ERC | CISST

LABORATORY FOR Computational Sensing + Robotics THE JOHNS HOPKINS UNIVERSITY

Visual Tracking of Surgical Tools in Retinal Surgery using Particle Filtering

Group 14
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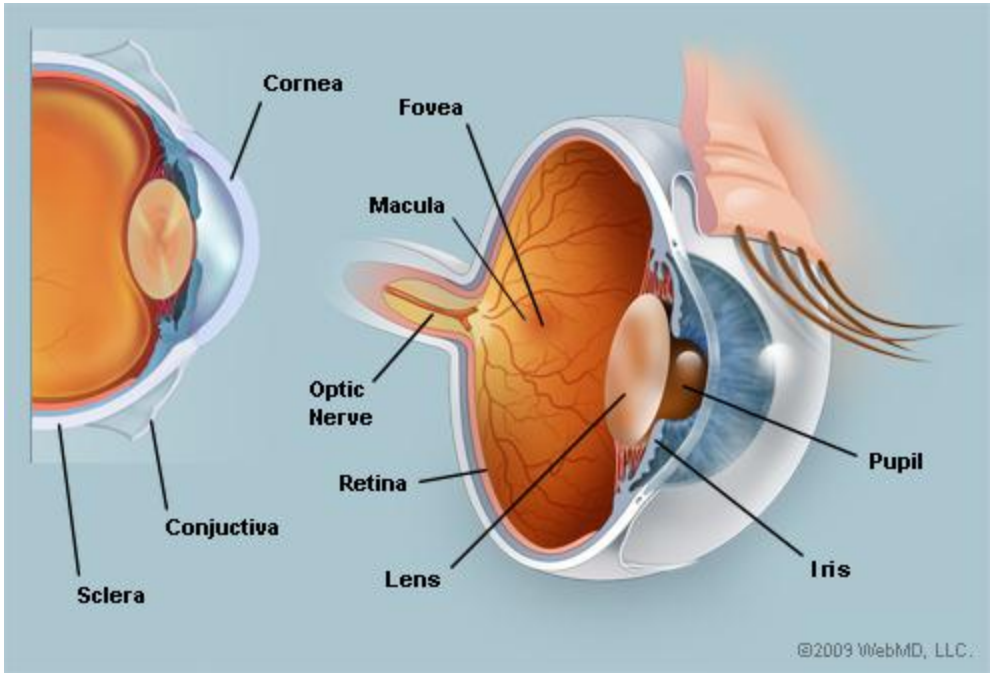
Outline

- Introduction
  - Background
  - Project Goals
- Technical Approach
- Project Management
  - Deliverables & Milestones, Timeline, Dependencies
  - Assigned Responsibilities, Management Plan

Vitreoretinal Surgery

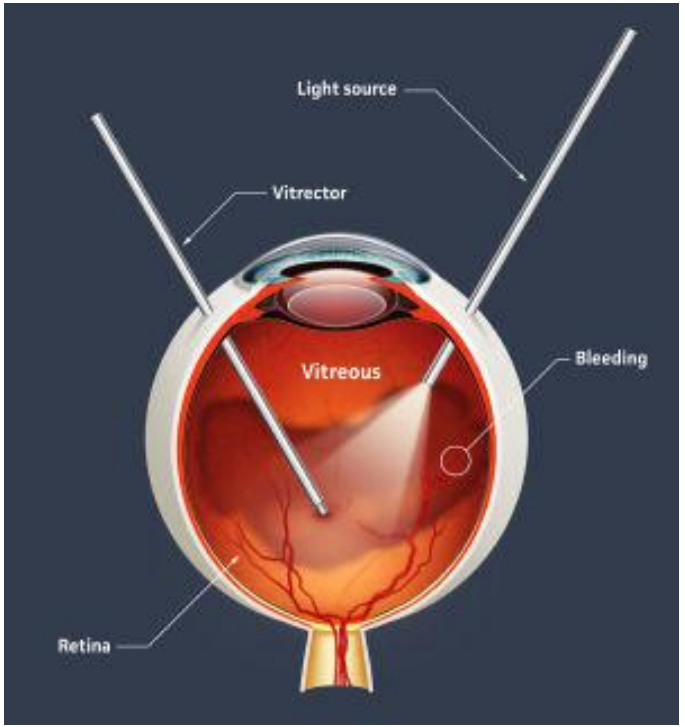
- Affects retina, macula, and vitreous fluid



http://www.webmd.com/eye-health/picture-of-the-eyes

Vitreoretinal Surgery

- Used to treat the following
  - Macular degeneration
  - Retinal detachment
  - Diabetic retinopathy
- Complications
  - Retina is very fragile
  - Indirect visualization
  - Physiological tremor
  - Lack of tactile feedback



http://www.eyedoctorguide.com/eye_problems/vitreoretinal_surgery_retina.html

Vitreoretinal Surgery

- Many tools to help surgeons with hand tremor
  - Microsurgical robot
  - Intraoperative data acquisition
    - Force transduction sensors
    - Optical coherence tomography (OCT) retinal scans
- Goal is to help surgeons with indirect visualization

