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Prototype of a Microsurgical Tool Tracker

Team 5

Students: Sue Kulason, Yejin Kim

Mentors: Marcin Balicki, Balazs Vagvolgyi, Russell Taylor

600.466 Advanced Computer-Integrated Surgery

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Outline

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Project Summary

- Problem: A need for tool tracker in eye surgery
  - Assess surgical performance
  - Ensure proper protocol
- Project Goal: Micro-Surgical Tool Tracker
  - Build a prototype of a goggle
  - Provide positional feedback

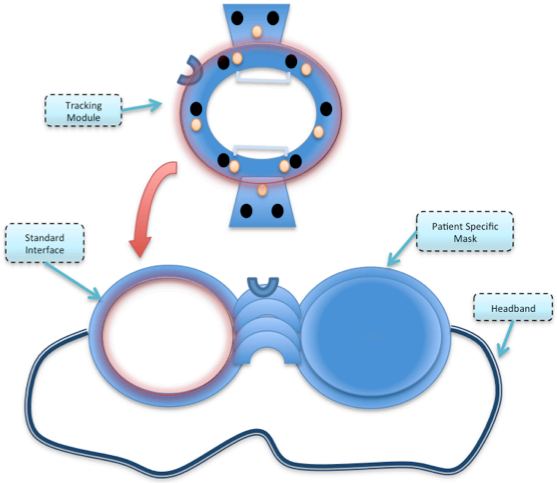

Figure 1. Idea proposed by Marcin Balicki

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Aims & Significance

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Specific Aims
Create a miniature tracking system for the eye
Track surgical instruments in real time
Utilize redundancy to reduce line-of-sight problems
Utilize fiducial markers on tools for identification
Evaluate tracking accuracy

Significance/Future Directions
Monitor surgical protocols
Surgical skill assessment
Improve surgical safety
Robot-assisted surgery
Adaptation to other micro surgeries

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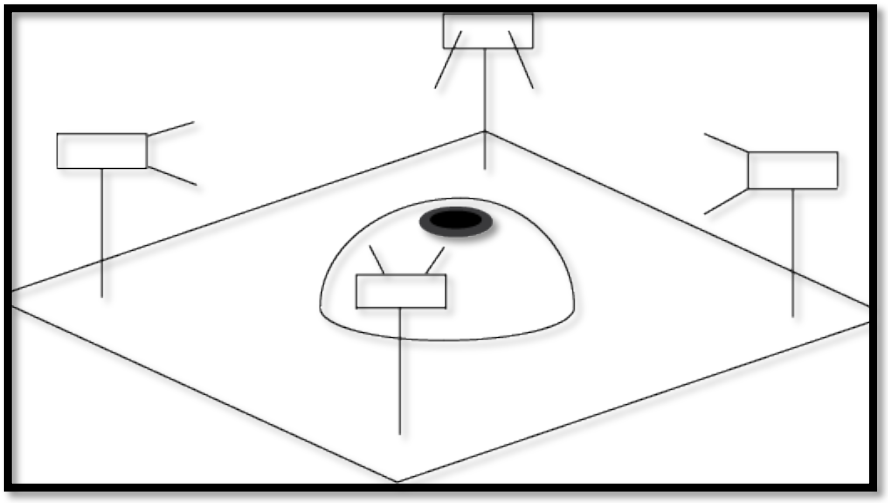
Progress: Mechanical Design

Constraints for Design
Size of the camera
Field of view of the camera
Processing ability of the camera
Motion of the surgeon's hands
Available area around the patient's eye



Proposed idea for initial prototype

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Progress: Mechanical Design

Chosen Camera:
Mini 7mm Flexible Inspection Camera Borescope Endoscope

Cost: $76.98

Resolution: 640x480 pixels(JPEG format)

