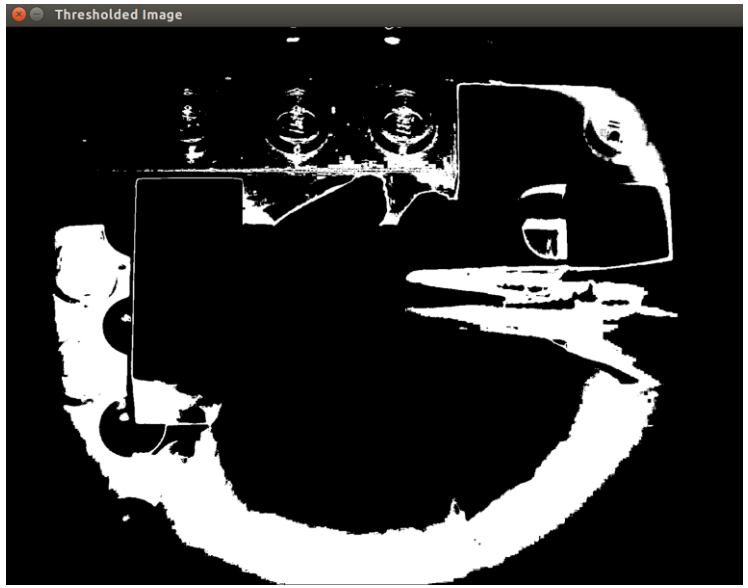
Tool Color Segmentation

Red Threshold R:
pixel values [40,140]



Green Threshold:
pixel values [50,100]

Blue Threshold:
pixel values [50,90]

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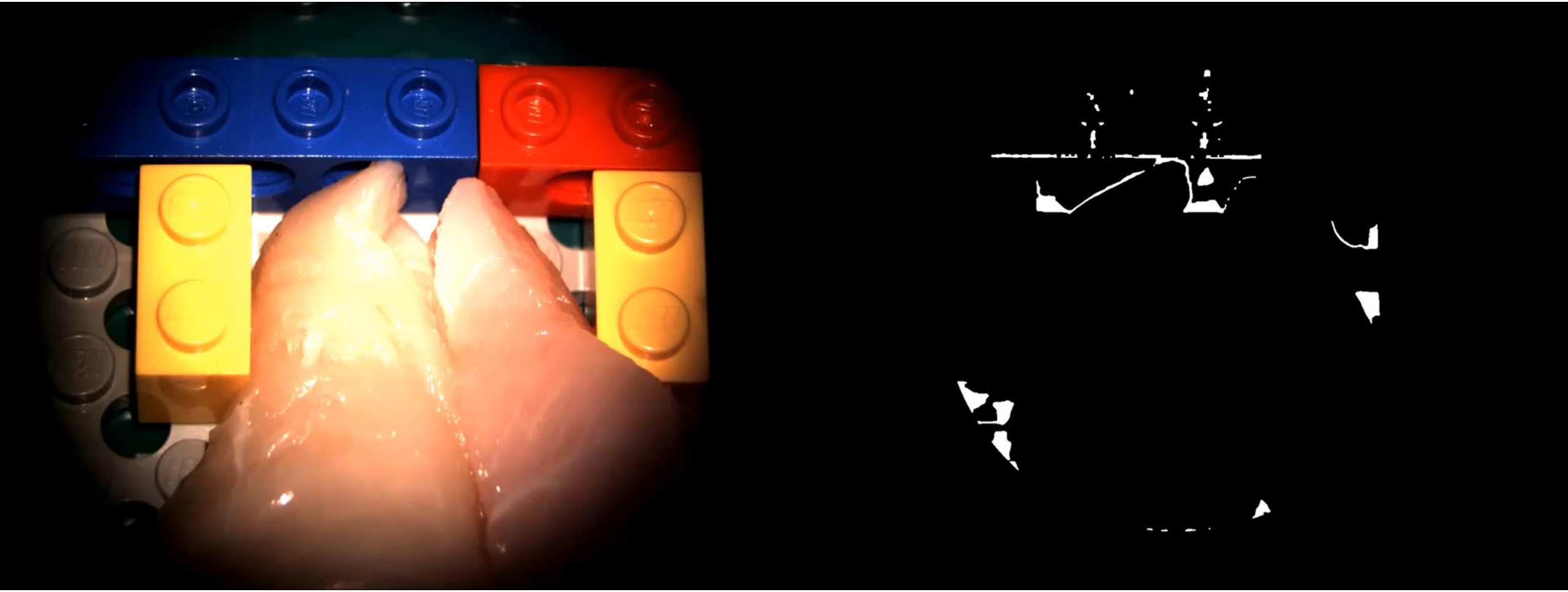
Tool Color Segmentation



