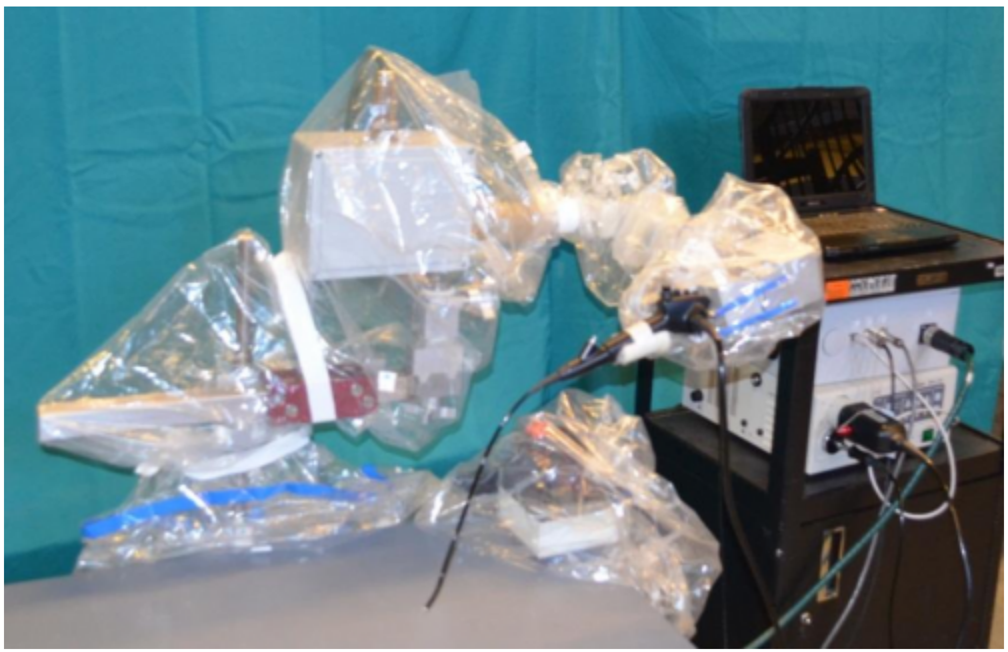
<Robo-ELF>

Human Subject Study, Controller, Computer Vision Tools



Courtesy of Kevin Olds

Mentors

Kevin Olds

Dr. Richmon

Members

Jong Heun Kim (BME)

Tae Soo Kim (CS)

Steve Park (ME)

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Project Goal

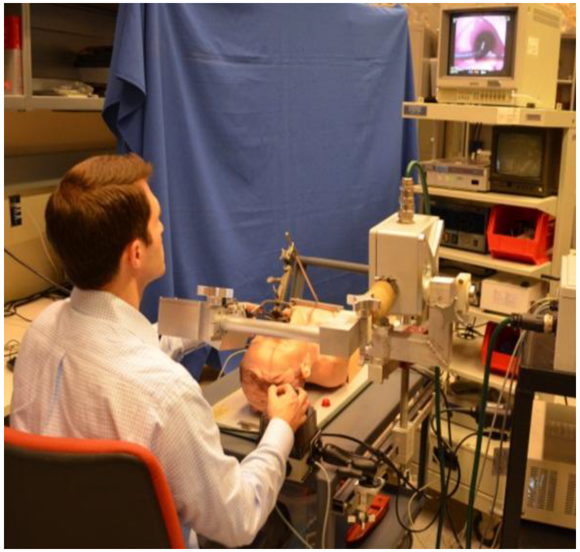
1. Program capable of providing quantitative endoscopic measurements from several monocular endoscopic images

2. Create ergonomic controller for the robot

3. Acquire clinical experimental data.

Background/Relevance

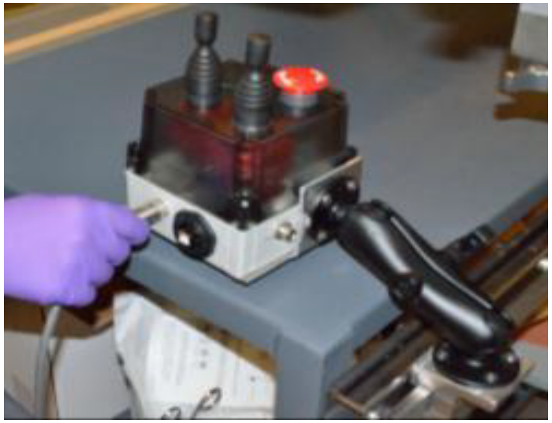
- Robo-ELF stands for **R**obotic **E**ndo-**L**aryngeal **F**lexible scope system
- Rigid Endoscope vs Flexible Endoscope
- Significances
  - Three active and two passive DOF
  - Keep the scope rigidly in place
  - overcome line of sight constraints
  - Allows one or two handed operations



