Retinal Image Registration Based on Keypoint Correspondences, Spherical Eye Modeling and Camera Pose Estimation

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Retinal Image Registration

Transforming images into **a single** coordinate system.

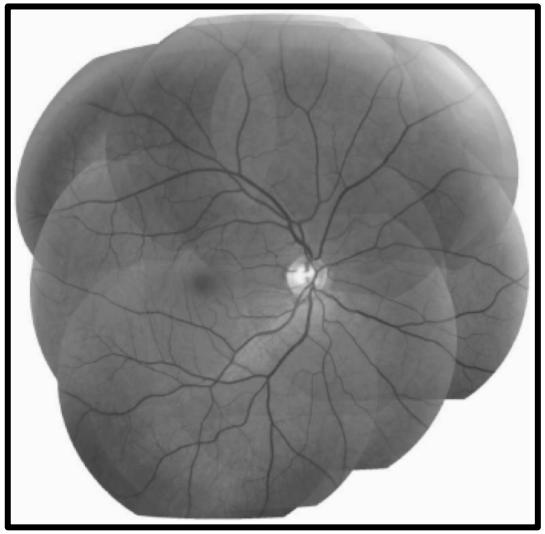
Warping an image to be placed **on top of another**, so that **overlapping pixels** image **the same physical point**.

Small overlap

- Mosaicing and stitching

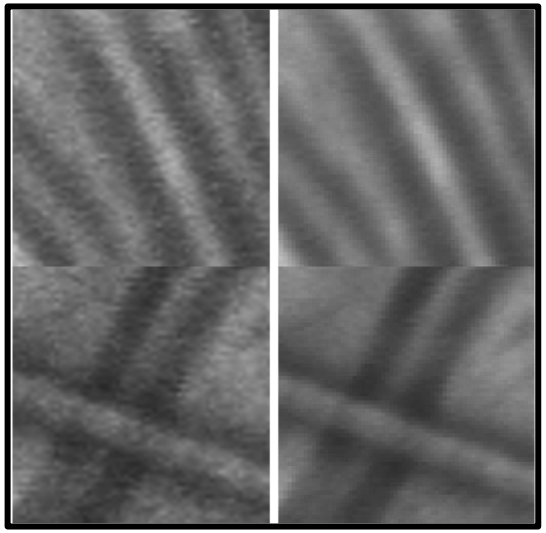
Large overlap

- Comparative analysis, images of higher resolution and definition



Small overlap

[Can 2002]