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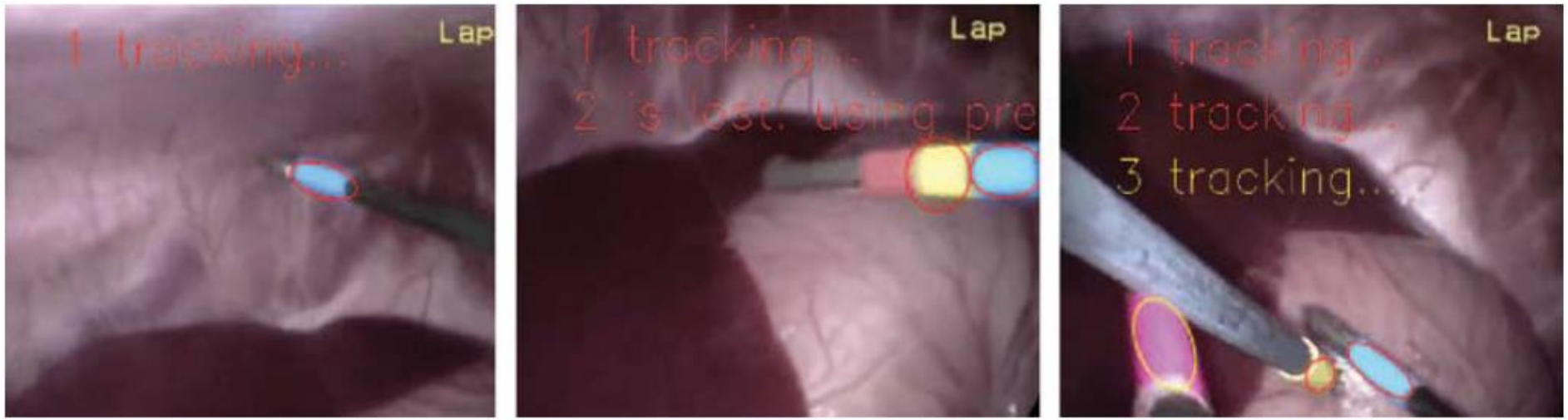
New Tool Tracking Approach

- Tool Tracking system
  - Real time
  - In-vivo
  - Uses color markers
  - Tools tracked using CAMShift + Kalman Filter



[2]

Figure 4. Tracking results.

