Date | **08/10/2013**

MICCAI TUTORIAL - VTR 2013

VIEW EXPANSION AND AUGMENTED REALITY IN SLIT-LAMP RETINAL IMAGING

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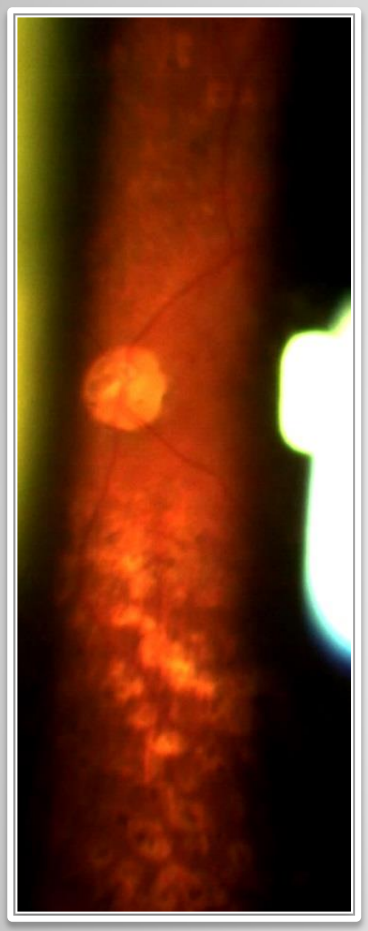
SUMMARY

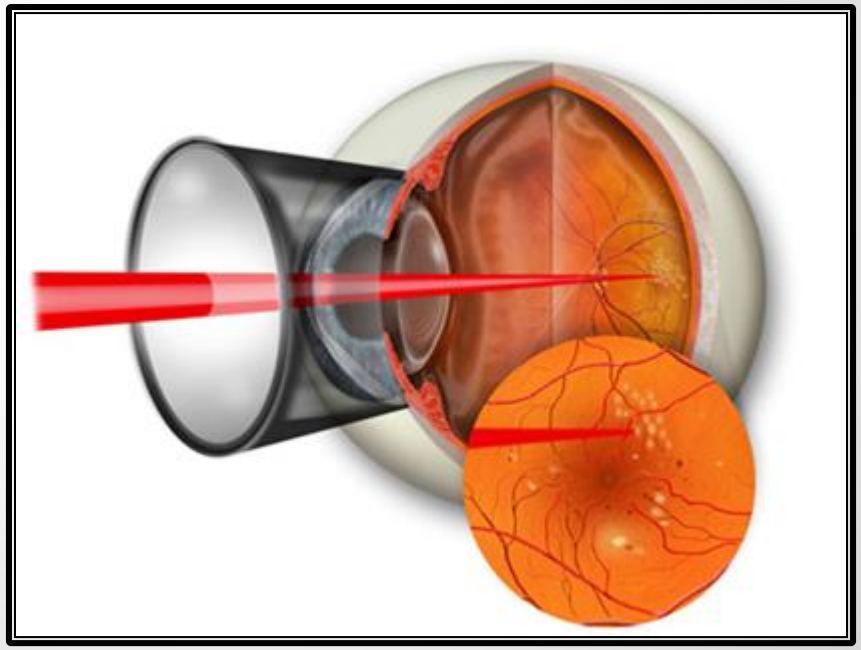
- Introduction and motivation
- Objective
- Extracting the retina
- Tracking the retina
- Computational aspects
- Current results
- Future work

INTRODUCTION



Retina treated with laser

- Panretinal photocoagulation as treatment for proliferative diseases such as diabetic retinopathy



[www.institutdeloeil.com]

THE SLIT LAMP

- The slit lamp is one of the most commonly used devices for laser delivery

- The slit-lamp is essentially a biomicroscope coupled with a high-intensity light source
- The laser is coupled to the slit-lamp