Focal distance: 2~8cm

Magnification: up to 10x

Others:
82cm USB cable
Waterproof head & cable
4 white LED adjustable brightness

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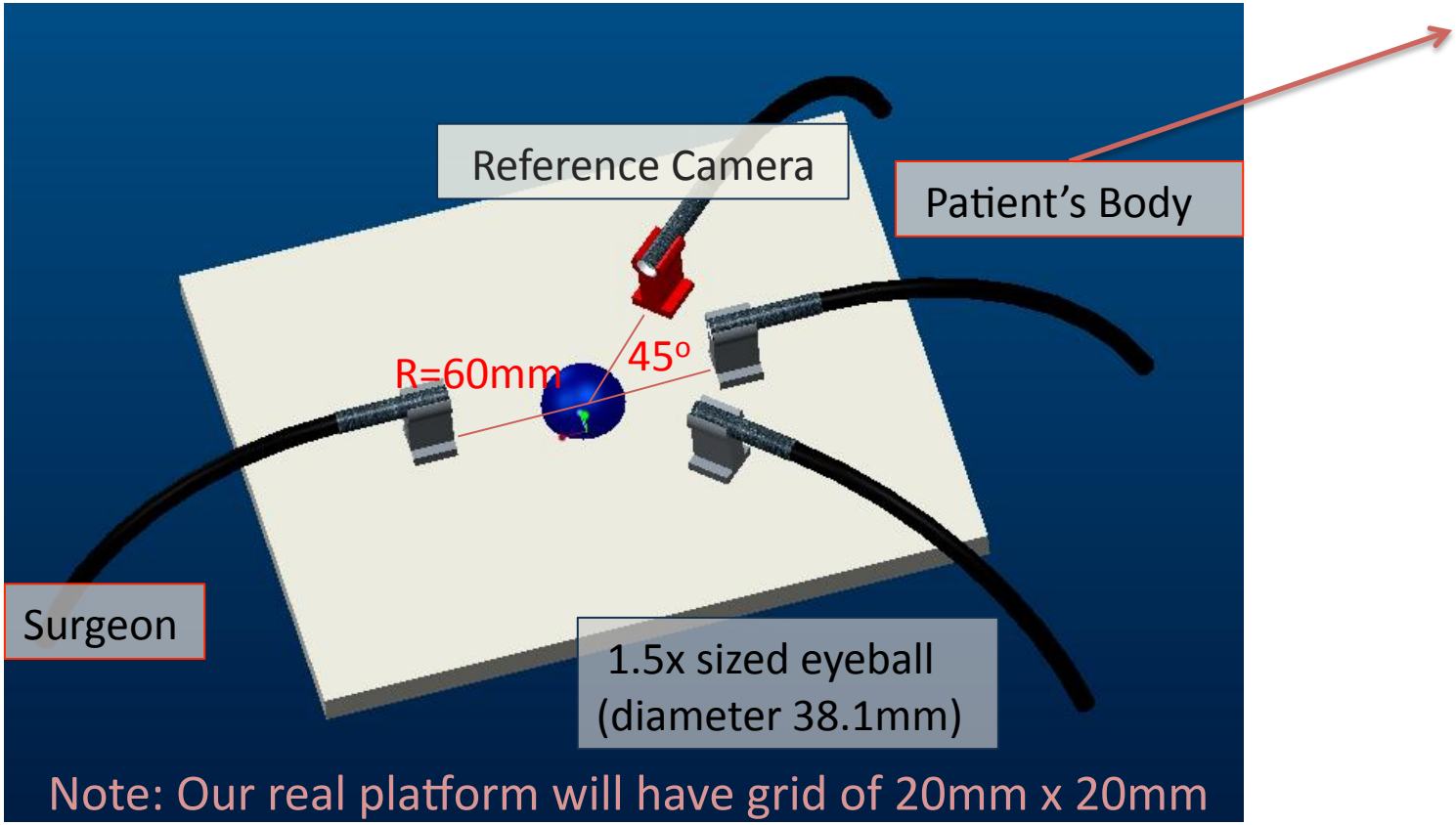
Progress: Mechanical Design



