

# Image Processing for Video-CT Registration in Sinus Surgery

## Project Proposal

Group 11

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### **1. Introduction**

Our project is “Image Processing for Video-CT Registration in Sinus Surgery” and its goal is to ultimately develop software that provides information about the surgery to the surgeon intraoperatively. For example, the software will be able to inform the surgeon where the optical nerve is so he won’t accidentally damage it. The project will begin with the team developing an algorithm to extract occluding contours from surgical video data. After detecting and tracking the contours in the video, we can register them to high-resolution CT images of the patient. Once registration to the CT image is successful we plan to optimize the algorithm and use both the detection algorithm and the registration algorithm on real-time data. Finally, we intend to develop an augmented reality program that delineates anatomical features during surgery. With high frequency detections and registrations we hope to be able to track surgical tools without using a magnetic tracker and see real-time feedback of surgical information.

### **2. Relevance**

Currently, magnetic trackers are common in robotic microsurgery where maintaining sight is difficult. Magnetic trackers are relatively inexpensive and do not require a line of sight to know where the tool is. However, they easily interfere with instruments, especially metal ones. High resolution magnetic trackers are also expensive while cheaper ones are generally inaccurate. Therefore to remedy the general inaccuracy of this technology we want to correlate high resolution CT scans of the patient with video feed from the endoscope. By registering the contours from video data to the CT image, we will be able to track the position of the endoscope.

Our hope is that in the future, with the improvement of computer vision and contour detection algorithms, physical trackers may not be necessary. We hope that CT and video data will be sufficient to track surgical tool position. In addition, we think that implementing augmented reality in surgery can not only facilitate the surgeon, but also reduce the risk of complications for the patient.

### **3. Technical Summary**

Our project consists of three discrete tasks, which we will outline below.

#### **3.1 Occluding Contour Detection**

We aim to develop an occluding contour detection algorithm. Occluding contours are notably different than edges since they define the boundary of physical objects. This complicates detection, as some high contrast edges may be results of texture and not geometry. Our detection algorithm will be written, tested and optimized in MATLAB. However, in order to perform real-time contour detection, we will convert our code to C/C++. We plan to examine two existing methods of contour detection, optical flow and single-image, and adapt one or a combination of both for sinus surgery endoscopy videos.

Single-image contour detection has been attempted by various groups over the years. One of the most basic and famous algorithms is the Canny edge detector, developed by John Canny in 1986. This algorithm examines contrast within the image to find edges and applies a series of filters to remove noise. However this method most notably does not distinguish between textured and occluding edges. More recently, complex image segmentation and machine learning algorithms have been developed that can discern occluding contours, and we plan to examine and adapt these for our purposes. Because our surgical videos are relatively uniform in shape, texture and lighting, we believe we can retrain these algorithms and construct robust classifiers that allows for accurate occluding contour detection.

However, single-image contour detection does not consider temporal data, and we believe that utilizing video can allow for much faster and more accurate occluding contour detection. For this, we will use optical flow. Optical flow is a well-established computer vision methodology that tracks points across sequential images. These points are distinct physical features within the image that shift as the camera or feature moves. If enough of the image is sampled, a vector displacement map can be constructed that shows the movement of features in the video. Since objects closer to the camera behave differently than objects farther away, namely they have greater displacement, this optical flow algorithm will allow us to discern edges by examining regions of similar movement.

There already has been some work done with single-image contour detection on sinus surgery video data. However the results lack sufficient detail and accuracy. We therefore believe that optical flow will provide the best solution because it utilizes all the data available, and our mentors agree. If it does not provide sufficient results, a combination of single image and optical flow may be optimal.

#### **3.2 Registration Algorithm Integration**

Registration with the magnetic tracker using occluding contours and CT scan data provides the real world application for our project. Simulating camera angles within the CT model and finding matches with the occluding contours from the endoscope video can enhance tracking the location of surgical instruments. One of our mentors, Seth Billings, has already constructed this algorithm. However it requires the occluding contours to function properly. Our contour detection algorithm must output a binary map as well as normal vectors to properly interface with Billing's registration algorithm.