Indirect Visualization

- Many limitations that hinder identification and localization of surgical targets
  - Field and Clarity of view
  - Depth perception
  - Illumination
- Long operating times and risks of surgical error

Project Goals

- Goal: Develop a direct visual tracking method for retinal surgical tools using particle filtering and mutual information
- Benefits of implementing a particle filter
  - Stochastic optimization method
  - Can be computed in parallel for speed
  - Computationally efficient
  - Robust

Technical Approach

- Direct Visual Tracking Method
  - Mutual Information
  - Particle Filter
- CISST
- GPU
- Microsurgical Workstation
- Error Analysis

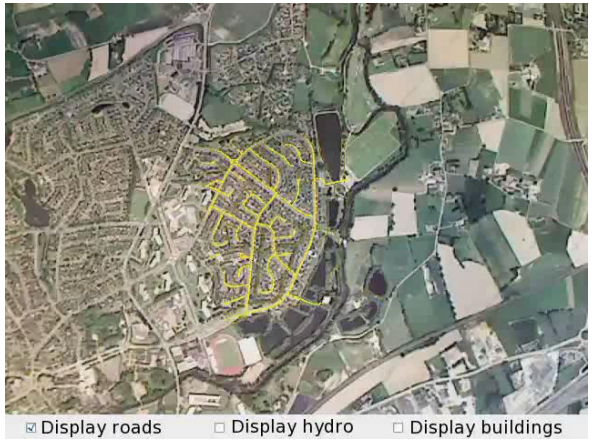
Mutual Information

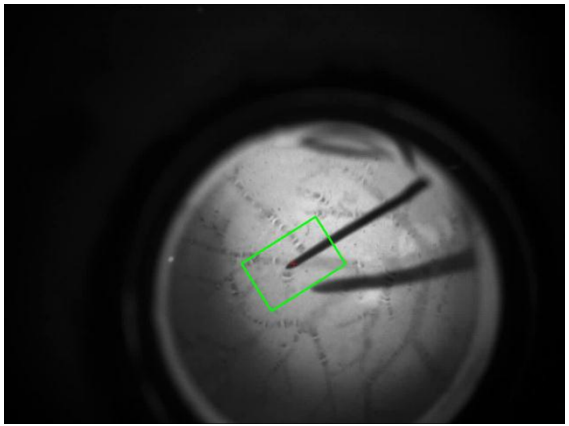
- Template registration
- Why not SSD or NCC?
- 4 DOF model

