Visual Tracking of Surgical Tools in Retinal Surgery Using Particle Filtering and Mutual Information

Computer Integrated Surgery II

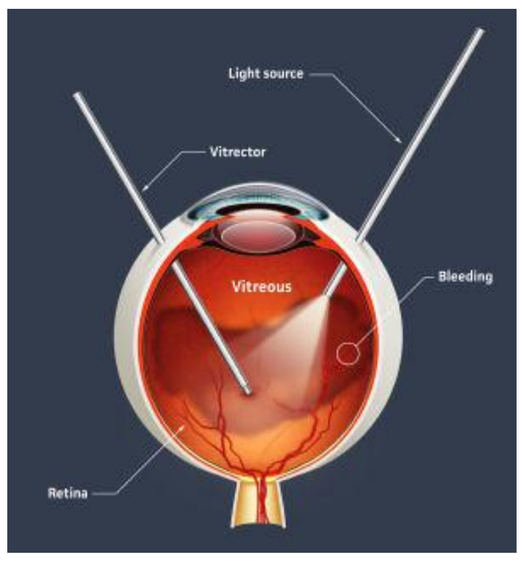
William Yang and David Li, under the instruction of Dr. Rogerio Richa and Dr. Russell Taylor

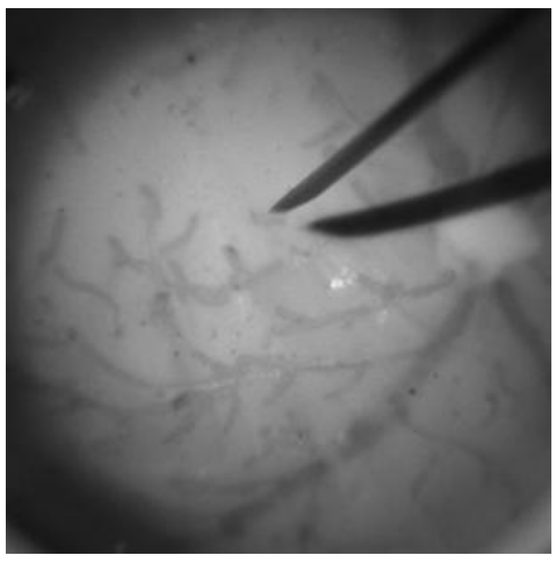
Problem

- Vitreoretinal surgery treats issues with retina and vitreous fluid
- Long surgical times and high risk of complications
- Further visualization techniques possible, but restricted
- Current procedures involve manual observation
- Surgeon desires something easy to implement, using current equipment, noninvasive, and simple to use

Introduction

- Project contributes to alleviating difficulties with indirect visualization by providing valuable data for other visualization techniques for integration such as intraocular OCT
- A tool tracking system using particle filters was created using mutual information as a similarity measure
- Used to track the position and angle of retinal tools with both live and prerecorded video
- Preliminary error analysis was performed using a ground-truth annotated data set





Schematic of vitreoretinal surgery and Microscope frame of vitreoretinal surgery

Solution

- Solution: Create software-based tool tracking method
- Particle filters were implemented for computational efficiency and avoidance of local minima
- Mutual information was used for robustness in varying illumination, rotation, and limited texture information
- Particle filter implementation is provided by OpenCV library
- CISST library integration via tracker filter included