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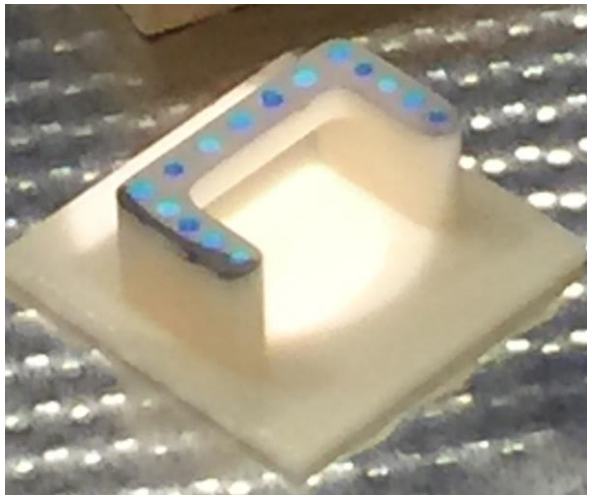
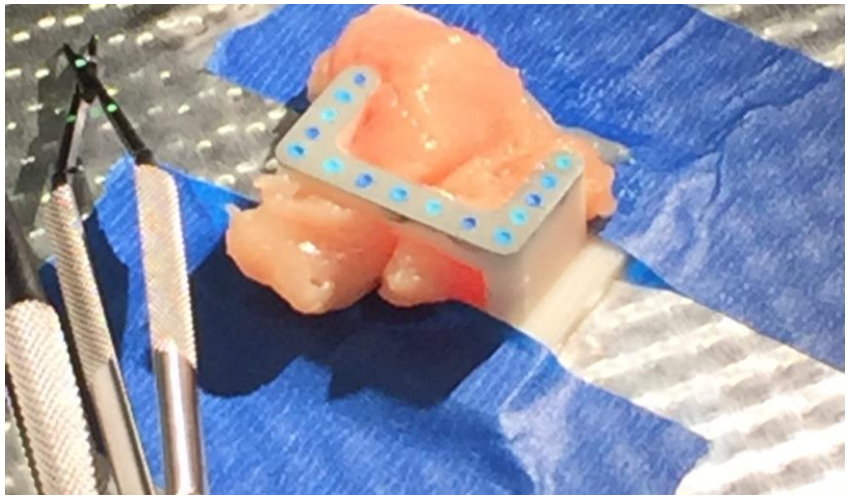
Recording Data

1. Camera motion validation video
2. Tool motion validation video
3. Chicken suturing: free-hand
4. Chicken suturing: robot-assisted



Painted chicken holder
(Designed by Abhinav Goyal)