**Courtesy of Kevin Olds*

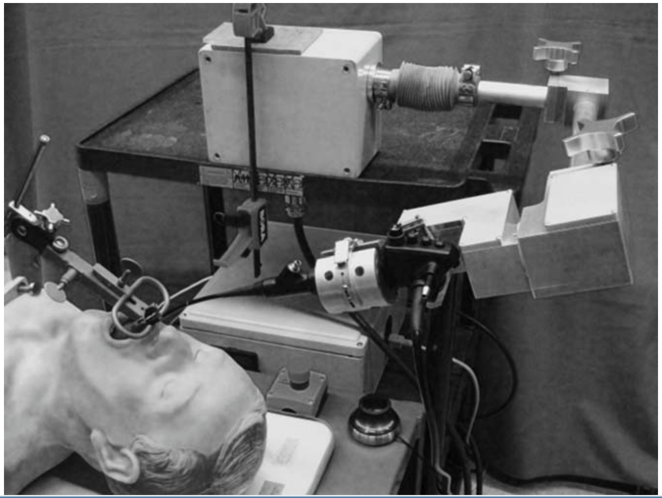
Background/Relevance (Cont.)

- Current Drawbacks
  - Bulky and not-so-ergonomic joystick
    - Digital (only On/Off states)
  - Endotracheal tube insertion for measurements.



Background/Relevance (Cont.)

- Current Drawbacks
  - ~~Bulky and not-so-ergonomic joystick~~
    Design a new intuitive and ergonomic controller.
  - ~~Endotracheal tube insertion for measurements.~~
    Endoscopic measurement software



Technical Approach (Human Subject Study)

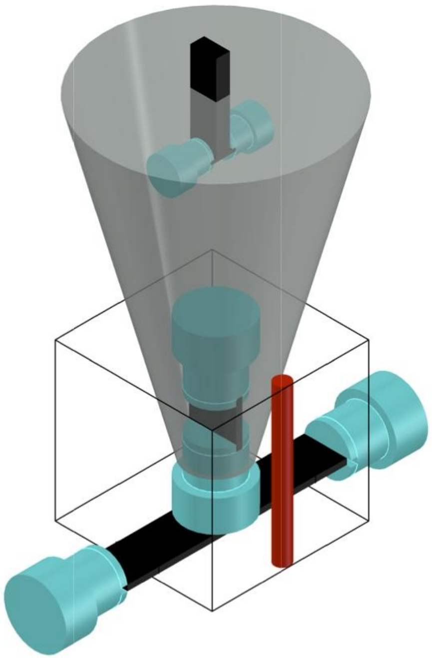
- To prove Robo-ELF as a superior system
- Knowledge of IRB protocols
  - tasks to test performance
- Full proficiency in setting up/ taking down of Robo-ELF
- Get appropriate training
- Tuning the robot for clinical use

Technical Approach (Joystick)

- A new joystick design **must** have…
  - Intuitive control interface
  - Small and easy to operate with one hand
  - Self reorientation
    (velocity control vs. position control)
  - Haptic feedback
  - Analog sensing instead of digital
  - Redundant input for safety
  - Cheap

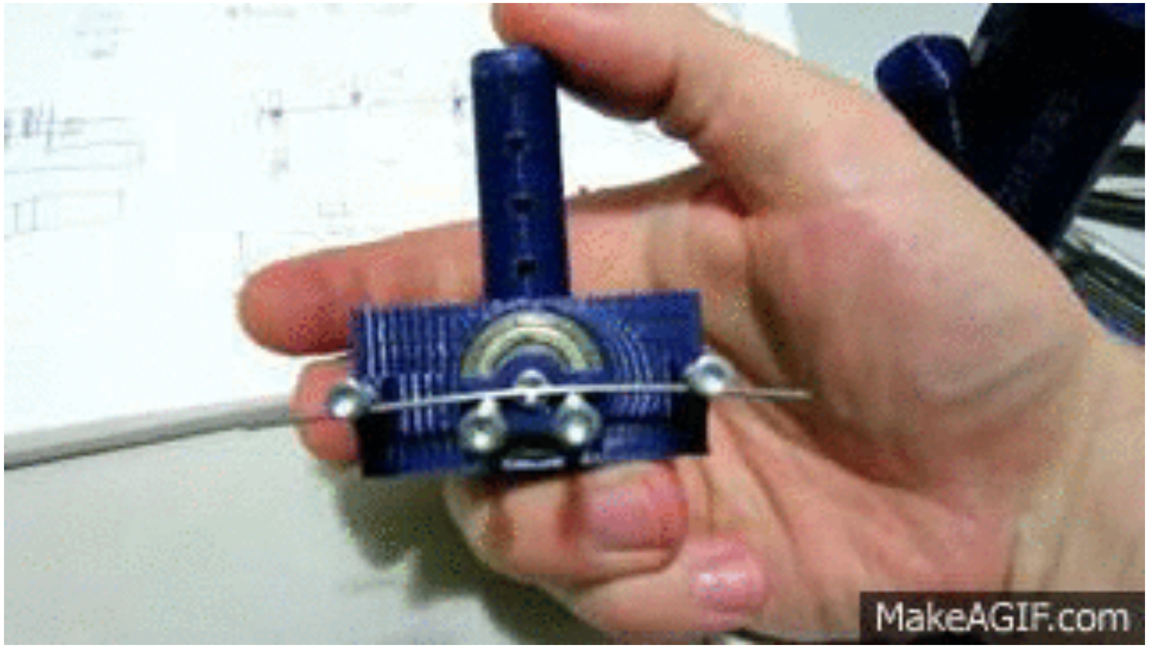
Technical Approach (Joystick)

