Image Processing for Video-CT Registration in Sinus Surgery

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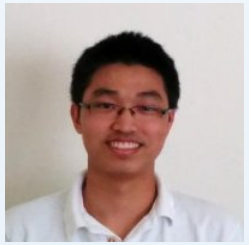
Team Members and Mentors

Team Members

Calvin Zhao
Biomedical Engineering 2015



Kyle Xiong
Biomedical Engineering 2015

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Mentors

Austin Reiter
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Overview

- Relevance
- Technical Summary
  - Contour Detection
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    - Single Image detection
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  - Augmented Reality
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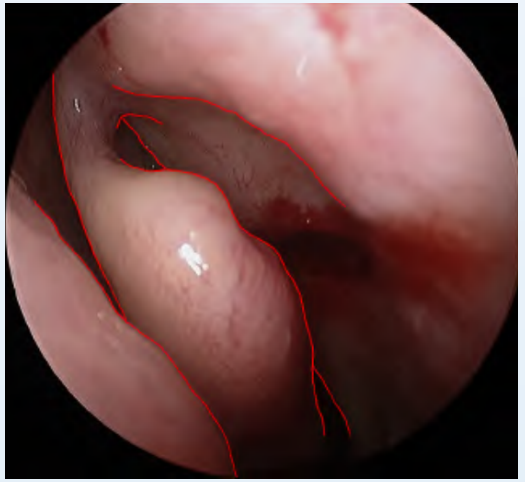
Relevance

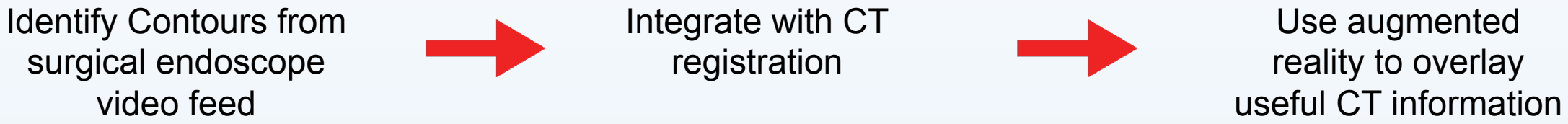
- Magnetic trackers are common in robotic microsurgery where maintaining line of sight is difficult.

Pros	Cons
Most are relatively inexpensive.	High interference, especially with metal instruments.
Does not require line of sight.	High resolution trackers are expensive.
	Cheaper ones are inaccurate

- Correlating high resolution CT scans with the endoscope video feed can greatly enhance registration precision. We can use image processing to find occluding contours as an alternative to using magnetic trackers.
- In the future, *physical trackers may not be necessary!* CT and video feed will provide adequate tracking on their own.



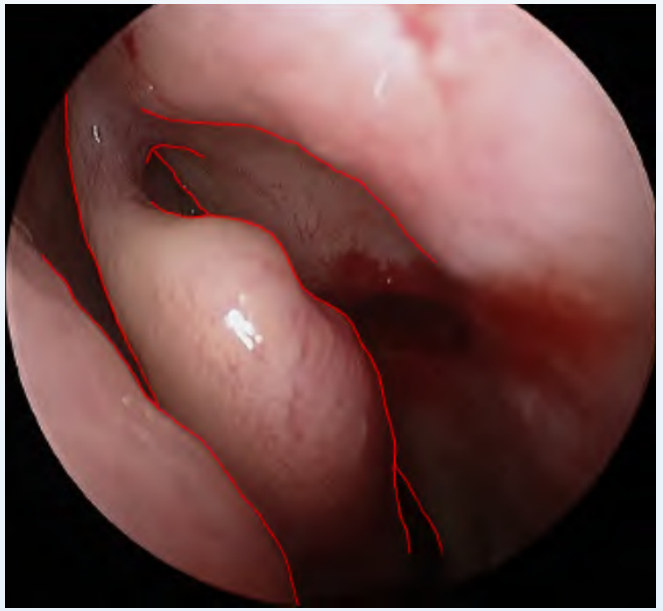
Technical Summary: Overview



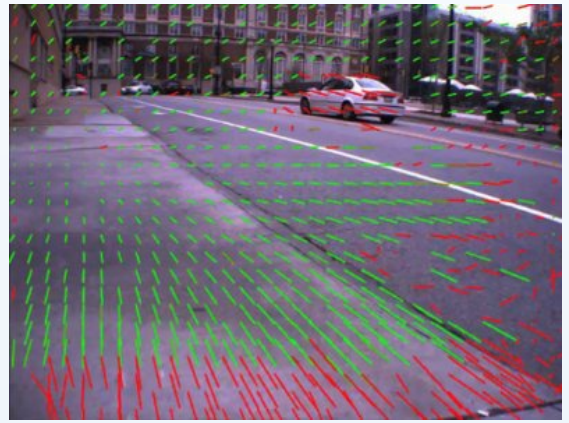
- Contour Detection: The goal of this project is to be able to rigorously register and track surgical tool position in CT coordinates by extracting occluding contours from video data.
- Integration: Contour detection will integrate with existing registration algorithm developed by Seth Billings
- Augmented Reality: AR overlay will be developed to provide real time information for the surgeon