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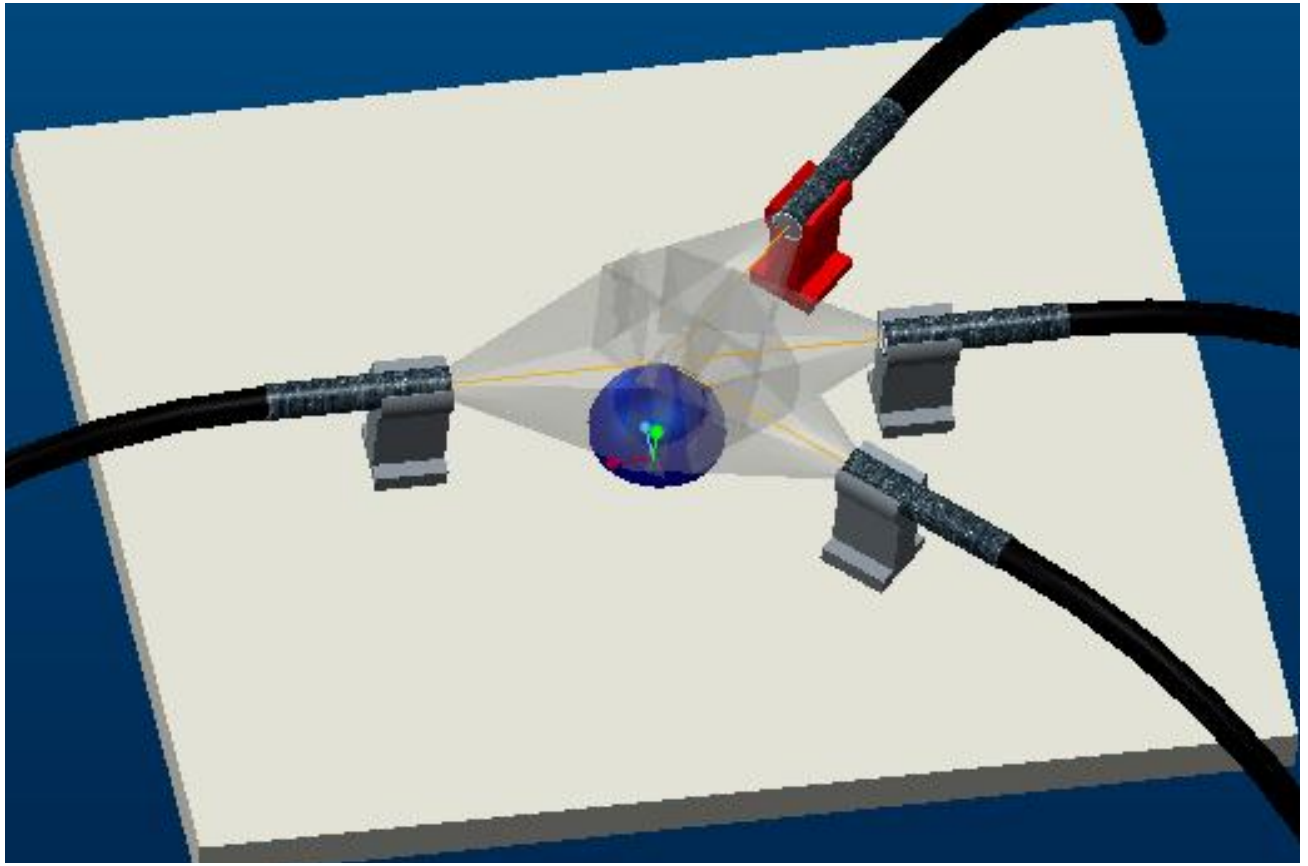
Progress: Mechanical Design



Project Summary | Aims & Significance | Progress: MD | Progress: TD | Deliverables | Dependencies | Milestones | Reading List