- Intuitive control interface/Small and easy to operate with one hand



Technical Approach (Joystick)

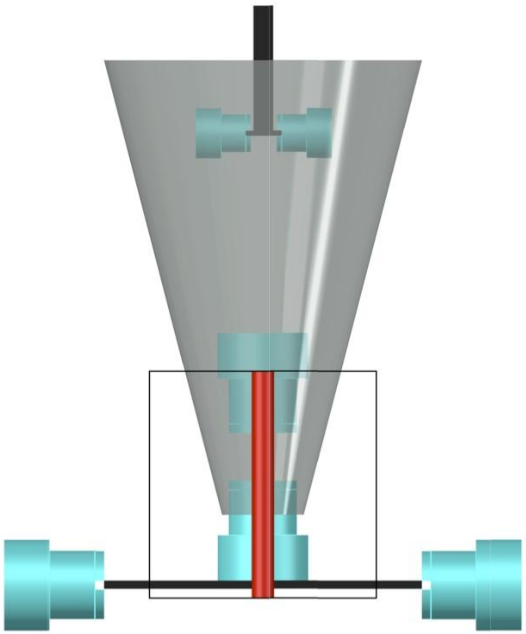
- Self reorientation/Haptic feedback
  - Gimbal System



https://www.youtube.com/watch?v=zIc_aMcjkkA

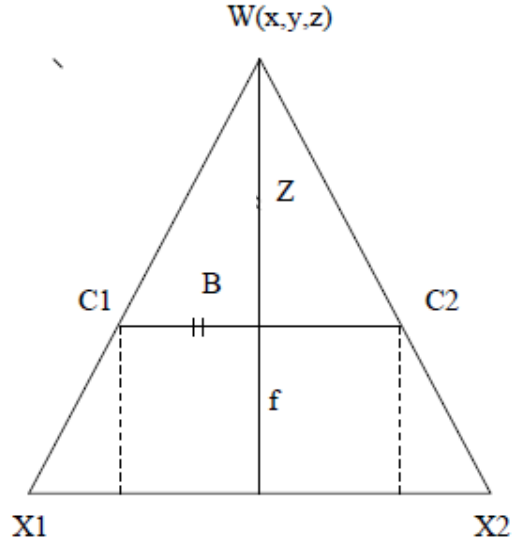
Technical Approach (Joystick)