Technical Summary: Contour Detection

- Existing methods of detecting contours are not optimized for sinus surgery video data.
- We aim to develop a new algorithm, based on existing algorithms, specifically to efficiently and accurately extract occluding contours.
- New algorithm will be initially written in MATLAB for testing and optimization
- Ultimately algorithm will be in C/C++ for real time feedback

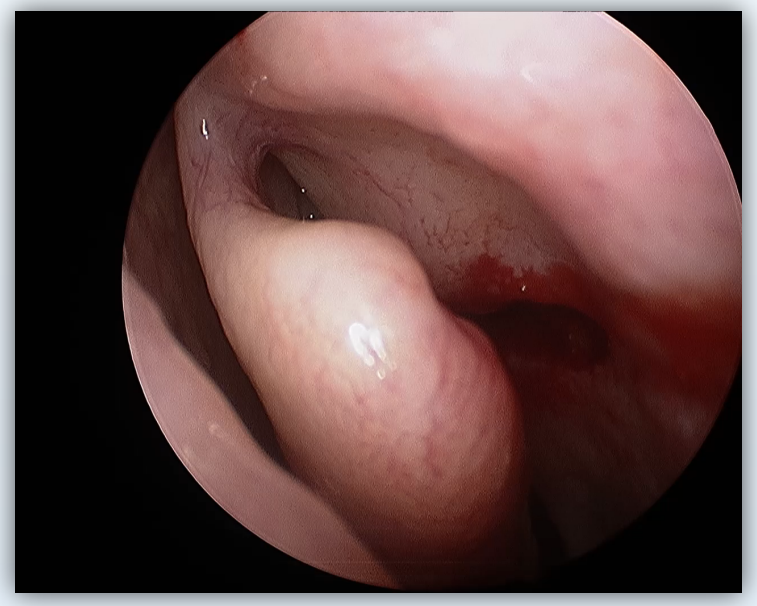


Technical Summary: Contour Detection



Plan A: Optical Flow for Occluding Contour Detection

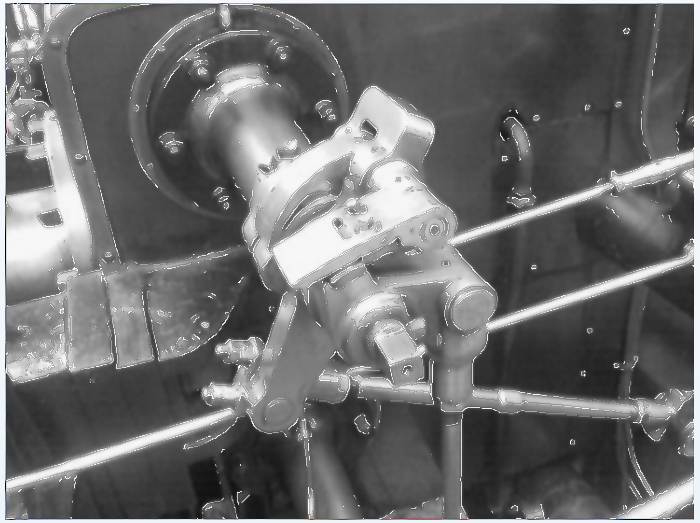
- Given a point (x,y) in one image, aim to find a point (x + Δx, y + Δy) in another image that matches the previous point.
- Examine vector change and magnitude to discern occlusion.
- Light source is well defined and constant so we can consider using pixel intensity (brightness) to help detect occlusion.