THE SLIT LAMP

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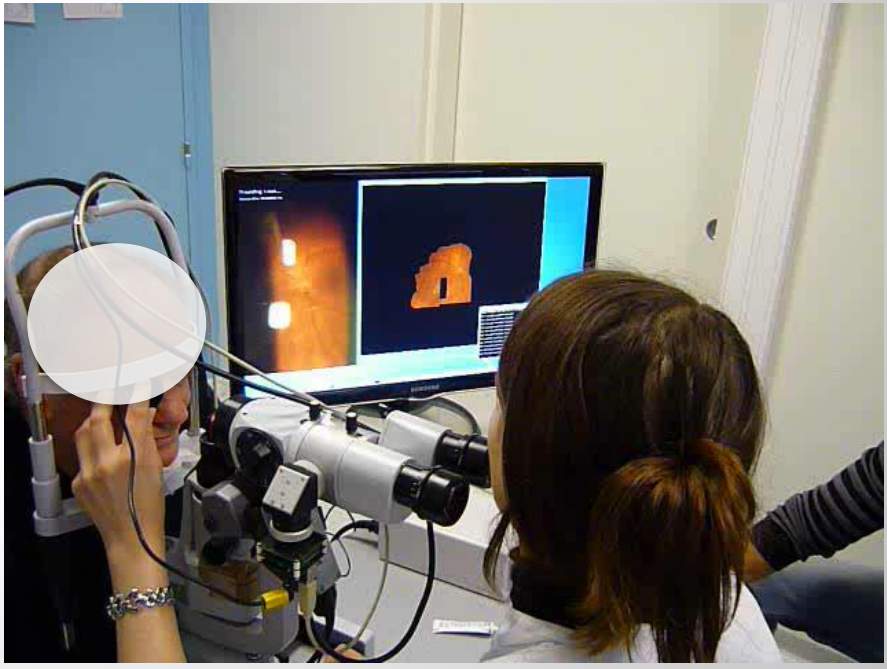

THE SLIT LAMP

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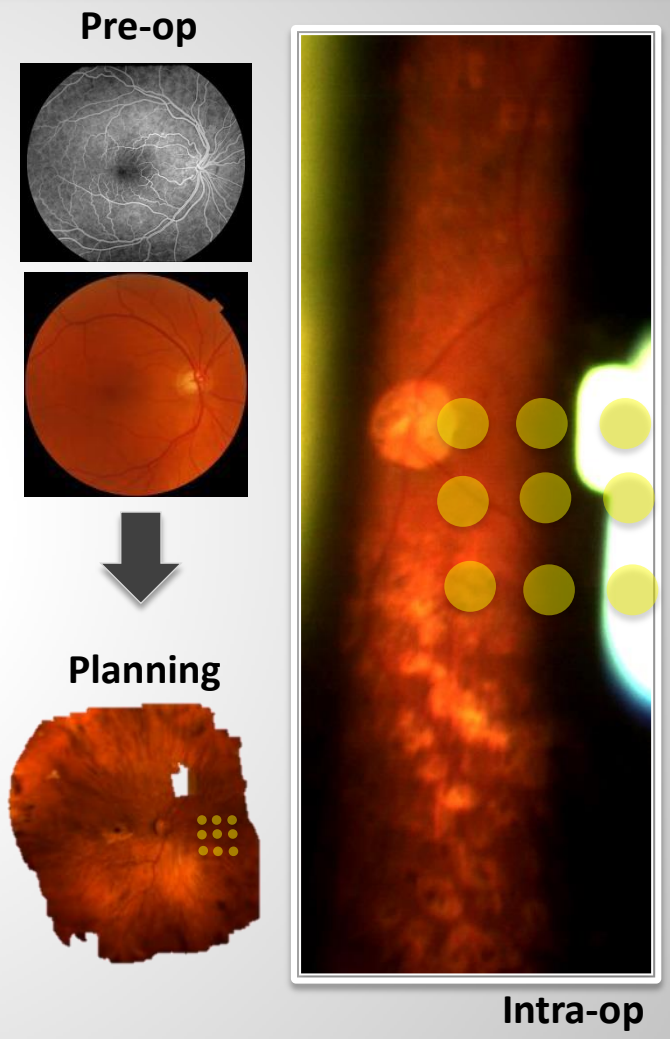
COMPUTER ASSISTANCE

- Computer assistance has the potential to improve
  - Navigation
  - Planning
  - Documentation
  - Diagnosing
  - Practitioner and patient comfort



OBJECTIVE

- The fundamental enabling technology:

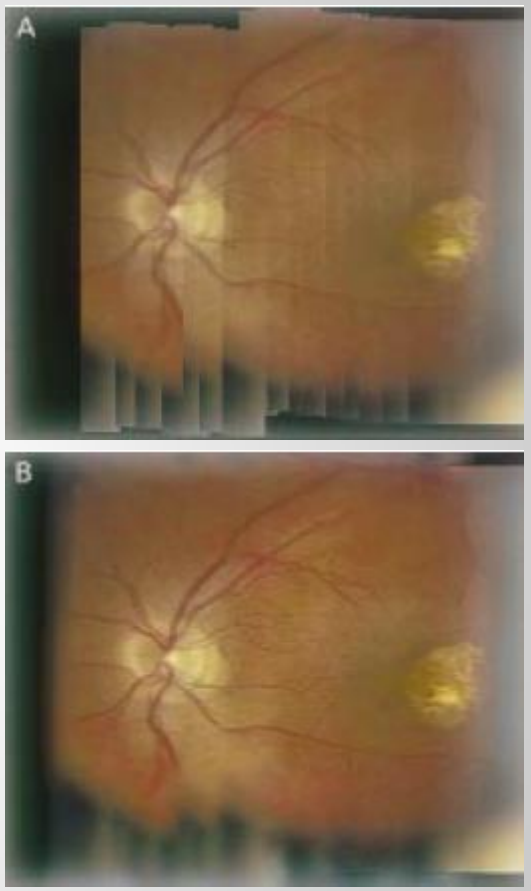
  Intra-operative retina tracking and mapping