- Analog sensing instead of digital
  - Pair of Potentiometer for redundancy



3D Distance From 2D Scope Images

- Intuition: Stereo Vision



$Z = depth$

$$Z = \frac{f * B}{x_1 + x_2}$$

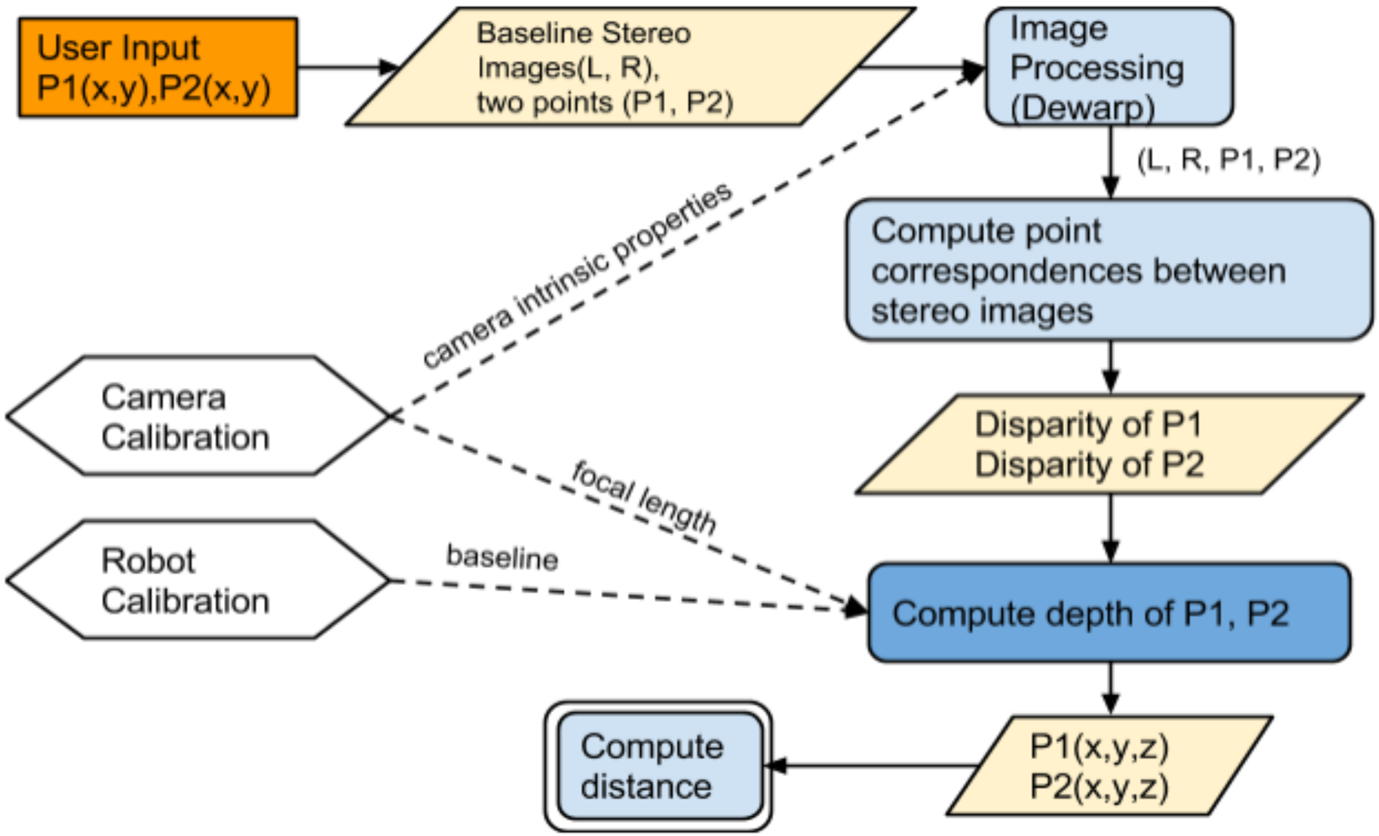
$$x_1 + x_2 = \text{disparity} = d$$

Figure 6.1: Stereo geometry.