Technical Summary: Contour Detection

Plan B: Still-image detection for Occluding Contour Detection

- Retrain existing algorithms with sinus surgery data
  - Algorithms for still-image contour detection exist
  - Utilize color, texture, brightness gradients around each pixel
  - Use machine learning on surgical images to optimize



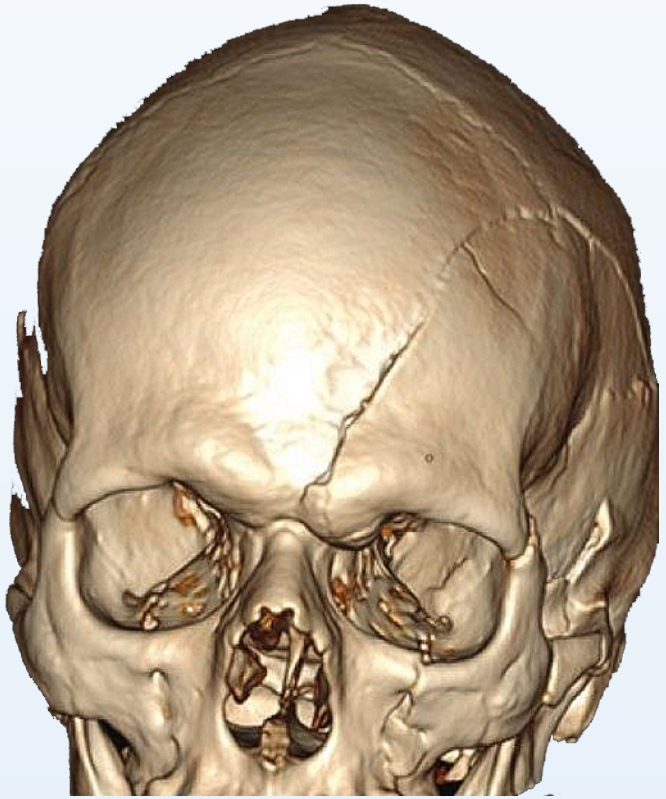
We decided to prioritize optical flow first to detect edges

Existing contour detection methods based on still-image detection aren't accurate with surgical video data

Using optical flow, we hope to derive better quality contours for video data

Technical Summary: Integration and AR

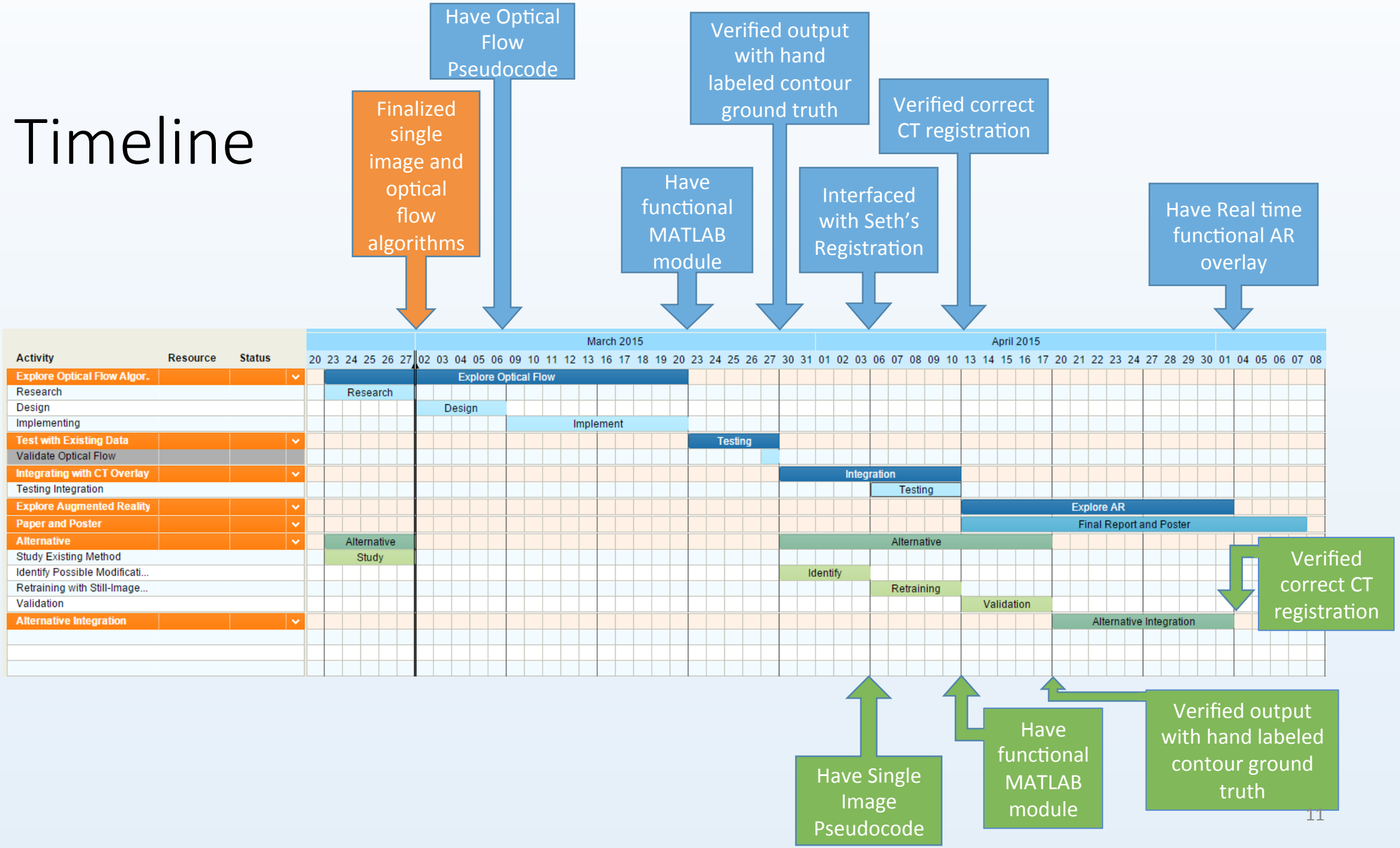
- When algorithm is complete we use an existing registration algorithm developed by Seth Billings to integrate contour detection with CT images.
- Once integration is complete and we develop an efficient algorithm, we will be able to use real-time contour detection to track the position of the tool tip in CT coordinates.
- We will use CT data with registration to overlay an augmented reality interface over the video in real time