- Research goals
  - Create na intra-operative mosaic of the retina from slit lamp video
  - Pre-operative information overlay

- Challenges
  - Reflections
  - Narrow slit
  - Poor texture
  - Accuracy

BACKGROUND

- Early works include
  - Berger et al. (2001)
- Similar solutions have been proposed in vitreo-retinal surgery
  - Becker et al. (2010)
- Commercially available solutions
  - Navilas
- Previous work at JHU
  - Hybrid tracking and mapping for vitreo-retinal surgery (Richa et al. 2012)



Asmuth et al. (2001)

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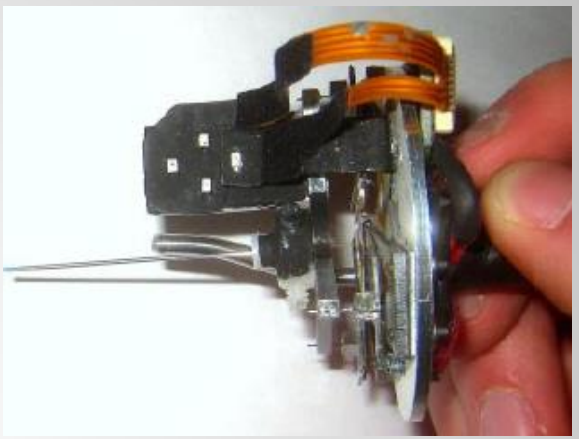
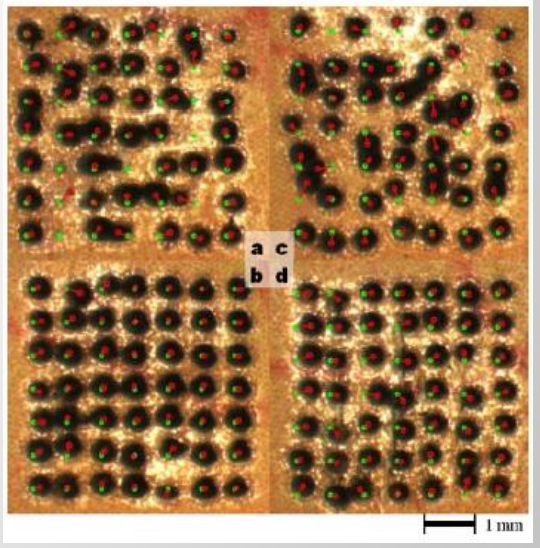
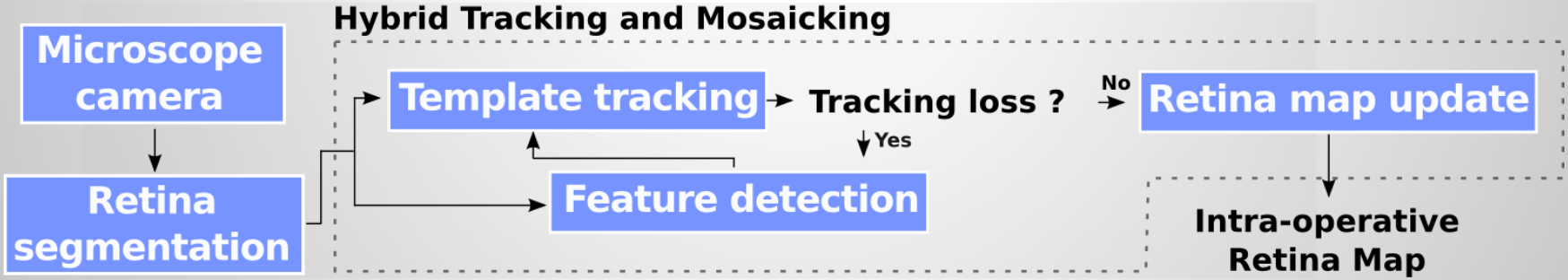




Becker et al. (2010)