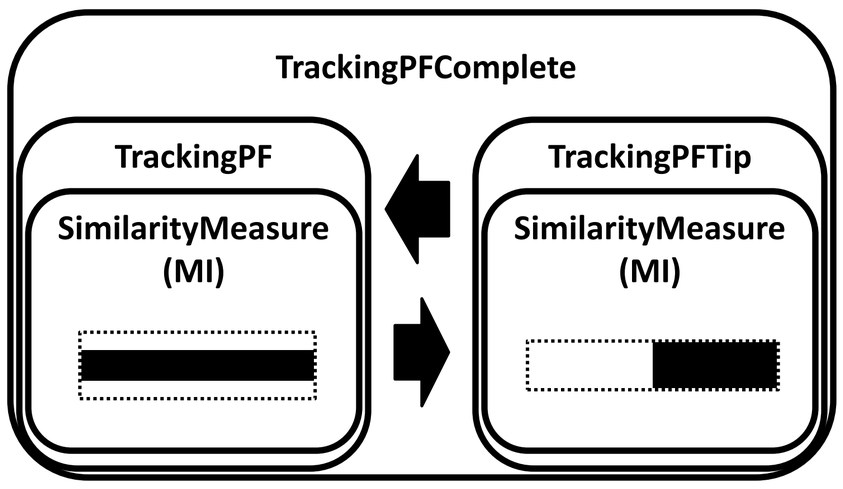
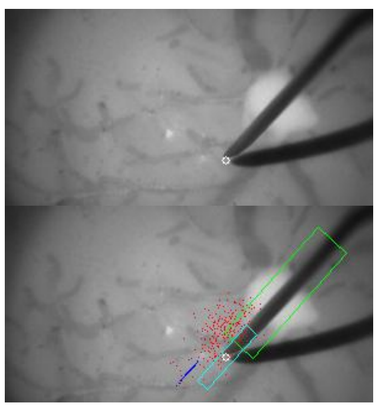


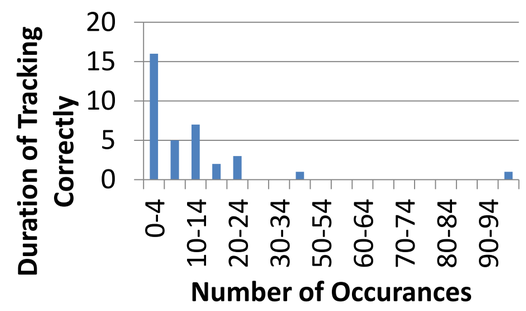
Diagram of classes used to implement the particle filters and their relations

Diagram of SVL Stream Design

Outcomes and Results

- Implemented on videos both prerecorded from actual surgery and live from phantom
- Error analysis conducted with MATLAB to model the Poisson distribution generated from the histogram of intervals of correct tracking
- Current gradient descent methods using sum of square differences or mutual information have P-values of 0.1





Depiction of tool tracking method with (A) No explanatory symbols and (B) Rectangles depicting the (green) shaft and (cyan) tip templates, as well as the (red) shaft and (blue) tip particles. Histogram of intervals of correct tracking.

- Outcome: Development of a new tool tracking method that uses particle filtering and mutual information and is comparably effective to other tool tracking implementations

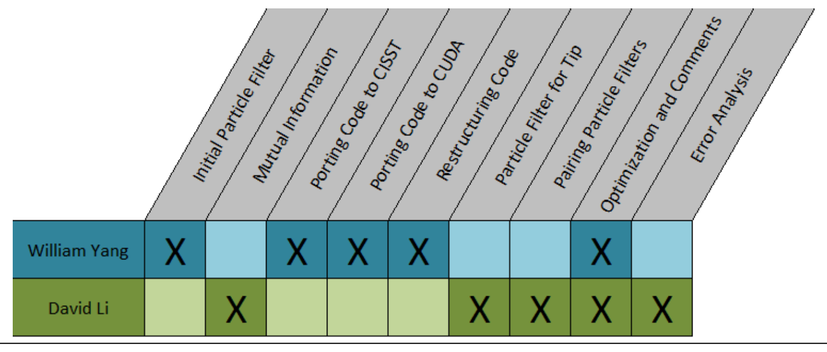
Future Work

- Asynchronous tracking
- Parallelization of code to support multiple particles at once
- Parallelization of mutual information algorithm
- Methods for dealing with specularity and background textures by using disparity maps
- Method for dealing with erroneous shadow tracking

Lessons Learned

- Installation of OpenCV, CISST, and CUDA is a top priority
- Optimization of code for CISST and parallelization should be performed from the start of development
- Particle filtering is very robust, but an ideal application should attempt to cover any weaknesses possible
- Lack of texture information used by mutual information can cause problems with specularity

Division of Labor



Publications

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•*Vitreoretinal surgery image taken from* *http://www.eyedoctorguide.com/eye_problems/vitreoretinal_surgery_retina.html*

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