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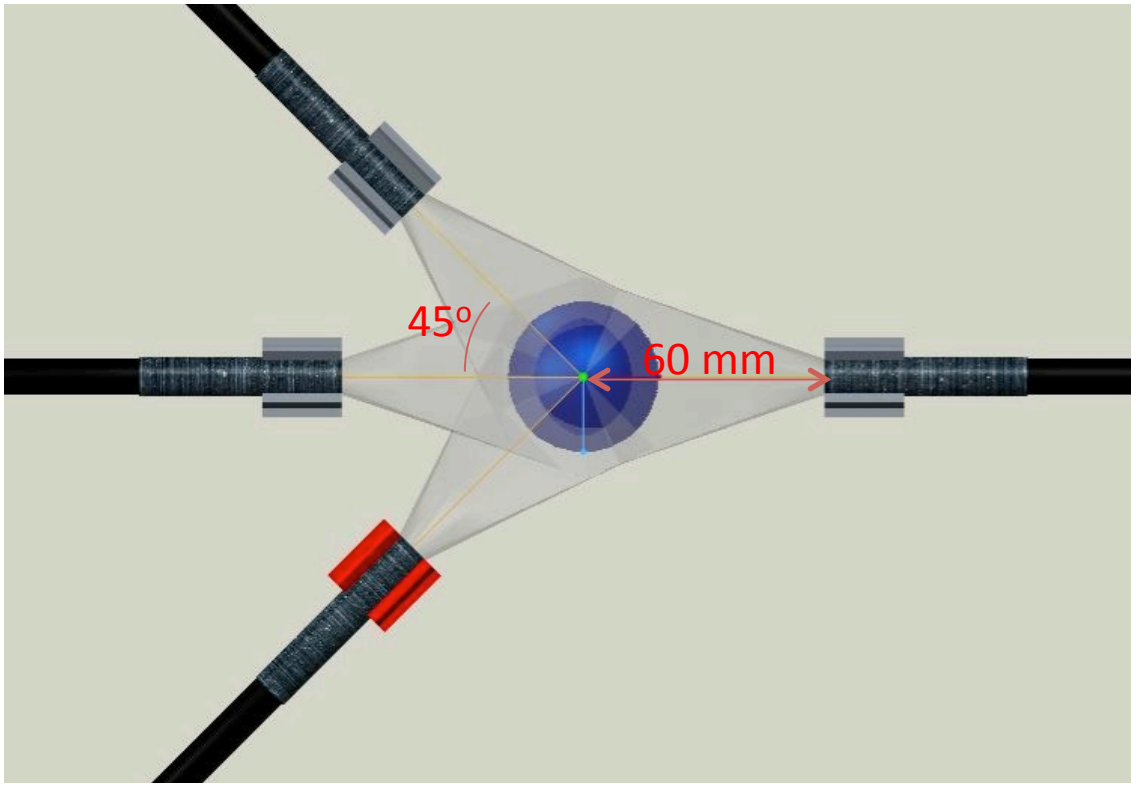
Progress: Mechanical Design



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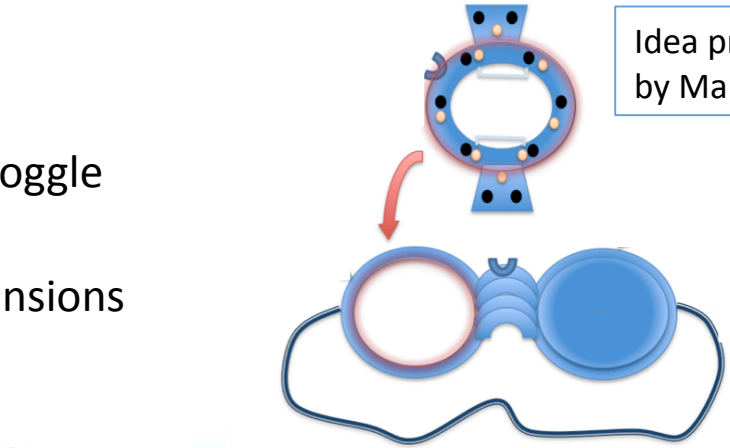
Progress: Mechanical Design

- **Original Plan:**
  - Conceptualize the design of the goggle prototype
  - CAD prototype with specific dimensions
- **Raised Problem:**
  - Limited space
  - Small field of view
  - Device fit to face
- **Revision in plan:**
  - Create a mock up
  - Determine optimized life-size design
  - Build CAD design scaled 1.5x