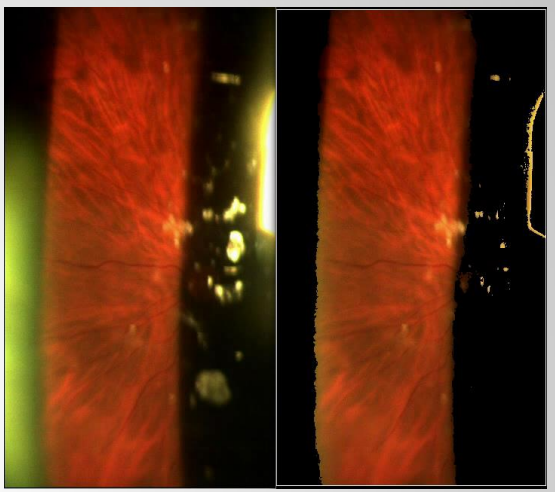
COMPONENTS

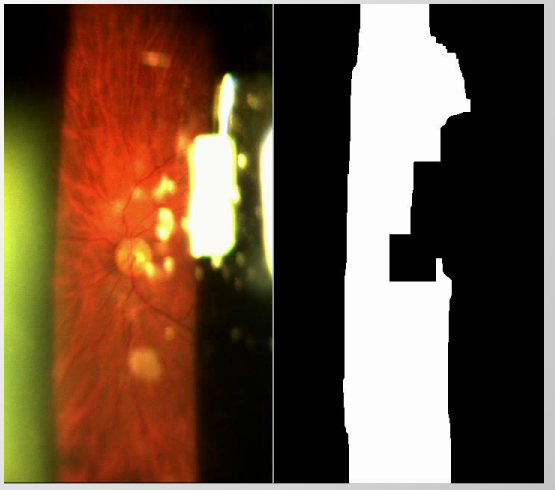
- System components
  - Retina segmentation
  - Robust visual tracking
  - Detection for tracking re-initialization
- Computational aspects



RETINA SEGMENTATION

- The retina must be segmented prior to tracking and detection
- Segmentation: quality vs. computational effort
  - Current solution – thresholding the balance of color components
  - Current research – incorporation of multiple visual cues (texture)
    - Ensemble methods
    - SVMs
    - Polynomial Mahalanobis





ROBUST VISUAL TRACKING

- Direct vs. feature-based visual tracking
  - Feature-based techniques show poor results
    - Repeatable patterns
    - Lack of distinguishable features
    - Blur
  - Direct visual tracking is sensible to illumination variations
    - Non-uniform illumination variations
    - Robust similarity measures are too computationally expensive to be locally applied