Deliverables

- Minimum: Develop algorithm for accurately and efficiently extracting occluding contours from surgical videos.
- Expected: A registration algorithm based on our contour detection method that can track tool-tip position in real time using only video data and CT images.
- Maximum: Augmented reality software from real-time contour detection and video-CT registration to provide surgeon with useful information.

Timeline


Have Optical Flow Pseudocode
Finalized single image and optical flow algorithms
Verified output with hand labeled contour ground truth
Verified correct CT registration
Have functional MATLAB module
Interfaced with Seth's Registration
Have Real time functional AR overlay
Activity
Resource
Status
March 2015
April 2015
20 23 24 25 26 27 02 03 04 05 06 09 10 11 12 13 16 17 18 19 20 23 24 25 26 27 30 31 01 02 03 06 07 08 09 10 13 14 15 16 17 20 21 22 23 24 27 28 29 30 01 04 05 06 07 08
Explore Optical Flow Algor.
Explore Optical Flow
Research
Research
Design
Design
Implementing
Implement
Test with Existing Data
Testing
Validate Optical Flow
Integrating with CT Overlay
Integration
Testing Integration
Testing
Explore Augmented Reality
Explore AR
Paper and Poster
Final Report and Poster
Alternative
Alternative
Alternative
Study Existing Method
Study
Identify Possible Modificati...
Identify
Retraining with Still-Image...
Retraining
Validation
Validation
Alternative Integration
Alternative Integration
Verified correct CT registration
Have Single Image Pseudocode
Have functional MATLAB module
Verified output with hand labeled contour ground truth

Milestone Goal Summary

- Research: Decide on which technique we want to use and which paper(s) we will develop our algorithm from
- Design: Construct and modify a draft of our algorithm with pseudocode
- Implementation: Have a package that can successfully run contour detection on an image or video
- Testing: Make sure our package is successful with our surgical video data based on hand labeled ground truth
- Integration with CT Registration: Ensure our generated occlusion contours correctly register to the CT images
- Augmented Reality: Be able to track important landmarks that are occluded from view on an AR interface based on CT registration

Assigned Responsibilities

Team Member Responsibilities

John	Kyle	Calvin
Lead augmented reality, testing and debugging	Lead designing of optical flow algorithm	Lead integration with registration algorithm
Track milestone progress	MATLAB implementation of optical flow algorithm	Lead alternative method (if optical flow fails)
Manage Git branches	Optimization of optical flow algorithm	Implementation of modifications
MATLAB implementation	C/C++ implementation of optimized algorithm	MATLAB implementation

Dependencies

Minimum

- Sinus surgery videos
  - Provided by Dr. Reiter
- Coffee

Expected

- Video-CT Registration algorithm from Seth Billings
  - Collaboration with Seth to make sure our algorithm interfaces with his
- Sinus Surgery video with corresponding CT data

Maximum

- DirectX software from Seth Billings
  - To implement for AR overlay

Management Plan

- Git: version control
- Podio: track milestone progress
- Weekly team meetings (Fridays @ 3PM)
- Weekly mentor meetings (Wednesday @ 10:30AM)
- Assigned leaders for each phase

Reading List

- "Determining Optical Flow", Proc. SPIE 0281, Techniques and Applications of Image Understanding, 319 (November 12, 1981); doi: 10.1117/12.965761
- “Contour Detection and Hierarchical Image Segmentation”, Arbelaez P., Fowlkes C., IEEE, Pattern Analysis and Machine Intelligence, Vol. 33, Issue 5 (March 22, 2011)
- Other papers as necessary, reading list is tentative before research phase.