Idea proposed by Marcin Balicki

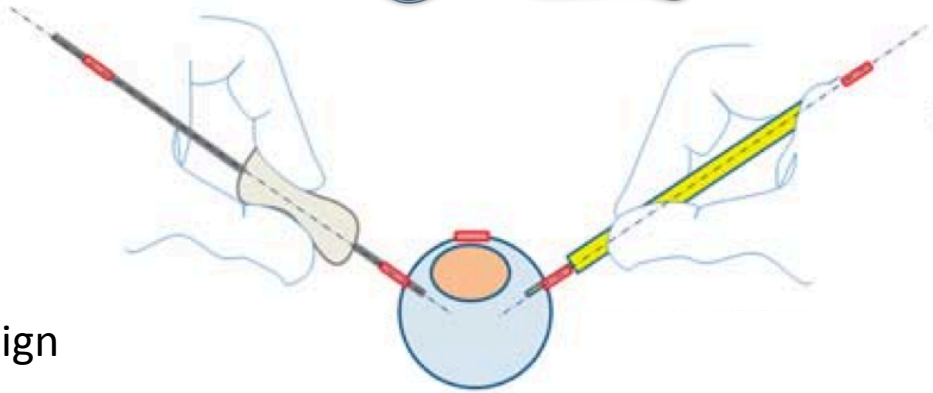


Figure from Hubschman et al

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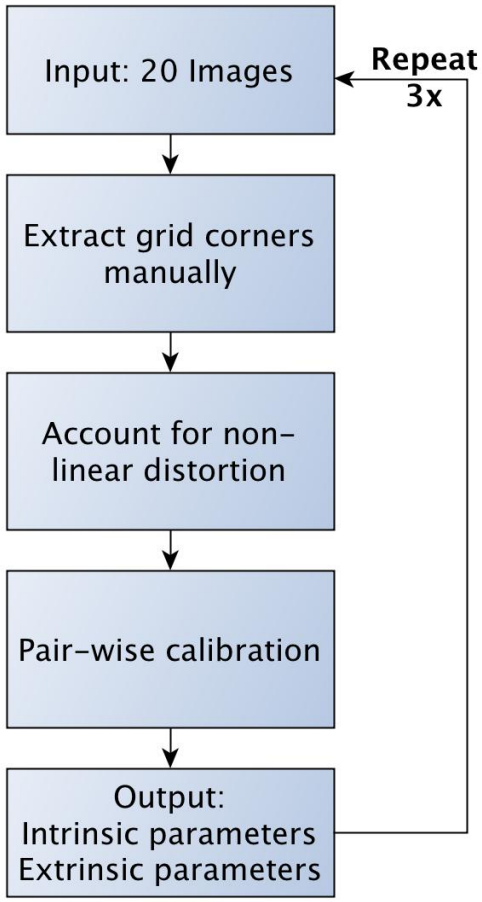
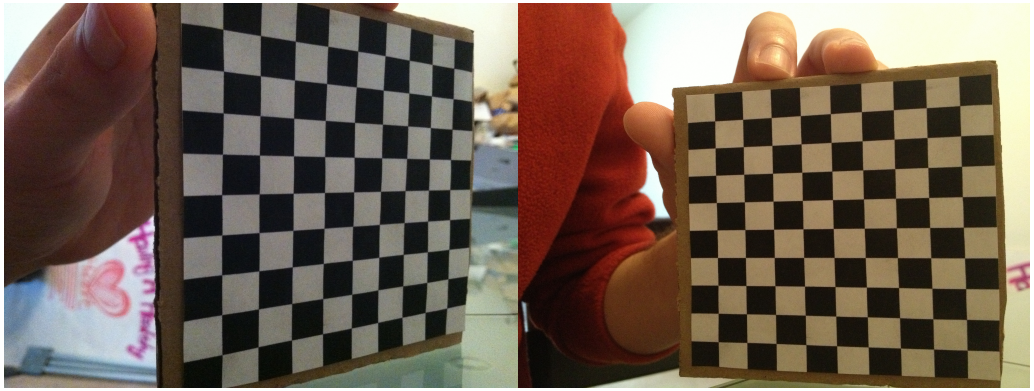
Progress: Tracking Design

Step 1: Calibration





Calibration Test:

- Compare intrinsic parameters of single to multi-camera calibration
- Compare measured distance between cameras to extrinsic parameters

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Progress: Tracking Design

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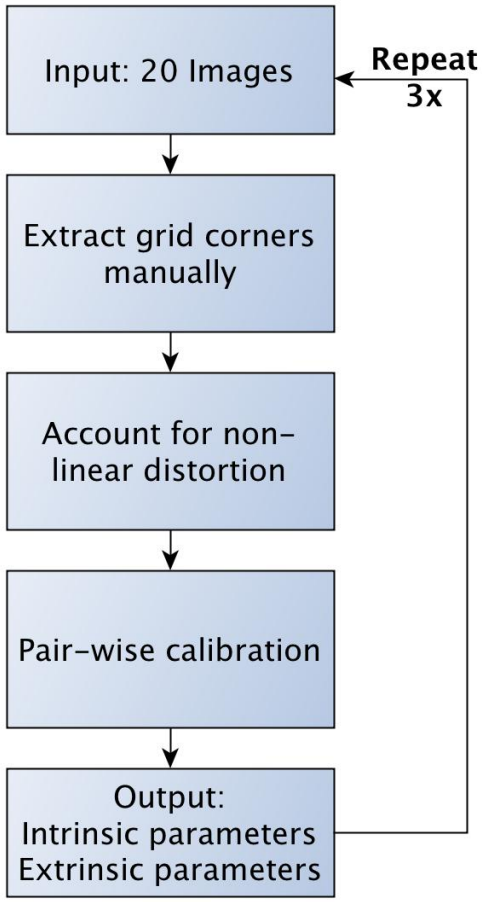