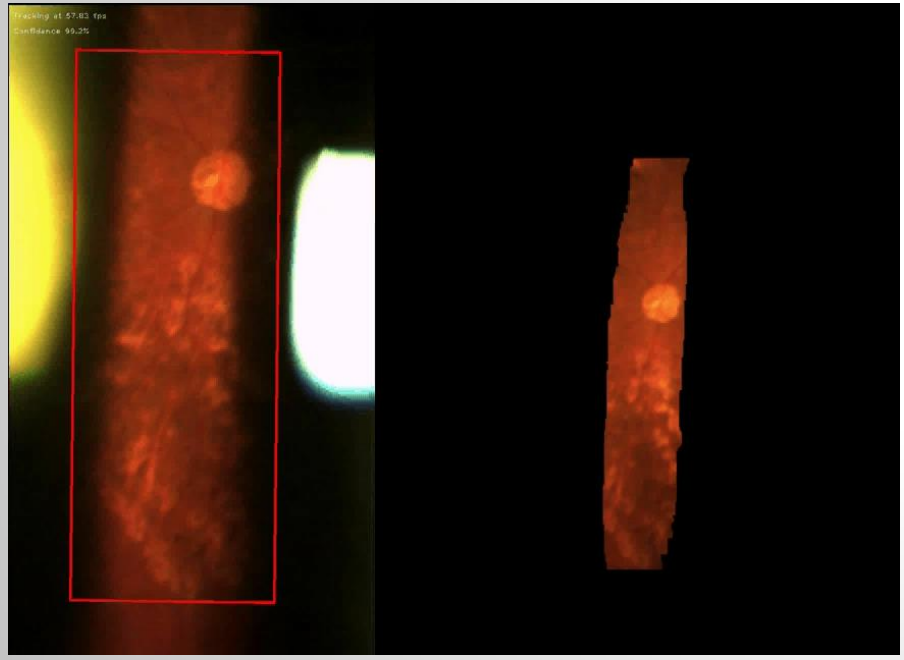
Retina tracking and mapping

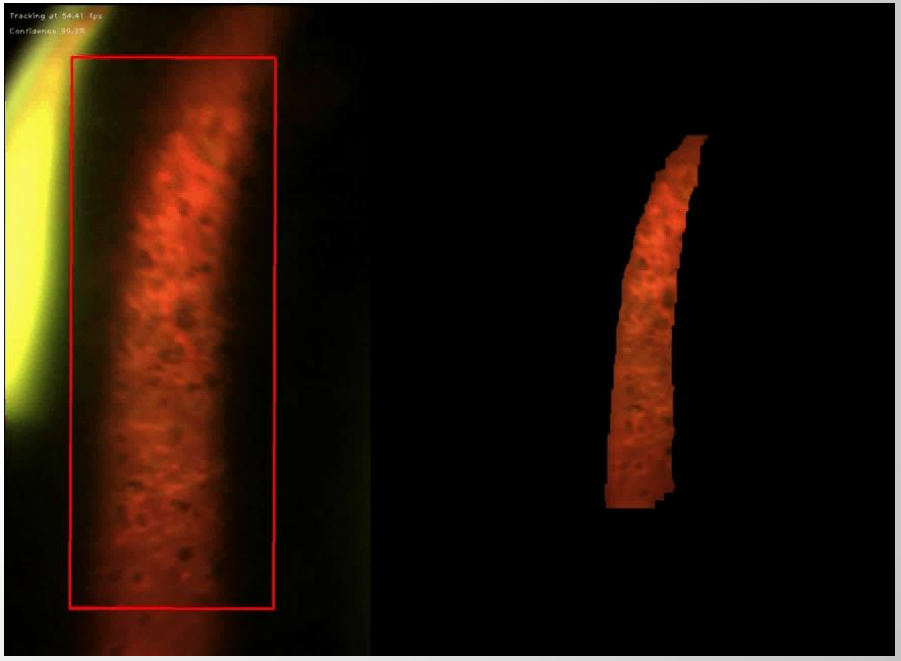
ROBUST VISUAL TRACKING

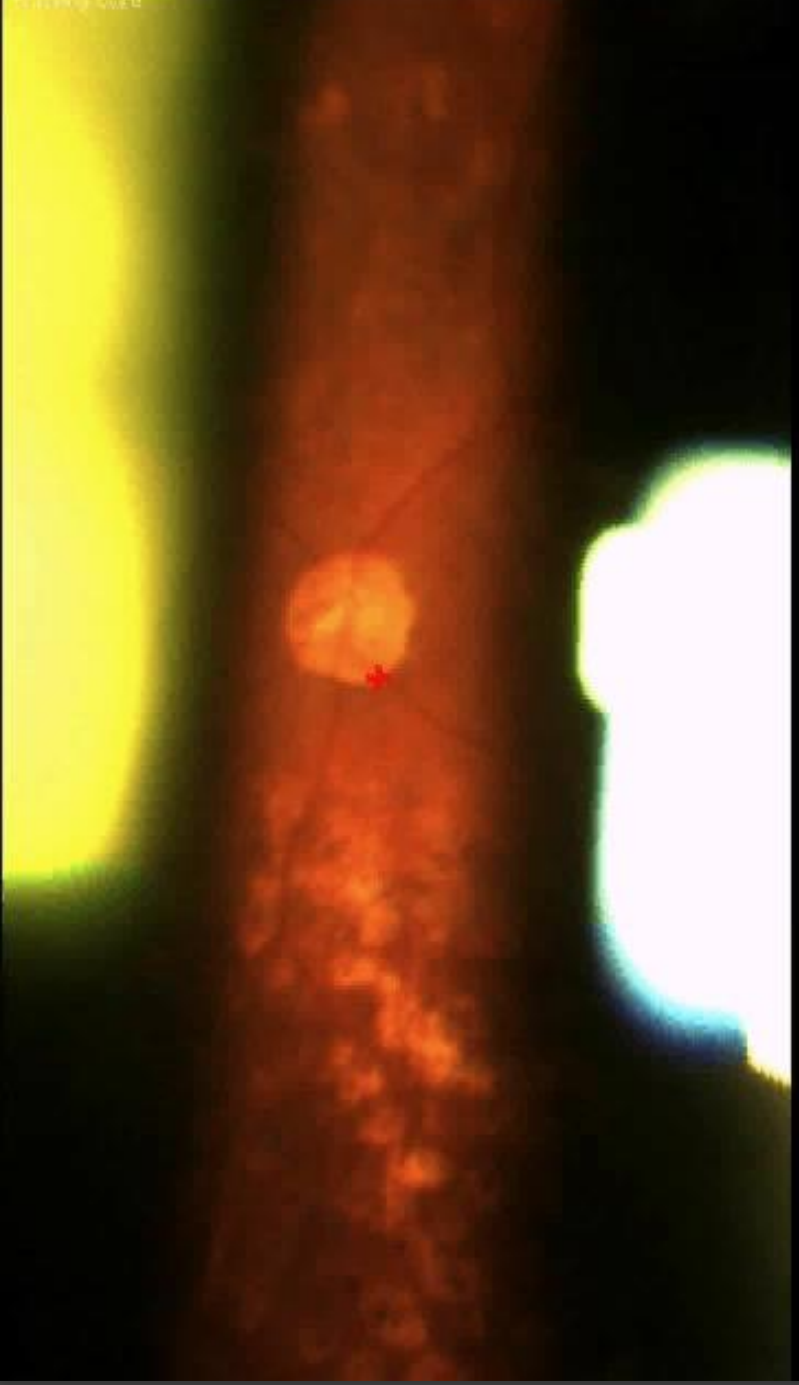
- Tracking specifications
  - Currently tracking rotation + translation (scaling is negligible)
  - Tracking using SSD + illumination compensation
  - A non-rigid illumination compensation model
    - Thin-plate spline surface to model gain variations
    - Global bias
- Forward-backward tracking
  - To increase robustness, we perform forward-backward tracking [Khalal2010]
  - Results with the highest NCC score are kept

ROBUST VISUAL TRACKING

- Forward-backward tracking
  - Due to the challenging visualization conditions, tracking is not smooth.