### **3.3 Augmented Reality Overlay**

Our augmented reality overlay will utilize the enhanced registration from Billing's algorithm to correctly map graphics onto the video feed. We will use the CT scan data as our overlay to demonstrate functionality. The overlay will be done in DirectX, as many of the current modules for the registration algorithm utilize it already.

## **4. Milestones**

We will have a set of tangible milestones to assess our progress along our timeline. The first milestone will be our research milestone; upon finishing reading the necessary literature, we will decide which technique or set of techniques to use for the completion of our project. Additionally, we will address any new developments we need to make for our algorithm. The second milestone will be our design milestone; by the end of the design phase, we will have constructed a finalized algorithm with pseudocode and/or a write up to guide us through the implementation phase. The third milestone will be our implementation milestone; after completing the implementation of our algorithm, we will have a package that can successfully run contour detection on a test image or video. We expect that bugs will be prevalent after this phase but we will work those out in the testing and debugging phase. The fourth milestone will be our testing milestone; here we will test our implementation against the surgical video data that we have. We need to make sure that our package is successful at identifying contours based on a set of hand made ground truths.

The fifth milestone will be our CT integration milestone; once we are finished working with Seth Billings in integrating our contour detection algorithm, we should be able to successfully register the tool tip location to the CT based on the video data. The sixth and final milestone will be the augmented reality milestone; after completion of this phase, we will be able to point out important landmarks, such as important nerves that are occluded from view, to the surgeon in an AR overlay.

## **5. Deliverables**

Our minimum deliverable is to develop the contour detection algorithm. We expect that after our implementation phase, we will need approximately one week to test and optimize the algorithm. At the minimum we will have developed an algorithm accurate and efficient enough to be used on live video.

Our expected deliverable is a working registration algorithm based on our contour detection method that can track tool-tip position in real time using only video data and CT images.

Our maximum deliverable is augmented reality software from real-time contour detection and video-CT registration to provide surgeons with useful information.

## **6. Timeline**

Based on the milestones given above, we have a timeline to ensure that we finish our goals. The research phase, where we will research existing methods of optical flow and study the currently available still image detection method for this project, will take place from 2/23 to 2/27. We will then design our algorithm with pseudocdoe from

3/02 to 3/06. After the design is complete, we will implement our code in MATLAB from 3/09 to 3/20. We will test our code for a week after that, from 3/23 to 3/27. On the last day of testing, we will decide if we want to continue with the optical flow method or change to the still image detection method. If we continue to work on the optical flow, we will perform integration with the CT registration algorithm for the next two weeks, from 3/30 to 3/10, with the second week focused more on testing the integration. Then we will explore and implement the augmented reality portion of the project for the final three weeks, from 4/13 to 5/1.

If we decide not to use the optical flow and revert to our alternative timeline, we will identify what needs to be modified from the existing method for one week, from 3/30 to 4/03, retrain the algorithm with our data for a week, from 4/06 to 4/10, and validate our results for the next week, from 4/13 to 4/17. We will then spend the final two weeks, from 4/20 to 5/01, performing the integration with the CT registration algorithm.

In both cases, we will work on the project paper and poster for the last four weeks of the class, from 4/13 to 5/07.

## **7. Dependencies**

The dependencies for this project are limited and we have planned ways to resolve them. In order to test that our program works in the proper context, we need the sinus surgery videos that will be provided to us by Dr. Reiter. For the integration phase, we will need Seth Billings' registration algorithm to plug our code into. We will also need the CT image data that corresponds to the surgery videos to make sure our registration is successful. This will be provided to us directly from Seth. Finally, we will need the DirectX graphics code from Seth Billings to plug our augmented reality software into, which Seth will also provide for us.

## **8. Management Plan**

We have constructed a management plan that allows for smooth collaboration and ample communication among the team members. Git will be our version control software, and we will host the code in a private Github repository. Podio will be our milestone tracking tool to communicate progress within the team. We will assign a team leader for each phase of the project so every member does his part in managing the team. We will meet as a team at least weekly, and we will meet with our mentors once a week.