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Project Proposal
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1. Stated Goal

The main goal of the project is to provide registration of preoperative images (OCT, fundus) to intraoperative microscopic stereo feed, with image overlay of specific landmarks from the surgeon during preoperative planning. The current approach of having the surgeon to manually track where the landmarks are increases the complexity of the surgeon's tasks. Some testing has been done in sinus operation feature detection inside Matlab by Rogerio Richa and Dan Mirota, but a full C++ implementation will be targeted here for speed and compatibility issues with other frameworks and modern hardware.

2. Team Members

Student: Xin Yuan Wang, Vincent Ng
Mentors: Gregory Hager, Marcin Balicki, Rogerio Richa, Russ Taylor

3. Short statement of Relevance

Visual information can be useful in guiding the surgeon during an operation where he experiences limited visual detail. During the operation, the surgeon already has limited mobility of the tools inside the retina. The surgeon also has to mentally track where he wants to explore from the preoperative images, and not re-trace his previous steps. With landmarks added by the computer, the surgeon can focus more on the actual procedure. The preoperative data from the OCT image can be useful in guiding the surgeon during the procedure, by integrating it to the live video feed from the microscope and displaying in a high resolution format.

4. Background

During the preoperative procedure, a wide angled fundus scan is taken of the retina. This interior surface of the eye allows the surgeon to pinpoint certain distinct or visually interesting locations to inspect. An Optical Coherence Tomography (OCT) scan is done at various locations to provide a higher resolution image of the cross section and layer structure of the eye.

Assisting the peeling of Internal Limiting Membrane (ILM) is a well target for this plan. Inside the retina, macular holes develop in the retina with no obvious cause or warning. ILM is a common procedure done during Macular Hole Surgery to repair these holes. Here, the OCT scan can be used to determine which portion of the surface to initiate peeling, and integrate it to the microscope feed.

5. Short Summary of Technical Approach

The major part of the problem involves registration. The registration of the images is feature-based. The preoperative data will be obtained as video (continuous images) or images, and tests can be done to track a specific feature through a specific time interval. Existing tools are available to extract features and match images (SURF, SIFT, ICP). Initial testing will be done on a short video, with the first 10 frames to provide feature detection, and the rest of the video to be used for registration. Validation methods have to be developed to ensure the accuracy and repeatability of the feature detection and registration.

To ensure the quality of feature extraction and matching of data, initial image processing for surgery video is important. Existing tools are openCV segmentation utility function, CISST framework to integrate with surgical tools.

To make the process applicable, we will use modern computing power to accelerate the process once it is complete and validated. The first way would be to understand how multi-core machines can be fully-utilized through forking different threads to tackle different parts of the process, or different areas of the image. The second way would be to utilizing GPU power. The second method is more complicated as the algorithm developed has to match the data input parameters and the machine's GPU specifications.

6. List of Deliverables

Minimum

Determine a valid algorithm (Speeded Up Robust Features - SURF) to do the feature detection and registration, understand and implement it. Ensure such program is thoroughly tested and validated (developing test/benchmark using manually picked annotations as ground truth) using data (surgical retinal and non-retinal)

Expected

Speed up the registration process using underlying hardware architecture (multi-core). Implement simple GUI that marks annotation for surgeon. Utilize initial image processing for real surgery videos.

Maximum

Deploy solution into OR. Have a well-structured way of integrating Fundus/OCT data using the GUI on the surgeon's screen. Allow for real-time image processing for more accurate fixture using GPU power.

7. Key Dates/Milestone(11 weeks)

Cycle 1:

- duration: 1.5-2 weeks(Feb 12- Feb 26)
- to do list: background reading, intra-intra feature detection and matching
- validation: use manually picked feature match as ground truth

Cycle 2:

- duration: 2.5-3 weeks(Feb 26- March 19)
- to do list: pre-op image processing(aperture, light cone, exposure issues) to refine actual data; pre-op/intra-op phantom annotation registration

- validation: use manually picked annotation match as ground truth

Cycle 3 and more:

- duration:6 weeks(March 19--early May), we don't have detailed validation yet, below are a list of options:
- speed-up (GPU, parallelization)
- GUI integration
- more advanced image processing (focus, interference w/ floatus)

8. Assigned Responsibilites

   For the initial cycle, the work will be collaborative so that both of us can understand how the basic algorithm for SURF works. For cycles 2 and 3, we plan to use each of our strengths to accomplish different tasks.

   - Paired programming (for cycle 1,2), shared responsibility of research/paper reading.
   - Cycle 2:
     i. Xin: Image Processing
     ii. Vincent: Plan GUI/GPU strategy
   - Cycle 3:
     i. Xin: Advanced imaging processing, GUI
     ii. Vincent: GPU/Parallelization
9. Dependencies(and ways of resolving them)
   - Cycle 1: Fundus image of the phantom model
   - Cycle 2: Pre-op/intra-op phantom data, rabbit retina pre-op/intra-op data
     i. stereo monitor display and head mounted display?
   - Cycle 3: Feedback from surgeons about our test GUIs (HIPPA training, observe an actual procedure to see what the surgeon might want from our project), access to actual hardware needed.
   - Poster budget: ~$100
10. Management Plan
    - Weekly Meetings with Richa and Taylor on Friday
    - Weekly FAQ session with Richa on Monday or Wednesday
    - Weekly paired programming for 15 hrs , paper-reading and algorithm discussion for 5 hours
    - Assess the viability of cycle 2-3 when cycle 1 is completed

11. Reading List

[1] I. Fleming S. Voros, B. Vágvölgyi, Z.A. Pezzementi, J. Handa, R.H. Taylor,G.D. Hager. "Intraoperative Visualization of Anatomical Targets in Retinal Surgery." 2008. Web. <http://www.cs.jhu.edu/~rht/RHT%20Papers/2008/wacv2008_Fleming.pdf>.

[2] Hong Shen Stewart, C.V.; Roysam, B.; Gang Lin; Tanenbaum, H.L. "Frame-rate Spatial Referencing Based on Invariant Indexing and Alignment with Application to Online Retinal Image Registration." Mar. 2003. Web. <http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1182101>.

[3] V. Mester, F. Kuhn. "Internal Limiting Membrane Removal in the Management of Full-Thickness Macular Holes." *Macular Surgery*. June 1999. Web. 14 Feb. 2011. <http://www.ncbi.nlm.nih.gov/pubmed/10926987>.

[4] Johannes P.W. Grimm, Clemens Wagner and Reinhard Männer. "Interactive RealTime Simulation of ILM." 2004. Web. <http://www.springerlink.com/content/64grw7h72r7l6t75/>.

[5] Paul M. Novotny, Jeff A. Stoll, Nikolay V. Vasilyev, Pedro J. Del Nido, Pierre E. Dupont, Todd E. Zickler, Robert D. Howe. "GPU Based Real-time Instrument Tracking with Three-dimensional Ultrasound." July 2007. Web. <http://www.cs.jhu.edu/~rht/RHT%20Papers/2010/SPIE%20Ophtalmology%202010%20-%20Liu.pdf>.

[6] Herbert Bay , Andreas Ess , Tinne Tuytelaars, and Luc Van Gool. "Speeded-Up Robust Features(SURF)." 2008. Web. <http://www.vision.ee.ethz.ch/~surf/papers.html>.