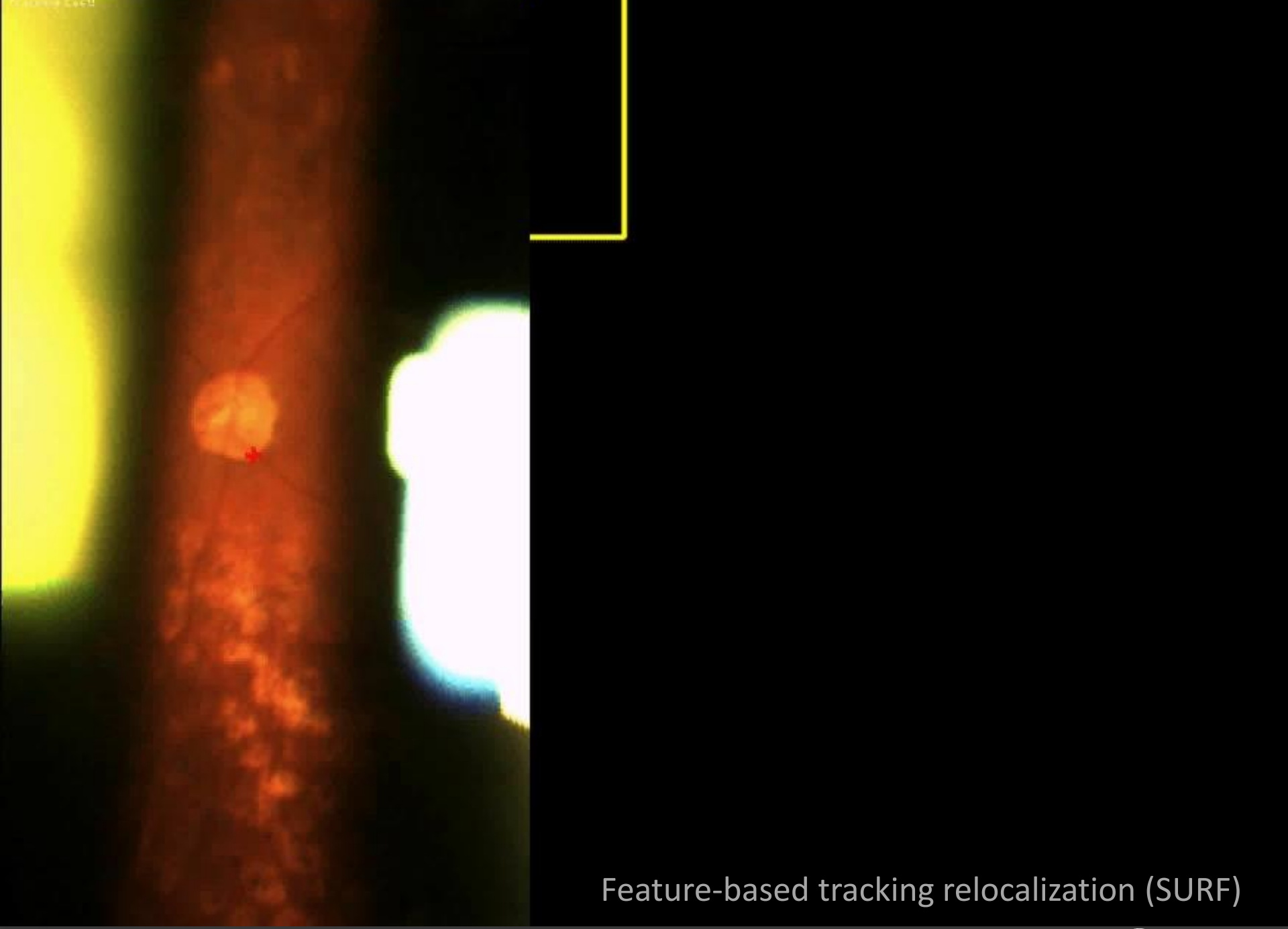




Backward tracking increases resilience, allowing for a smoother reconstruction

TRACKING RE-INITIALIZATION

- Tracking fails eventually (occlusions, patient motion)
  - How to restore tracking?
- First approach – a feature map is created alongside the mosaic
  - Tested several approaches
    - SIFT, SURF, Ferns, Orb, Brisk ..
  - Conclusions:
    - Few distinguishable features on retina
    - Traditional feature detection/matching does not perform well