Chicken holder, chicken breast, painted tools

*Photos by Abhinav Goyal

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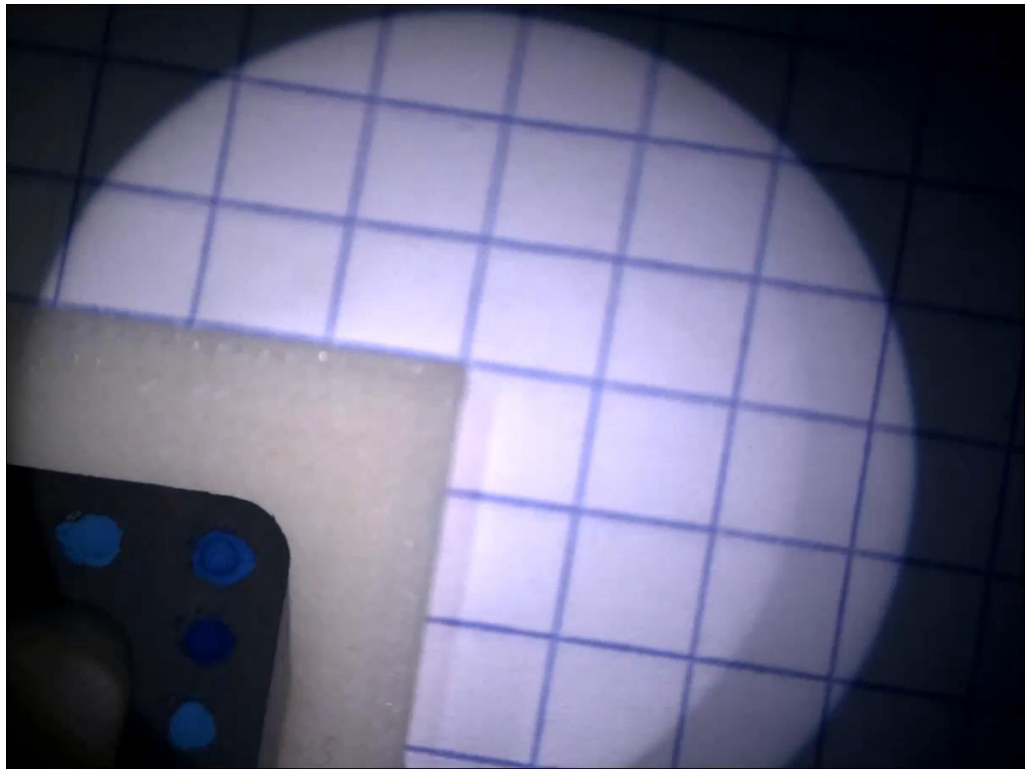
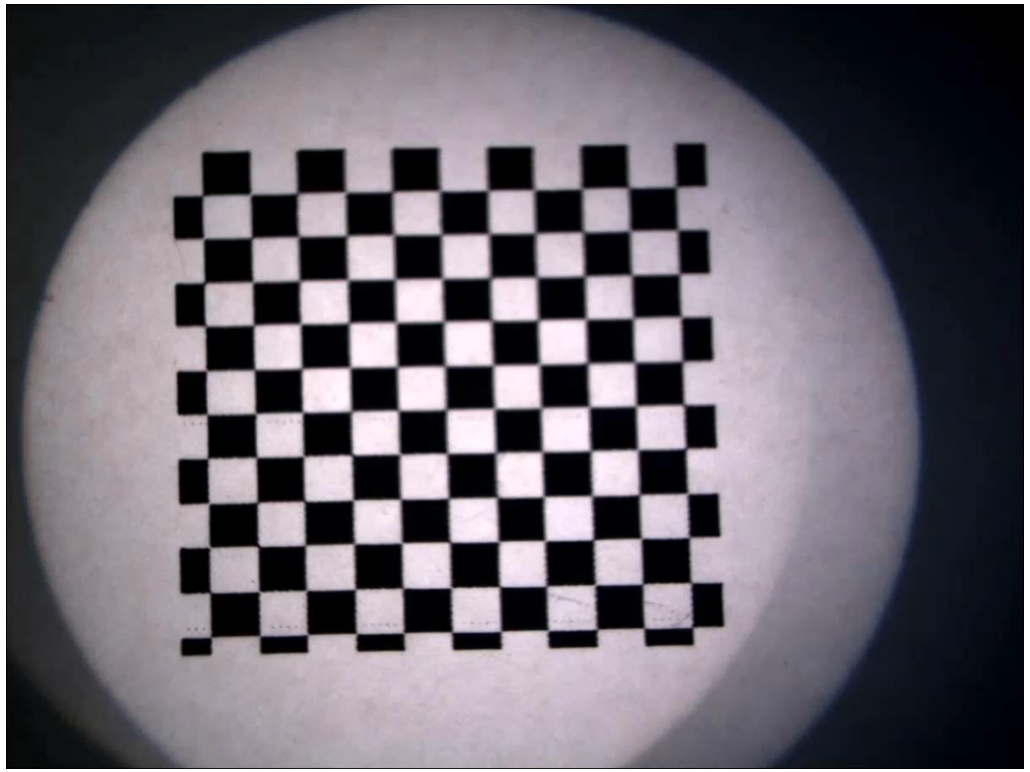
Validation Videos