Image courtesy of Prof. Mubarak Shah
of University of Central Florida

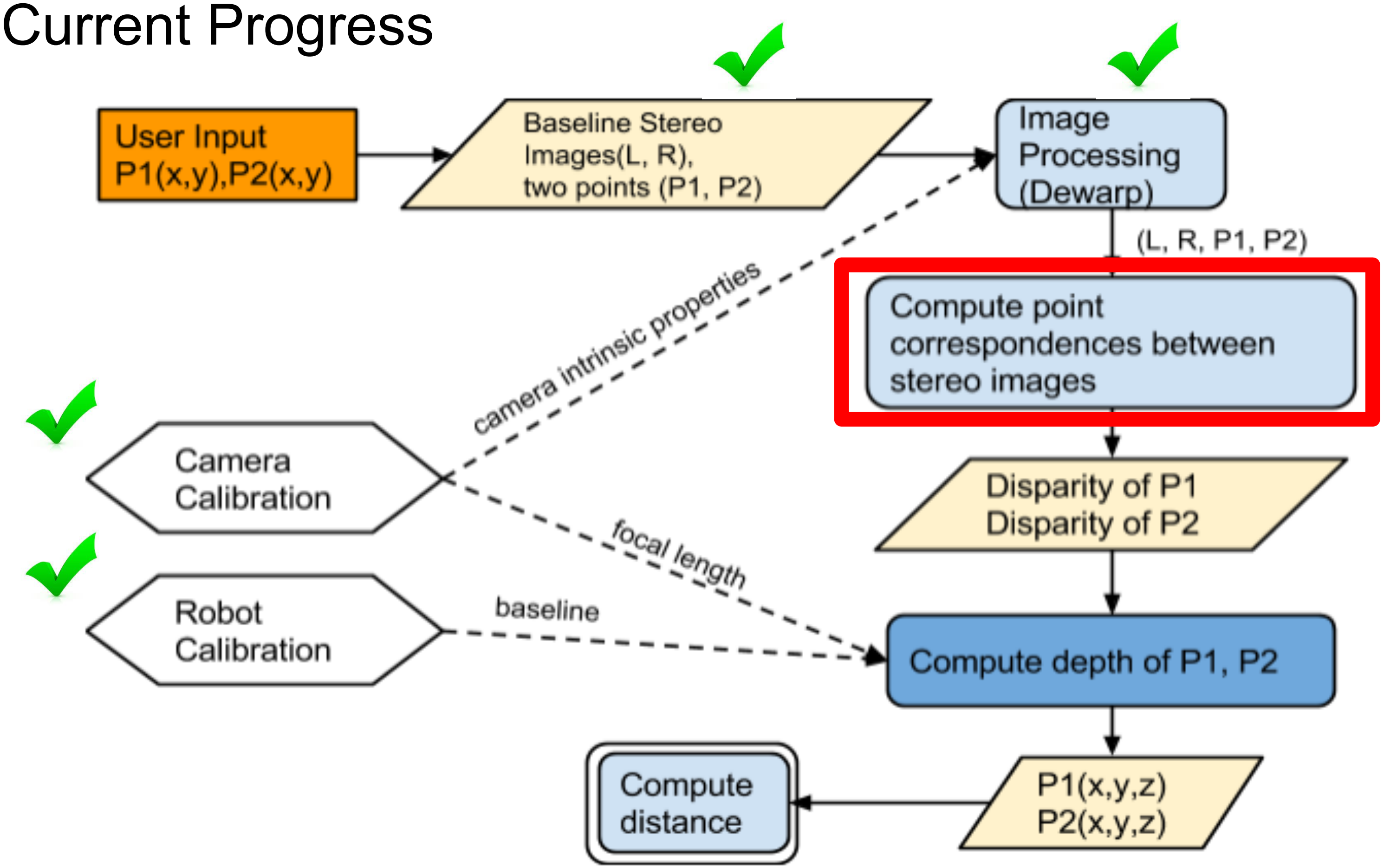
3D Distance From 2D Scope Images

- Workflow



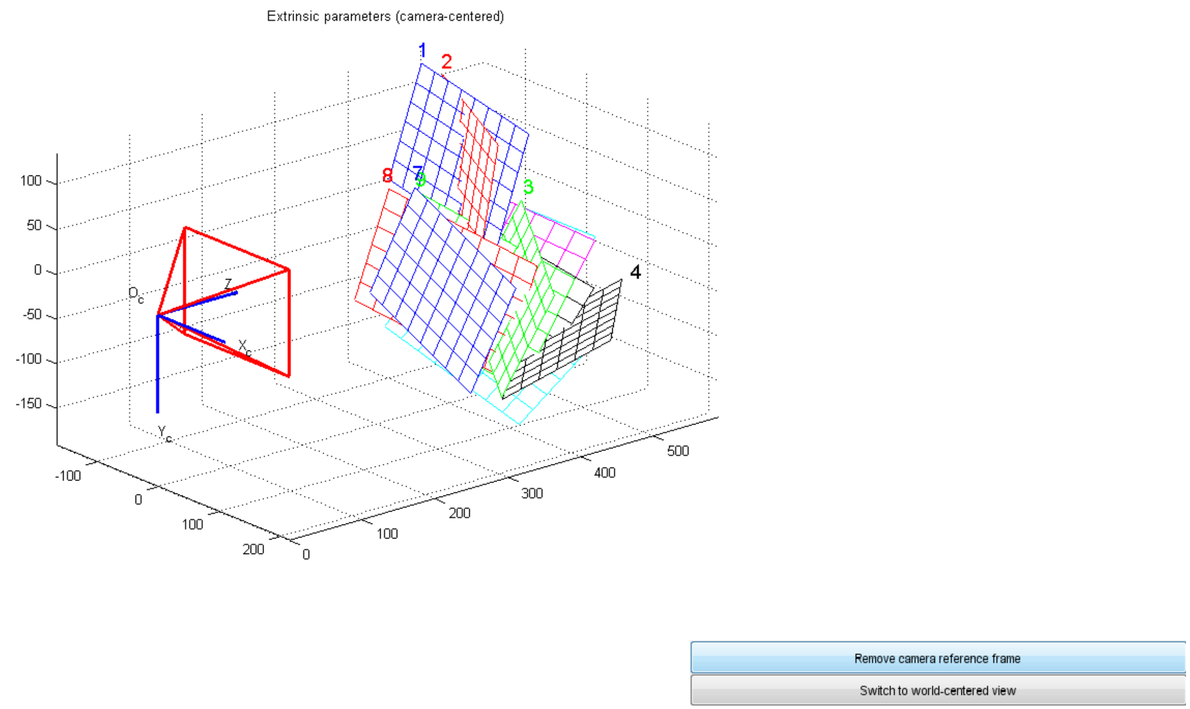
3D Distance From 2D Scope Images