$h(I) = -sum_r[p_I(r) \log(p_I(r))]$

$h(I, I*) = -sum_{r,t}[p_{II*}(r, t) * \log(p_{II*}(r, t))]$

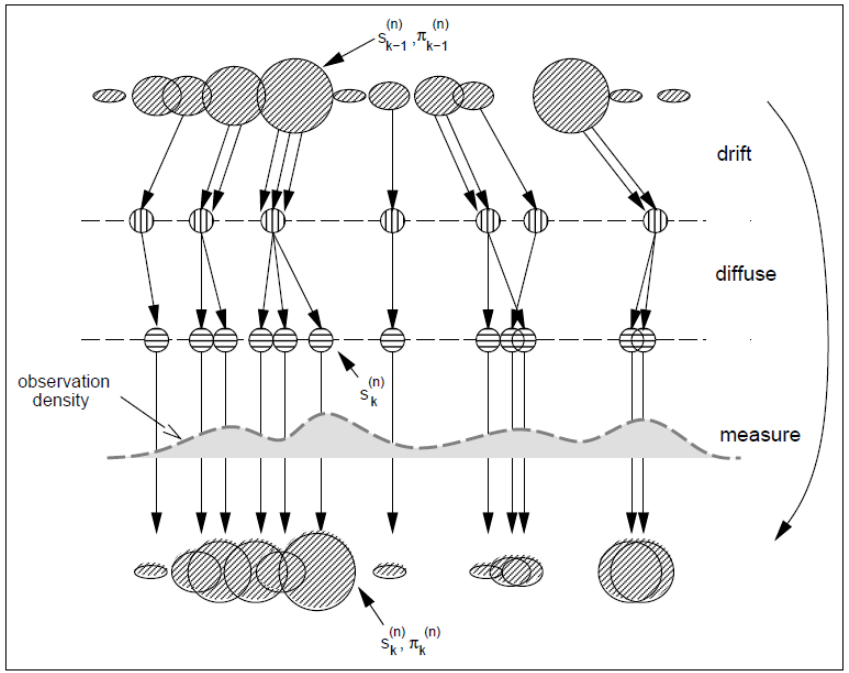
$MI(I, I*) = h(I)+h(I*)-h(I, I*)$





Particle Filter

- “Condensation”
- Avoid local minima in gradient descent
- Supports alternative hypotheses
- Iterative: calculate weights, resample



GPU

- Parallel evaluation of particles
- Higher frame rate
- Increased robustness

http://www.beyond3d.com/content/articles/77

Error Analysis

- Usage of first fully annotated and freely available image data set for tool detection in *in vivo* retinal microsurgery
- Tool Detection using Mutual Information
  - Evaluation on entire test set after validating on validation set
  - Correct predictions are within 10 pixels of true location for both (A) and (B)
- Tool Tracking using Particle Filtering
  - Evaluation on video sequences
  - Failed whenever true position of (B) is greater than some threshold σ, re-initialized using ground truth to continue analysis

Deliverables

Minimum

- OpenCV demo of tool tracking using mutual information and particle filtering (offline video)
- Documentation of code

Expected

(including Minimum)

- CISST code running on surgical platform (online)
- Documentation of code
- Poster and paper

Maximum

(including Expected)

- GPU implementation
- Documentation of code

Milestones

Minimum

- Milestone 1: Particle filter with SSD
- Milestone 2: Mutual information similarity measure