Camera Motion Validation Video



Tool Motion Validation Video



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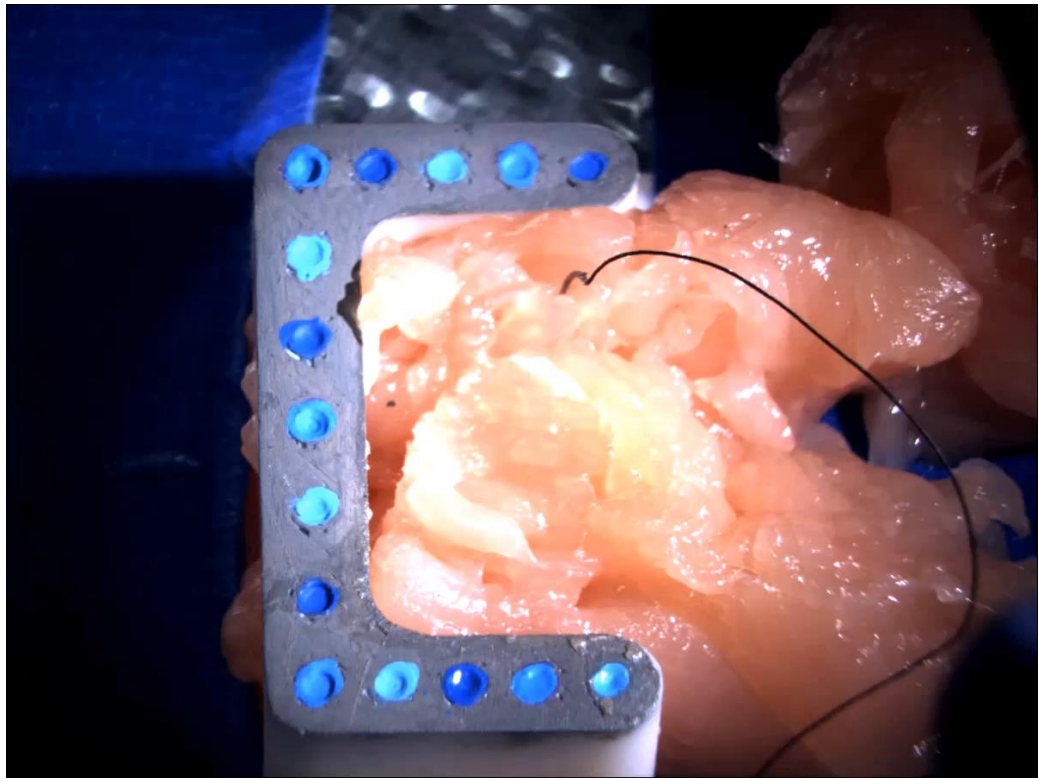
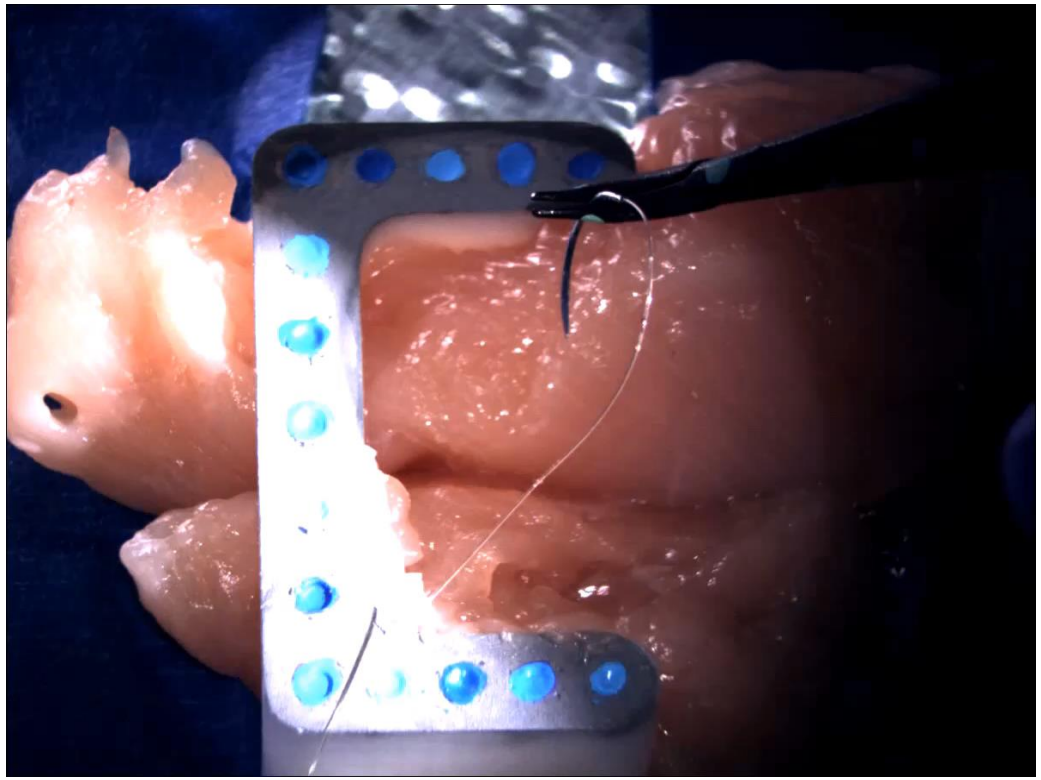
Suturing Videos