- Current Progress



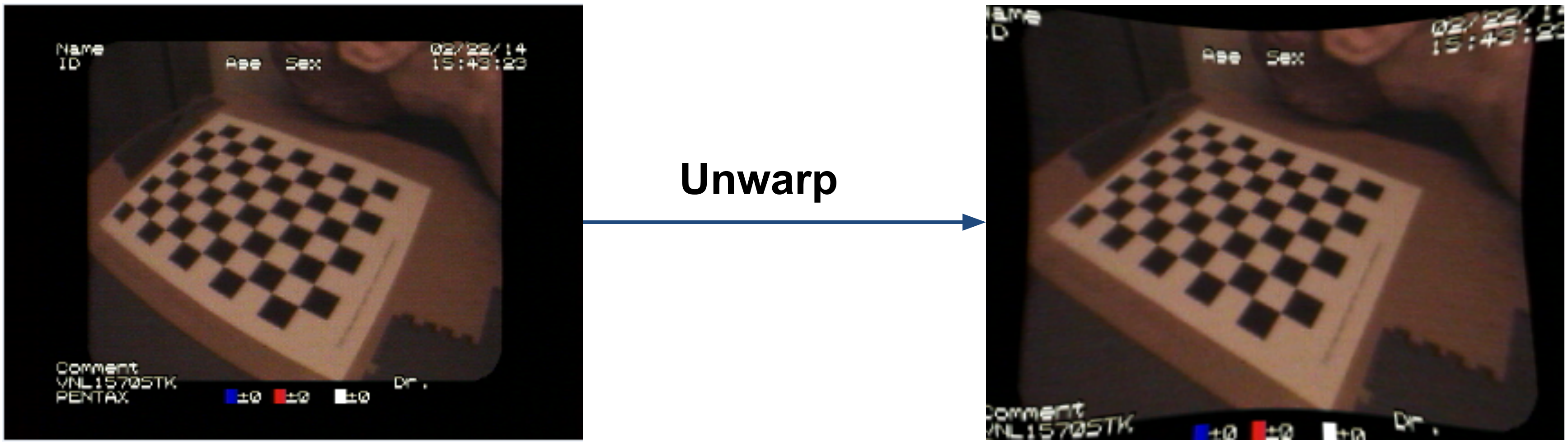
Current Progress

- Camera calibration → Camera parameters



Current Progress

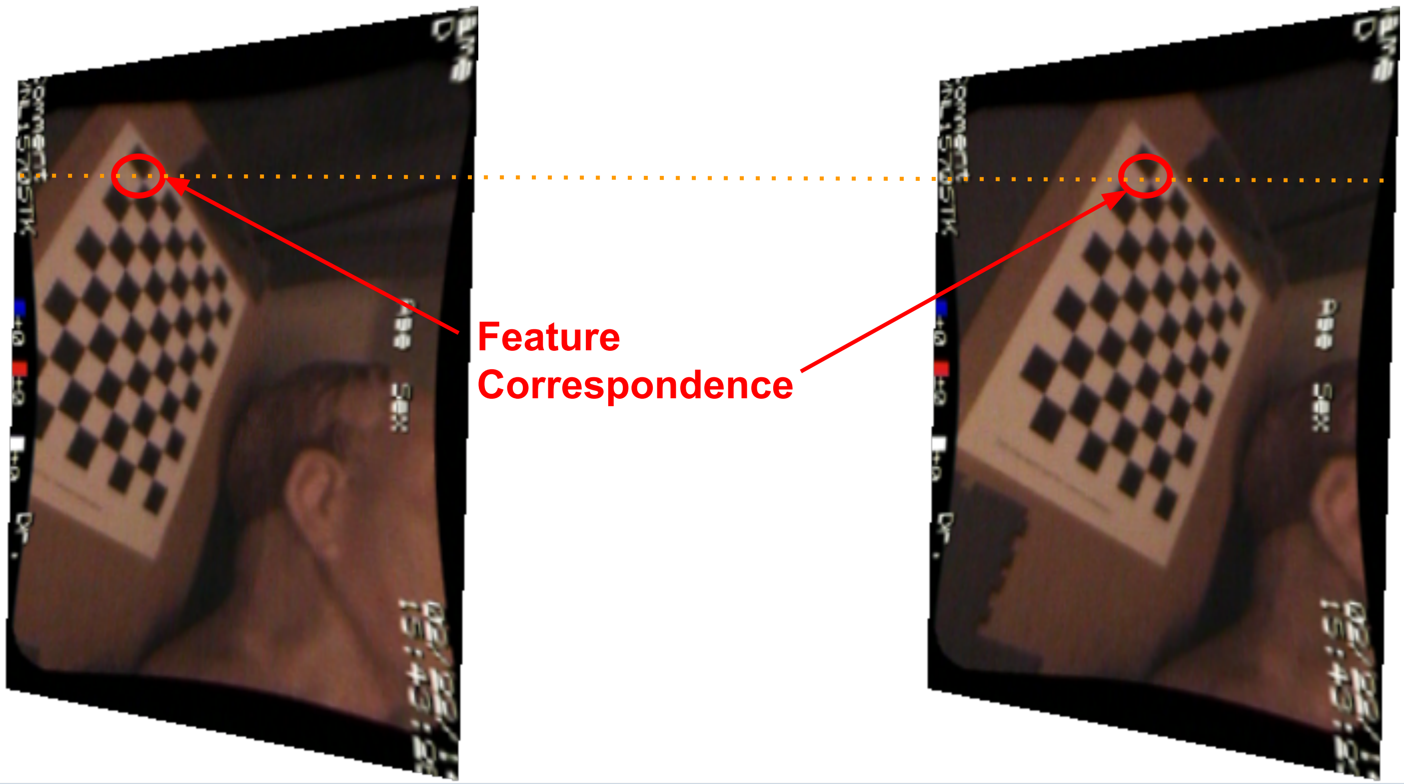
- Image unwarping using camera's intrinsic parameters