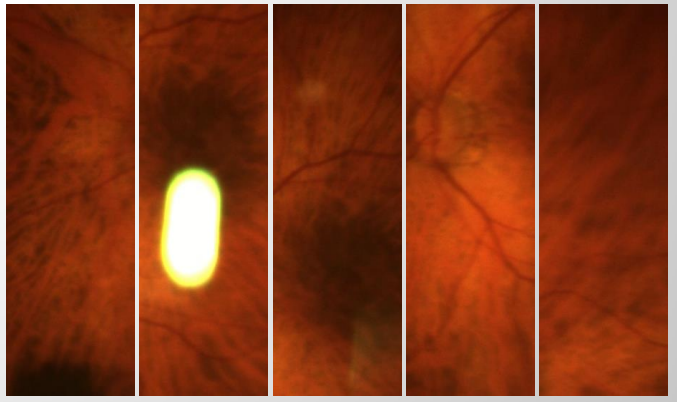
Feature-based tracking relocalization (SURF)

TRACKING RE-INITIALIZATION

- Inspired by SLAM re-localization [Lovegrove2011], we are currently researching into template matching approaches
- The characteristics of retinal images impose a different challenge

Man-made environment

Human retina



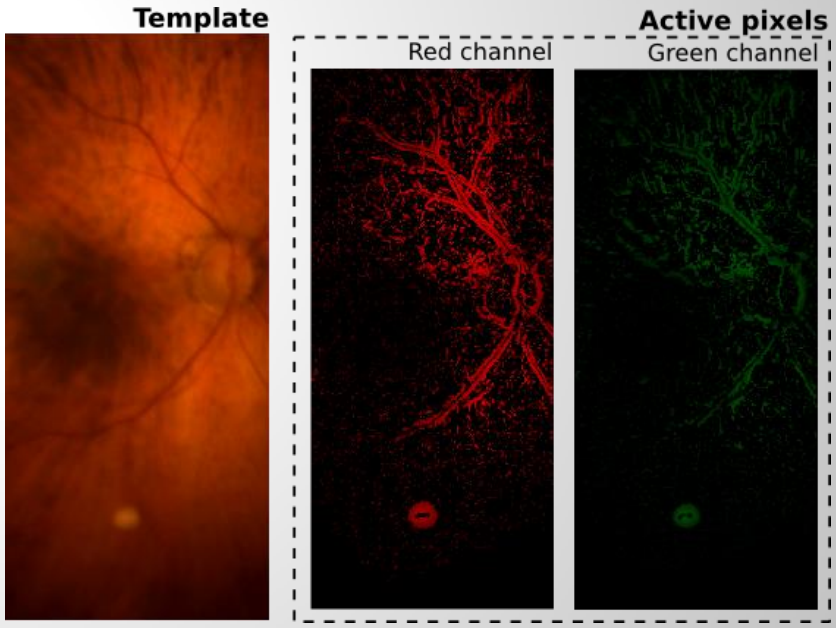
Template-based tracking relocalization

ROBUST VISUAL TRACKING

- Tracking quickly becomes computationally expensive

320x240 px template = 76,800 pixels (x2 x2)

- Pixel selection is an alternative
  - Standard selection based on gradient magnitude leads to poor performance
  - Method proposed in [Meilland11] shows the best performance



COMPUTATIONAL ASPECTS

- Can we operate at 60fps? (16.66 ms)
- Insufficient performance on CPU
  - I7 3.8GHz, 2.4GHz RAM

  → maximum of 4 ESM iterations, 20% active pixels 550x180 px template

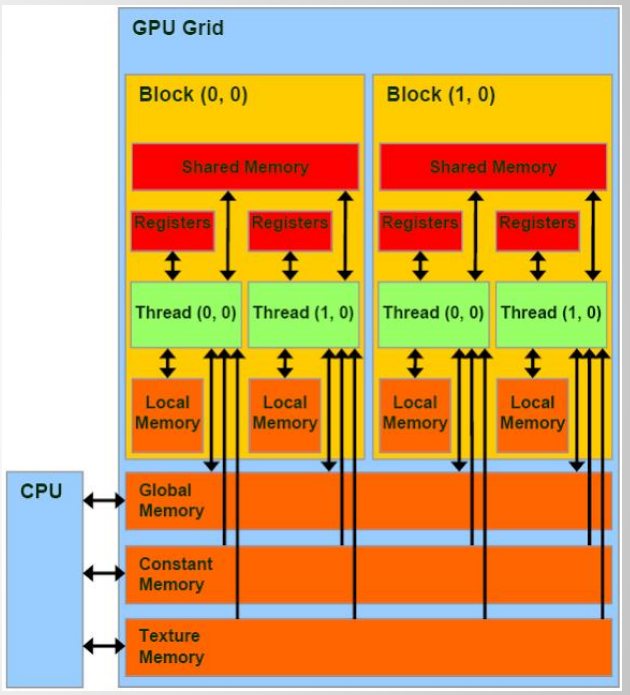
  → that is ~4ms per iteration using 1/5 of the downsampled image

  → multithreading with OpenMP
- Several operations can be parallelized
  - Image Warp
  - Sobel
  - ...