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Problems, Exposures, Dependencies

Dependency	Proposed Solution	Status
Access to microscope and video capture computer	Coordinate with Dr. Taylor and lab	*Resolved*
Chicken holding phantom	Enlist other members of the lab to help me	*Resolved*
Access to robot	Determine when robot will be needed. Coordinate with Dr. Taylor and lab	*Resolved, will need to coordinate with Paul again to record more data*
Access to tools	Coordinate with Dr. Taylor and lab	*Resolved*
~~Access to optical tracking system~~	~~Coordinate with Dr. Taylor and lab~~	~~*Pending*~~
Problem	**Proposed Solution**	**Status**
Triangulating points took longer than planned	changed tool tracking approach and updated plan	*Resolved*

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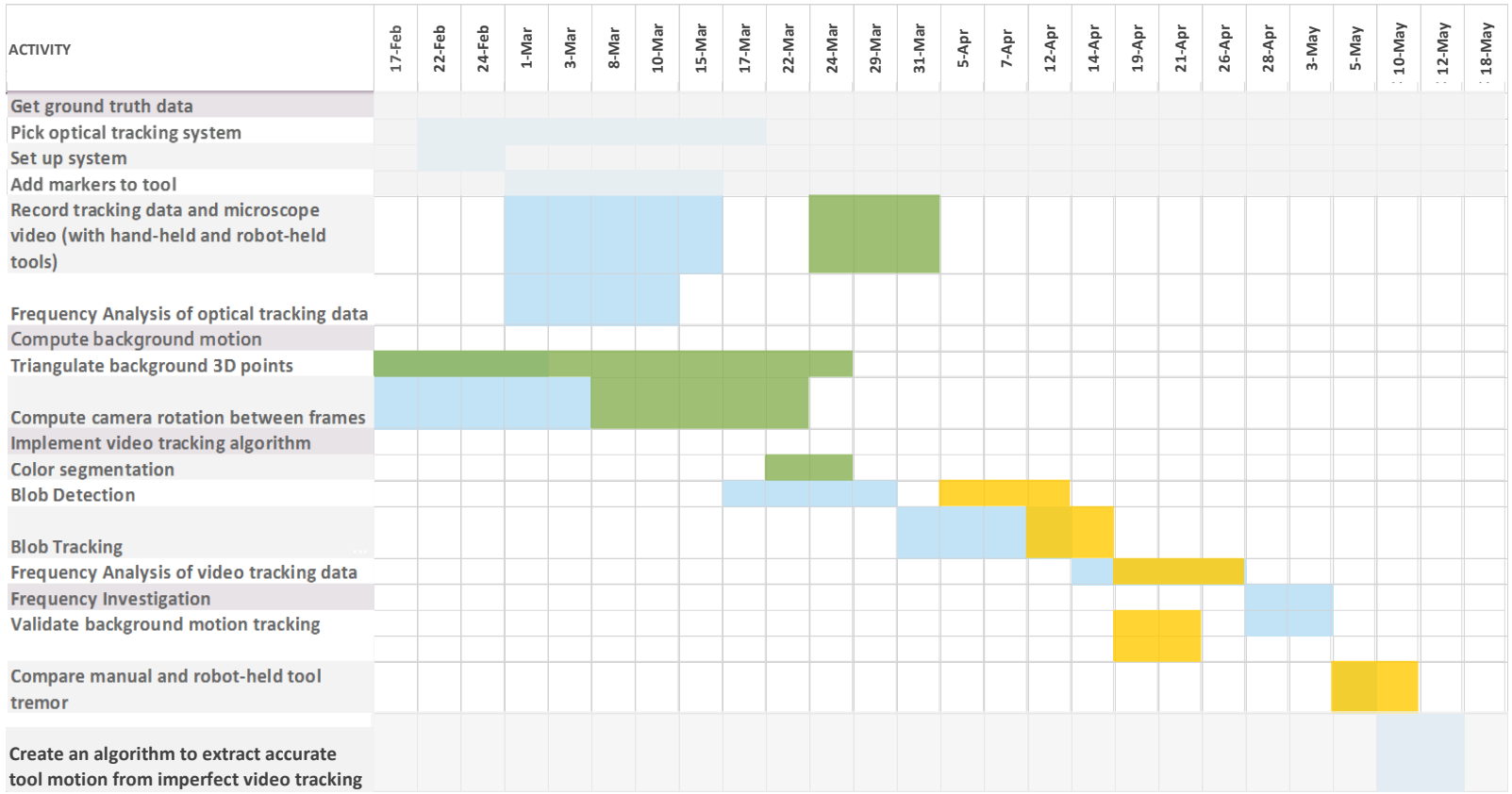
Timeline