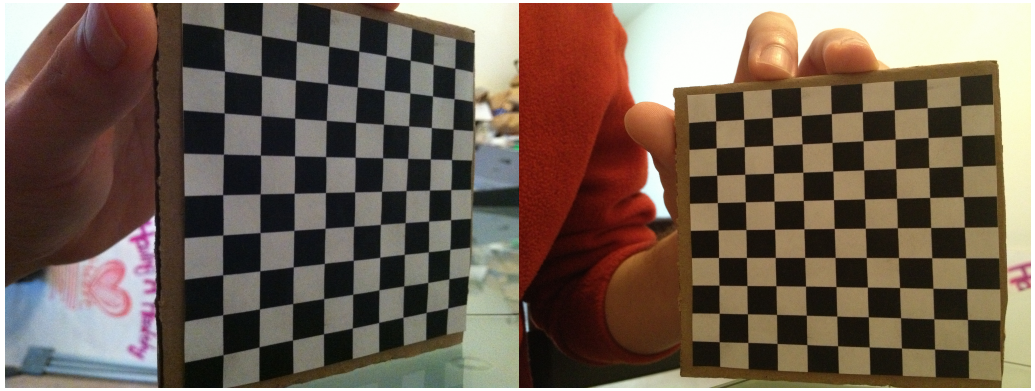

Alternative Approach:

- Use Balazs' code to calculate H from 6 points
- Create GUI to manually select pixels
- Write code to extract R and T from H
- Added Dependency: OpenCV

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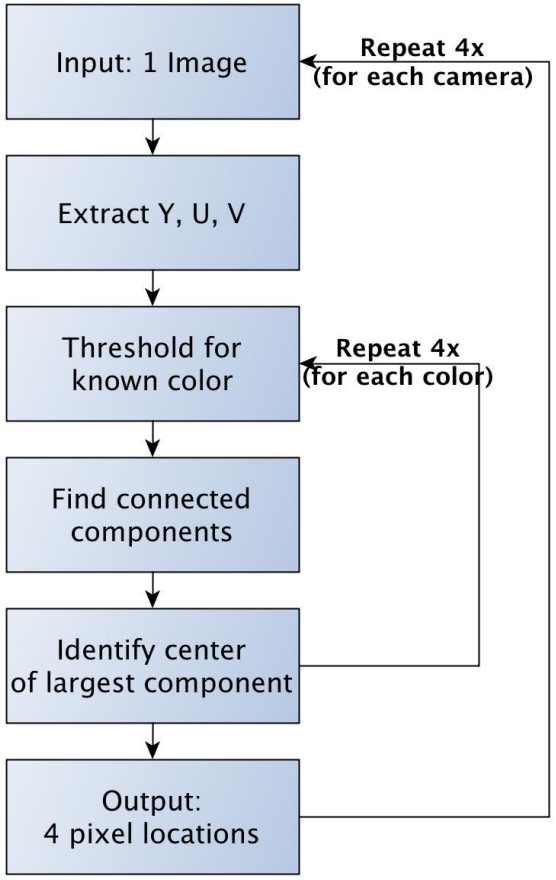
Progress: Tracking Design

Step 2: Detection

Threshold:
- Discretized color space such that a range of values = a color
- Pixel Color = YClass[Y] & UClass[U] & VClass[V]

Connected Components:
- 2 runs of a tree-based union

Detection Test:
- Segment for trocars and markers
- Mask to original image
- Overlay and compare