COMPUTATIONAL ASPECTS

- Should we expect a x10 speed gain using GPUs? Not really...

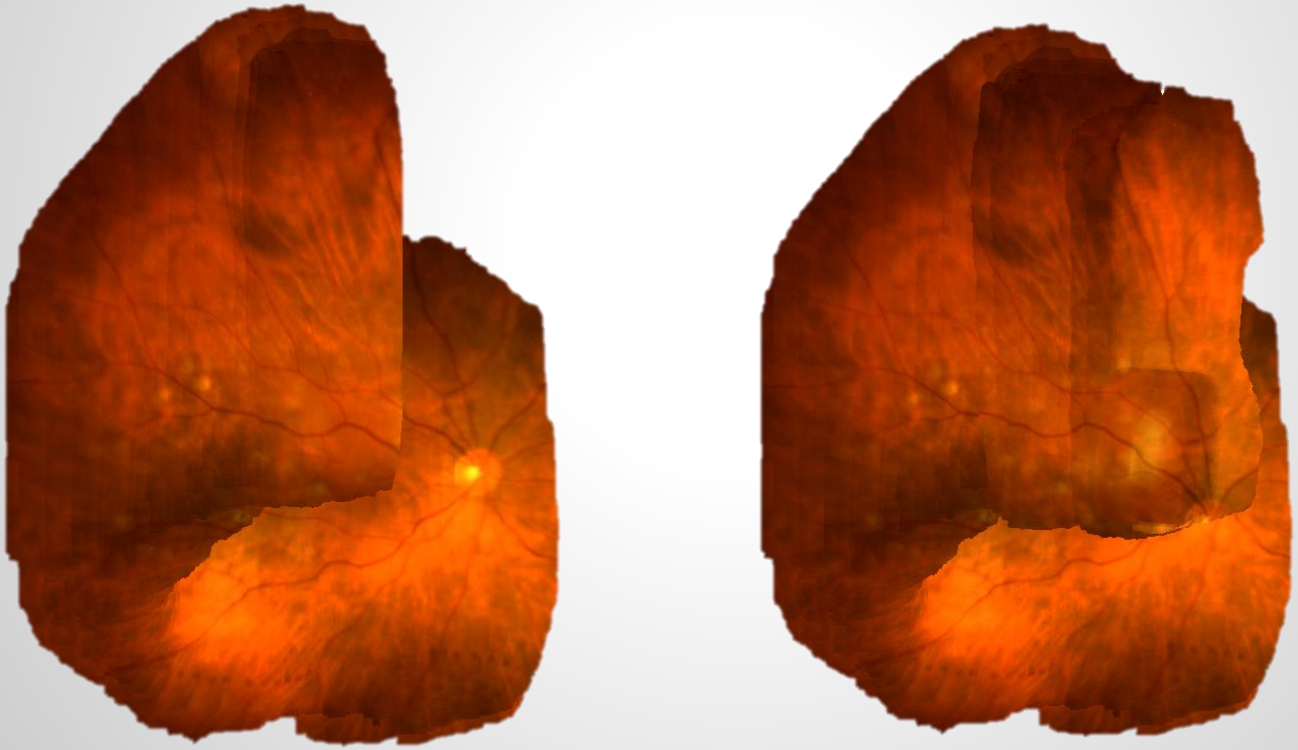
- Same algorithm is faster on a GTX 680
  - → For tracking 20k pixels (RG channels)
    - ~3.9ms on CPU
    - ~0.9 ms per iteration on GPU (x4 faster)
  - → 720HD image upload to GPU takes 0.7 ms
  - → Global memory is slow
  - → Fermi vs Kepler architecture
  - → We expect faster results in near future



CUDA architecture

CONCLUSION AND FUTURE WORKS

- Mosaicking the retina is not a simple task
- Current approach is promising but there are issues



CONCLUSION AND FUTURE WORKS

- Future work will focus on improving tracking and detection fronts
- Pre-op/Intra-op registration (e.g. fundus, angio ...)

Going beyond ...

- Control a multispectral illumination source to reduce phototoxicity
  - Epilepsy ?
  - Hardware development

Date **08/10/2013**

THANK YOU FOR YOUR ATTENTION!

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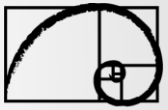

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