Legend

- Initial Plan
- Completed
- Current Plan

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Deliverables

	Original	Updated
Min	A system capable of measuring tool movement (using existing tracking system)	An algorithm to triangulate 3D points from stereo video and track background motion (with fiducial points)
	Frequency results from tracked tool movement (using existing tracking system)	Tool tracking algorithm using microscope video for painted tool
	An algorithm to triangulate 3D points from stereo video and track background motion (with fiducial points)	
Expected	Tool tracking algorithm using microscope video	Validation of triangulated points using known world motion (robot or measured)
	Frequency analysis of the tool tip motion from a stereo video	Frequency analysis of the tool tip motion from a stereo video
Max	An algorithm to get accurate tool tip motion and tremor from microscope video	Comparison of hand-held and robot-held tool tremor
	Comparison of hand-held and robot-held tool tremor	

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Management Plan

- Weekly meetings with Dr. Taylor and Dr. Reiter

Reading List

- Camera motion calc
  - **S. Leonard, A. Reiter, A. Sinha, M. Ishii, R. Taylor, and G. Hager, "Image-Based Navigation for Functional Endoscopic Sinus Surgery Using Structure From Motion," in *SPIE*, San Diego, 2016.**
- Tool tracking
  - **B. Allen, F. Kasper, G. Nataneli, E. Dutson, and P. Faloutos, "Visual Tracking of Laparoscopic Instruments in Standard Training Environments," in *MMVR,* Newport Beach 2011.**
  - **R. Sznitman, K. Ali, R. Richa, R. Taylor, G. Hager, and P. Fua, "Data-driven visual tracking in retinal microsurgery. In Medical Image Computing and Computer-Assisted Intervention," in *MICCAI,* Nice 2012.**
  - **Loubna Bouarfa, Oytun Akman, Armin Schneider, Pieter P. Jonker and Jenny Dankelman (2012) In-vivo real-time tracking of surgical instruments in endoscopic video, Minimally Invasive Therapy & Allied Technologies, 21:3, 129-134, DOI: 10.3109/13645706.2011.580764**
  - W. Zhao, C. Hasser, W. Nowlin, and B. Hoffman, "Methods and systems for robotic instrument tool tracking with adaptive fusion of kinematics information and image information," U.S. Patent 8108072 B2, Jan 31, 2012.
  - A. Cano, F. Gaya, P. Lamata, P. Sanchez-Gonzalez, and E. Gomez, "Laparoscopic Tool Tracking Method for Augmented Reality Surgical Applications," in *LNCS,* vol. 5104, pp. 191-196, 2008.

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References

[1] https://www.youtube.com/watch?v=HXTEFoFJ9iA&t=617s

[2] L. Bouarfa, O. Akman, A. Schneider, P. Jonker, and J. Dankelman, “In-vivo real-time tracking of surgical instruments in endoscopic video,” in *Minimally Invasive Therapy & Allied Technologies*, 21, 3, 129-134, May 2011.

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