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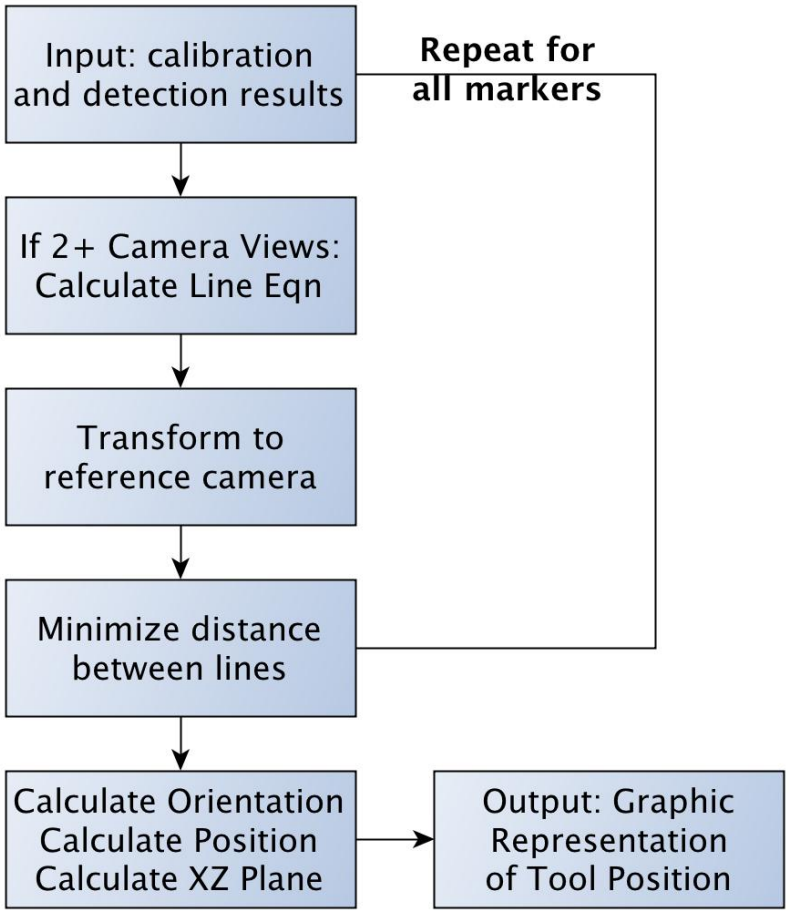
Progress: Tracking Design



Step 3: 3D Point Reconstruction

Tracking Test:

-Use Steady Hand Eye Robot for accuracy

- Move from position A to position B with known distance apart

- Calculate tool positions and compare to distance

Effects on Segmentation:

- Based on previous tool position, create bounding box

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Deliverables

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Minimum (3/18)	Expected (4/26)	Maximum (5/13)
CAD design of prototype	A scaled prototype	Life-size prototype
Design of phantom	A scaled phantom	Life-size phantom
Specifications of equipment	Offline multi-camera calibration	Evaluation of tracking accuracy
Calibration scheme	Offline segmentation/ tracking algorithms	Real-time tracking
Segmentation/tracking scheme		

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Deliverables

Minimum (3/18)		Expected (4/26)	Maximum (5/13)	
CAD design of prototype		A scaled prototype	Life-size prototype	✖
Design of phantom	✔	A scaled phantom	Life-size phantom	✖
Specifications of equipment	✔	Offline multi-camera calibration	Evaluation of tracking accuracy	
Calibration scheme	✔	Offline detection/tracking algorithms	Real-time tracking	
Detection/tracking scheme	✔			

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Dependencies

Dependency	Proposed Solution	Due Date
Ophthalmic Surgery Observation	Schedule through Marcin Balicki Acquire videos online	2/25 3/4
Access to Expertise	Weekly mentor meetings Survey literature	2/14 3/11
CISST Libraries	Training with Balazs Vagvolgyi If not, custom libraries as needed	3/4
Other Off-the-shelf Libraries	Research and plan accordingly Back-up plan: Implement on our own	3/11
Access to Steady Hand Eye Robot	Get initial plan approved Schedule through Marcin Balicki	3/11 4/8
Equipment	Evaluate constraints Purchase off-the-shelf components (OTC)	3/4 3/11
Funding	Propose budget plan to Dr. Taylor	3/4

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Access to Expertise	Weekly mentor meetings Survey literature	2/14 3/11	✔ ✔
CISST Libraries	Training with Balazs Vagvolgyi If not, custom libraries as needed	3/4	✖
Other Off-the-shelf Libraries **OpenCV**	Research and plan accordingly Back-up plan: Implement on our own	~~3/11~~ **4/1**	✖
Access to Steady Hand Eye Robot	Get initial plan approved Schedule through Marcin Balicki	3/11 4/8	✔ ✖
Equipment	Evaluate constraints Purchase off-the-shelf components (OTC)	3/4 3/11	✔ ✔
Funding	Propose budget plan to Dr. Taylor	3/4	✔
Parallel Camera Function	**Determine cause and plan accordingly**	**4/8**	✖