Current Progress

- Stereo image rectification + correspondence

Left image | Right image



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Deliverables

1) **Minimum (estimated March 26, 2014):**
   A. Assist Dr. Richmon in using the Robo-ELF Scope in the OR.
   B. A fully designed ergonomic controller for the Robo-ELF Scope manipulation.
   C. Documentation for the Robo-ELF Scope controller
   D. Software to get real measurements from 2D scope images of an artificial setting + software documentation
2) **Expected (estimated April 30, 2014):**
   A. Fully interfaced and functioning ergonomic controller with the Robo-ELF.
   B. Software to get real measurements from 2D scope images of the larynx.
   C. Software documentation
3) **Maximum (estimated May 07, 2014)**
   A. Identify the disadvantages with the current prototype (feedback from surgeons) and produce an improved version of the controller.
   B. Software that reconstructs a 3D model from the 2D scope images.

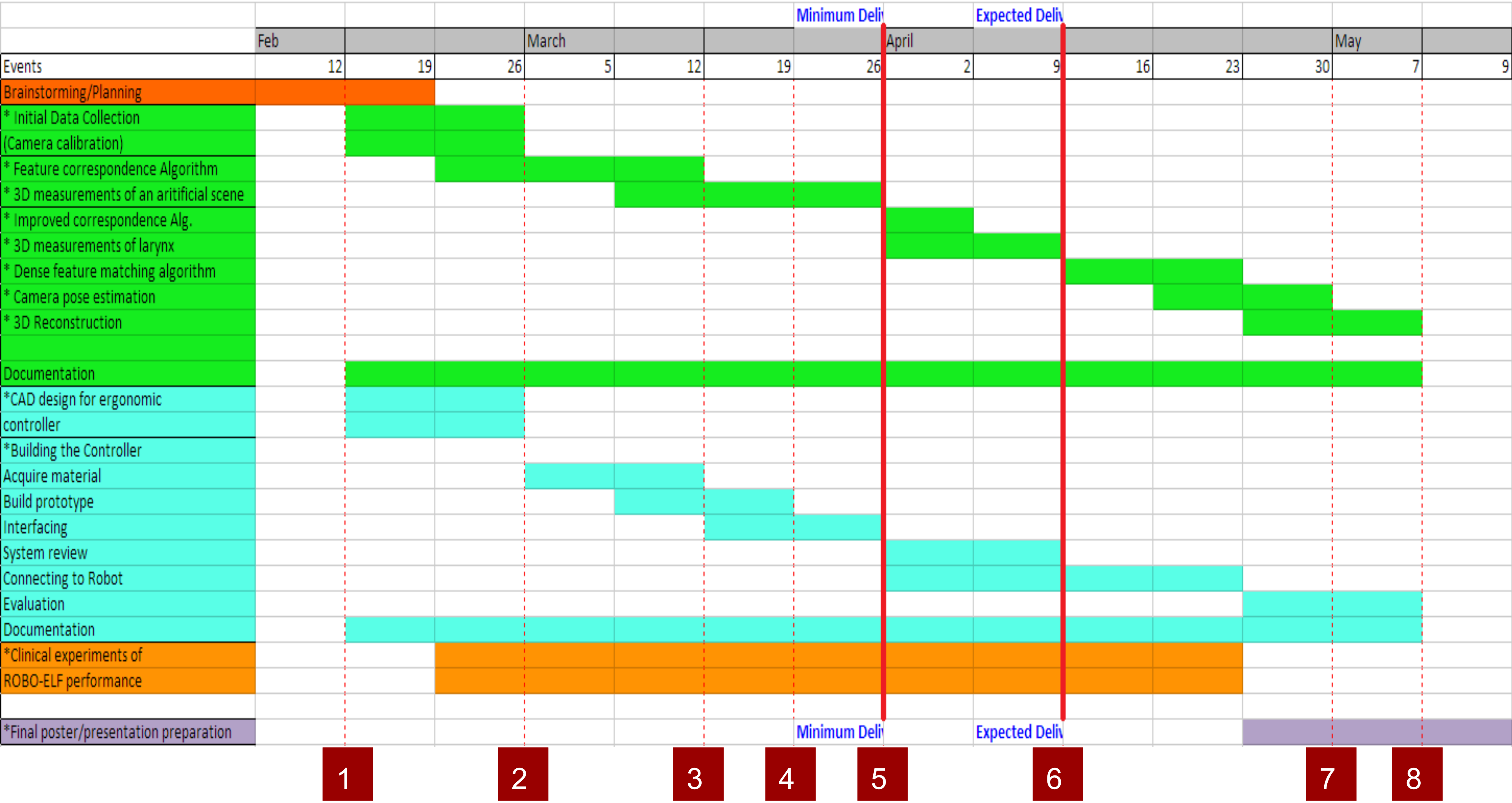
Dependencies

- ✔ **Access to Robo-ELF**
- ✔ **JHU IRB approval**
    - Just approved!
- ✔ **Medical consult & OR visit**
- ✔ **Images from the scope**
- ✔ **Software for 3D reconstruction**
    - OpenCV, Matlab
- ✔ **Cost**
    - The project is already funded by Johns Hopkins Hospital Department of Otolaryngology and Johns Hopkins University Internal Funds.
    - Will be funded up to $1000 (but most likely not have to spend over $300)