Expected

- Milestone 3: Port algorithm to CISST library

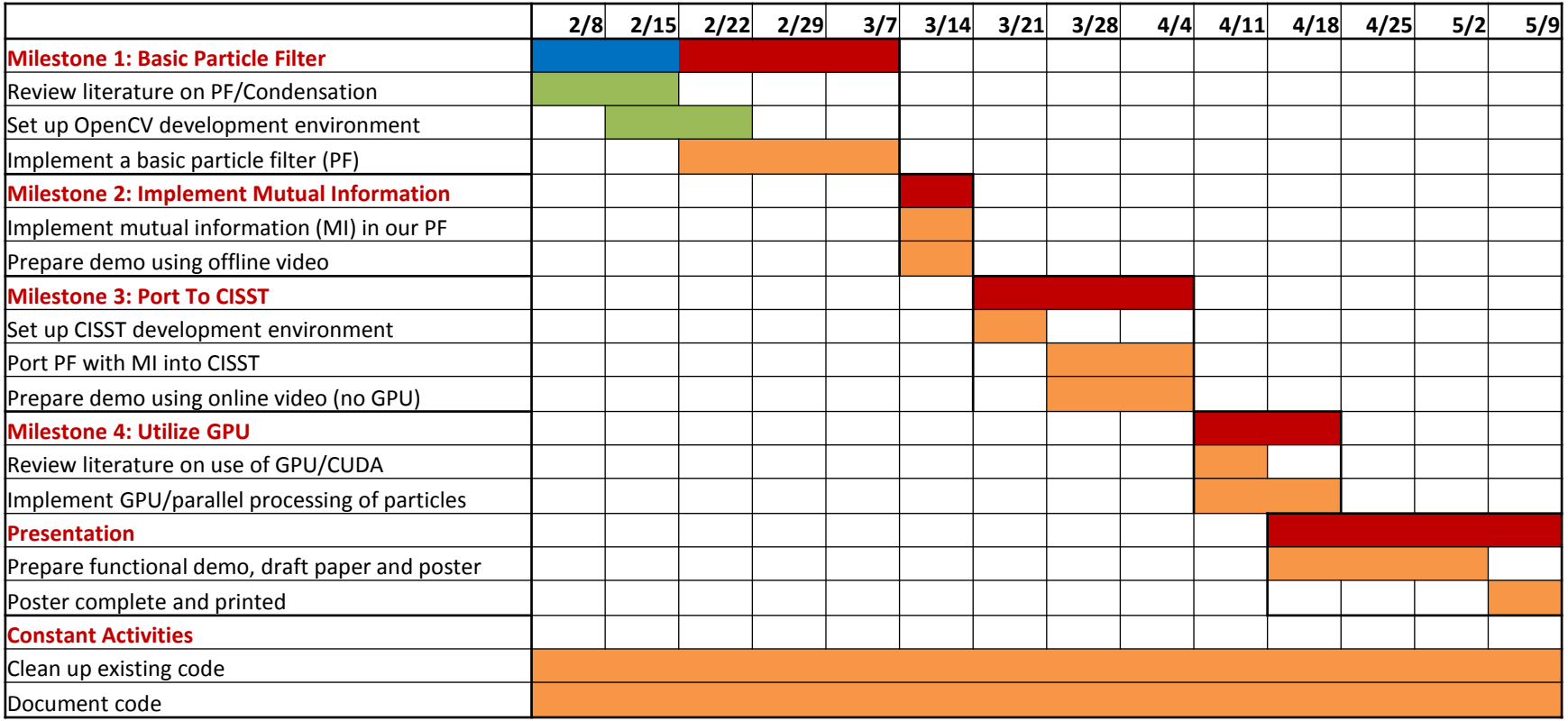
Maximum

- Milestone 4: GPU or other parallel implementation added

Timeline

- 2/15: Review literature on PF/condensation - DONE
- 2/22: Set up OpenCV dev environment – DONE
- 3/7: Milestone 1 (basic PF) achieved
- 3/14: Milestone 2 (PF+MI) achieved
- 3/28: Set up CISST dev environment
- 4/4: Milestone 3 (port to CISST) achieved
- 4/11: Review literature on use of GPU/CUDA
- 4/18: Milestone 4 (GPU) achieved
- 4/25: Clean up and refine on-going documentation
- 5/2: Prepare functional demo, draft paper and poster
- 5/9: Poster complete and printed

Timeline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2/15
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3/7
3/14
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3/28
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5/2
5/9
Milestone 1: Basic Particle Filter
Review literature on PF/Condensation
Set up OpenCV development environment
Implement a basic particle filter (PF)
Milestone 2: Implement Mutual Information
Implement mutual information (MI) in our PF
Prepare demo using offline video
Milestone 3: Port To CISST
Set up CISST development environment
Port PF with MI into CISST
Prepare demo using online video (no GPU)
Milestone 4: Utilize GPU
Review literature on use of GPU/CUDA
Implement GPU/parallel processing of particles
Presentation
Prepare functional demo, draft paper and poster
Poster complete and printed
Constant Activities
Clean up existing code
Document code

Assigned Responsibilities

- Tentative division
  - Primary coder codes main implementation while partner checks code for errors and suggests improvements
- David Li
  - Particle filter implementation
  - Porting OpenCV implementation into CISST
- William Yang
  - Mutual information
  - GPU/Parallel processing implementation
- Universal responsibilities
  - Documentation
  - Demo, Draft paper, and Presentation

Dependencies

- Development environment for Milestones 1 and 2
  - Resolved (Visual Studio/OpenCV)
- Development environment for Milestones 3 and 4
  - Will work with Rogerio (CISST libraries)
- Access to CUDA-enabled GPU for Milestone 5
  - Resolved for offline development; will work with Rogerio for online
- J-Card access to robotorium
  - Resolved
- Use of microretinal surgery workstation
  - Will need to schedule when ready
  - If not accessible, will work on pre-recorded data

Management Plan

- Weekly:
  - Meetings with Rogerio on Wednesdays
  - Reassessment of timeline
- Continuous:
  - Programming and peer code review (source code revision control)
  - Meet as needed to discuss and test
  - Documentation of code

Reading List

- Balicki, M., Han, J., Iordachita, I., Gehlbach, P., Handa, J., Taylor, R., and Kang, J. (2009). Single Fiber Optical Coherence Tomography Microsurgical Instruments for Computer and Robot-Assisted Retinal Surgery. *MICCAI 2009,* 108-115
- Dame, A. and Marchand, E. (2010). Accurate real-time tracking using mutual information. *IEEE Int. Symp. on Mixed and Augmented Reality*, *ISMAR'10,* 47-56.
- Isard, M. and Blake, A. (1998). Condensation – conditional density propagation for visual tracking. *Int. Journal of Computer Vision*, 29, 5-28.
- Richa, R. et al. (2012). An Evaluation Framework for in vivo Microretinal Tool Detection and Tracking. *MICCAI*
- Richa, R. et al. (2012). Hybrid SLAM for Intra-operative Information Augmentation in Retinal Surgery. *MICCAI*

Questions?