Milestones

Date	Milestones	Responsibility	Status
3/11	Offline Tracking System Design (Sue)	-Calibration Scheme -Segmentation Scheme -Tracking Scheme	Done
3/18	Design of Prototype and Phantom(Yejin)	-Conceptual design of Eye and Face -CAD of the prototype	In Progress *(Delayed)*
4/1	Build Phantom (Yejin)	-Build & attach eye to platform -Build & attach skull and nose to platform	In Progress
4/1	Calibration Implementation (Sue)	-Implement single camera/multi camera calibration -Run test to verify success	In Progress

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Milestones

Date	Milestones	Responsibility	Status
3/11	Offline Tracking System Design (Sue)	-Calibration Scheme ✔ -Segmentation Scheme ✔ -Tracking Scheme ✔	Done
~~3/18~~ **4/8**	Design of Prototype and Phantom(Yejin)	-Conceptual design of Eye and Face ✔ -CAD of the prototype	In Progress *(Delayed)*
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Milestones

Date	Milestones	Responsibility	Status
4/8	Prototype of Device (Yejin)	-Rapid prototype goggle device -Rigidly attach cameras -Attach miscellaneous fixtures	Not Done
4/15	Test of Segmentation (Sue)	-Implement Segmentation Method -Run test to verify success	Not Done
4/29	Test of Tracking Implementation (Sue)	-Implement tracking algorithm -Run test to verify success	Not Done
5/13	Evaluation of Micro-Surgical Tracker(Yejin)	-Static tool coordinate accuracy -Dynamic tool coordinate accuracy -Miscellaneous accuracy	Not Done

Reading List

Clinical Background:

J. D. Pitcher, J. T. Wilson, S. D. Schwartz, and J. Hubschman, “Robotic Eye Surgery: Past, Present, and Future,” J Comput Sci Syst Biol, pp. 1–4, 2012.

Neily, Mills, et al. "Incorrect Surgical Procedures Within and Outside of the Operating Room." Archives of Surgery 16 Nov. 2009: Vol. 144, No.11:1028-1034. Web. 12 Feb. 2013

Mechanical Design Constraints:

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M. Nasseri, E. Dean, S. Nair, and M. Eder, “Clinical Motion Tracking and Motion Analysis during Ophthalmic Surgery using Electromagnetic Tracking System,” in 5th International Conference on BioMedical Engineering and Informatics (BMEI 2012). 2012.

G. M. Saleh, G. Voyatzis, Y. Voyazis, J. Hance, J. Ratnasothy, and A. Darzi, “Evaluating surgical dexterity during corneal suturing.,” Archives of ophthalmology, vol. 124, no. 9, pp. 1263–6, Sep. 2006.

K. Guerin, G. Vagvolgyi, A. Deguet, C.C.G. Chen, D. Yuh, and R. Kumar, "ReachIN: A Modular Vision Based Interface for Teleoperation," in the MIDAS Journal - Computer Assisted Intervention, Aug. 2010.

Reading List

Calibration:

J. Y. Bouguet. Camera Calibration Toolbox for Matlab. 2008.

Tomas Svoboda. A Software for Complete Calibration of MultiCamera Systems. Talk given at MIT CSAIL. Jan 25, 2005.

A. Borkar, M. Hayes, and M. T. Smith, "A Non Overlapping Camera Network: Calibration and Application Towards Lane Departure Warning" IPCV 2011: Proceedings of the 15th International Conference on Image Processing, Computer Vision, and Pattern Recognition. 2011.

Segmentation:

J. Bruce, T. Balch, and M. Veloso, “Fast and inexpensive color image segmentation for interactive robots,” in Proc. IEEE Intl. Conf. Intell. Robot. Syst., 2000, pp. 2061–2066.

M. K. Hu, “Visual pattern recognition by moment invariants,” Information Theory, IRE Transactions on, vol. 8, no. 2, pp. 179–187, 1962.

Y. Deng. “Color Image Segmentation.” Computer Vision and Pattern Recognition, 1999 IEEE Computer Society Conference.

Tracking:

K. Zimmermann, J. Matas, and T. Svoboda. "Tracking by an Optimal Sequence of Linear Predictors." IEEE Transactions on Pattern Analysis and Machine Intelligence. 31(4), 2009

A. Yilmaz, O. Javed, M. Shah. “Object tracking: A survey.” ACM Computing Surveys Volume 38 Issue 4, Article No. 13. 2006.

Questions?