Milestones

	Milestone	Planned Date	Expected Date	Status
1	Scope image data collection	Feb. 12	Feb. 12	**Completed**
	Camera calibration	Feb. 26	Feb. 12	**Completed**
	Robot calibration	Feb. 26	Feb. 20	**Completed**
2	Initial CAD design of the controller	Feb. 26	Feb. 24	**Completed**
3	Order and acquire all controller parts	Mar. 12	Mar. 12	In progress
4	Build prototype	Mar. 19	Mar. 19	
	Interfacing with the robot	Mar. 26	Mar. 24	
5	3D distance from 2D scope images of an artificial scene	Mar. 26	Mar. 12	In progress
	Minimum deliverable met			
	3D distance from 2D scope images of the larynx	Apr. 09	Apr. 09	
	Expected deliverable met			
6	Get input from Dr.Richmon about the controller	Apr. 09	Apr. 09	
7	3D reconstruction of an artificial scene using the scope images	Apr. 30	Apr. 30	
8	3D reconstruction of the larynx	May. 07	May. 07	

Timeline


Minimum Deliv
Expected Deliv
Feb
March
April
May
Events
12
19
26
5
12
19
26
2
9
16
23
30
7
9
Brainstorming/Planning
* Initial Data Collection
(Camera calibration)
* Feature correspondence Algorithm
* 3D measurements of an aritificial scene
* Improved correspondence Alg.
* 3D measurements of larynx
* Dense feature matching algorithm
* Camera pose estimation
* 3D Reconstruction
Documentation
*CAD design for ergonomic
controller
*Building the Controller
Acquire material
Build prototype
Interfacing
System review
Connecting to Robot
Evaluation
Documentation
*Clinical experiments of
ROBO-ELF performance
*Final poster/presentation preparation
Minimum Deliv
Expected Deliv
1
2
3
4
5
6
7
8

Management

- Weekly meeting with Kevin Olds (Wed 3pm).
- Bi-weekly team meetings.
- **Tae Soo Kim**: Computer Vision Component
- **Jong Heun Kim**: Human Subject Study
- **Steve Park**: Ergonomic Controller

Reading List

1) Darius Burschka, Ming Li, Russell Taylor, and Gregory D. Hager. Scale-Invariant Registration of Monocular Stereo Images to 3D Surface Models. In *Proceedings of IROS*, pages 2581-2586, 2004.
2) Darius Burschka and Gregory D. Hager. V-GPS – Image-Based Control for 3D Guidance Systems. In *Proc. of IROS, pages 1789*–1795, October 2003.
3) Darius Burschka and Gregory D. Hager. V-GPS(SLAM): – Vision-Based Inertial System for Mobile Robots. In *Proc. of ICRA, April* 2004.
4) Olof Enqvist, Fredrik Kahl, Carl Olsson. 2011. Non-Sequential Structure from Motion. *Computer Vision Workshops (ICCV Workshops), 2011 IEEE International Conference*. p. 264-271.
5) Daniel Mirota, Russell H. Taylor, Masaru Ishii, and Gregory D. Hager. Direct endoscopic video registration for sinus surgery. In *Medical Imaging 2009: Visualization, Image-guided Procedures and Modeling. Proceedings of the SPIE*, volume 7261, pages 72612K-1 - 72612K-8, February 2009.
6) Kevin Olds, Alexander T. Hillel, Elizabeth Cha, Martin Curry, Lee M. Akst, Russell H. Taylor, Jeremy D. Richmon. Robotic Endolaryngeal Flexible (Robo-ELF) Scope: A Preclinical Feasibility Study. *The Laryngoscope*; 2011; 121; 2371-2374
7) Toan D. Pham, Rucker Ashmore, Lisa Rotelli. 2011. Proportional joystick with integral switch. U.S. Patent 7931101, filed October 13, 2006, and issued April 26, 2011.
8) Hanzi Wang, Daniel Mirota, and Gregory D. Hager. A generalized kernel consensus based robust estimator. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 32(1):178-184, 2010.
9) William M. Wells III, Paul Viola, Hideki Atsumi, Shin Nakajima, Ron Kikinis. 1996. Multi-modal volume registration by maximization of mutual information. *Medical Image Analysis*. v. 1. p 35–51.

Thank you.
Questions?