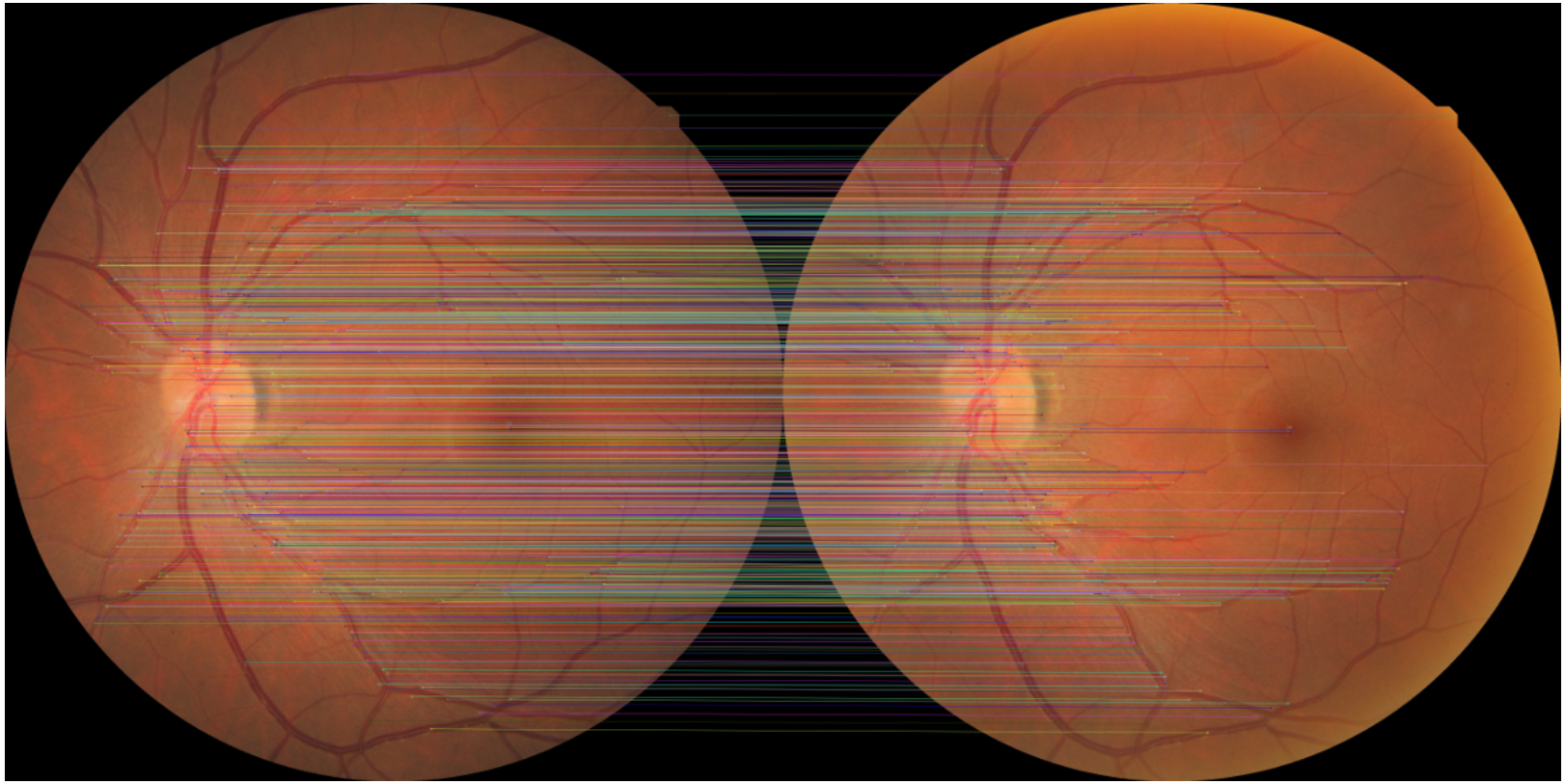
Large overlap

[Hernandez-Matas 2014]

Proposed Method

- Employs a 3D approach to registration:
  - **spherical eye model**
  - treat registration as a **model-based, 3D pose estimation problem**
- An **objective function**, based on **distances of corresponding keypoints** in the registered images is optimized to find the solution.
- **Particle Swarm Optimization** (PSO) [Poli 2007] is employed
  - parallelizable due to **independent particles**
  - No derivatives

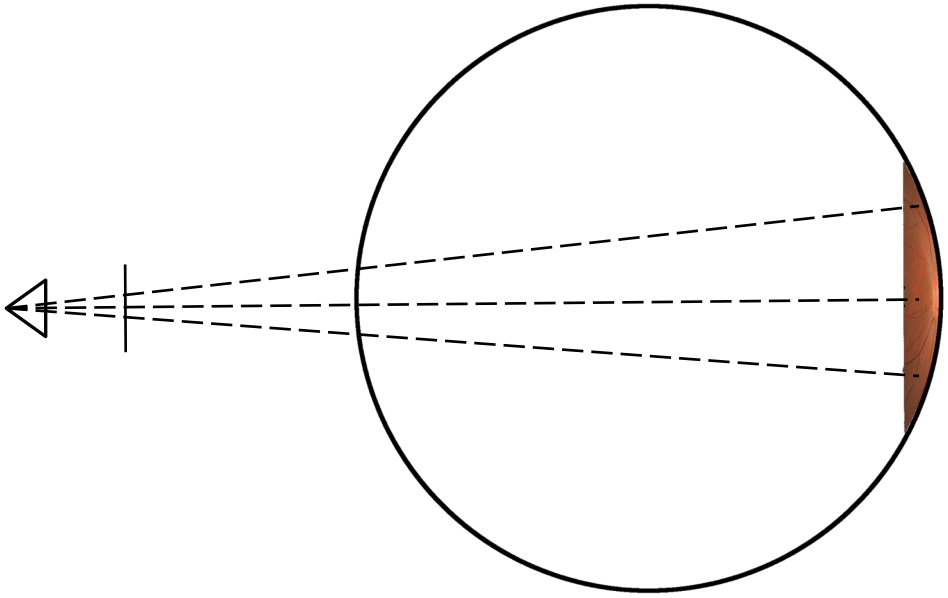
Keypoint Correspondences

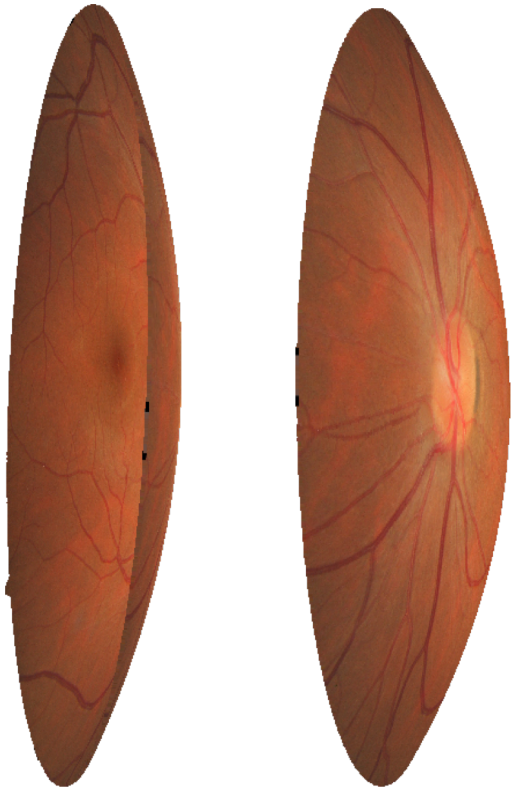


Spherical Eye Model

Known system geometry (model-based)

3D eye model [Navarro 1985] allows treating as 3D pose estimation problem.



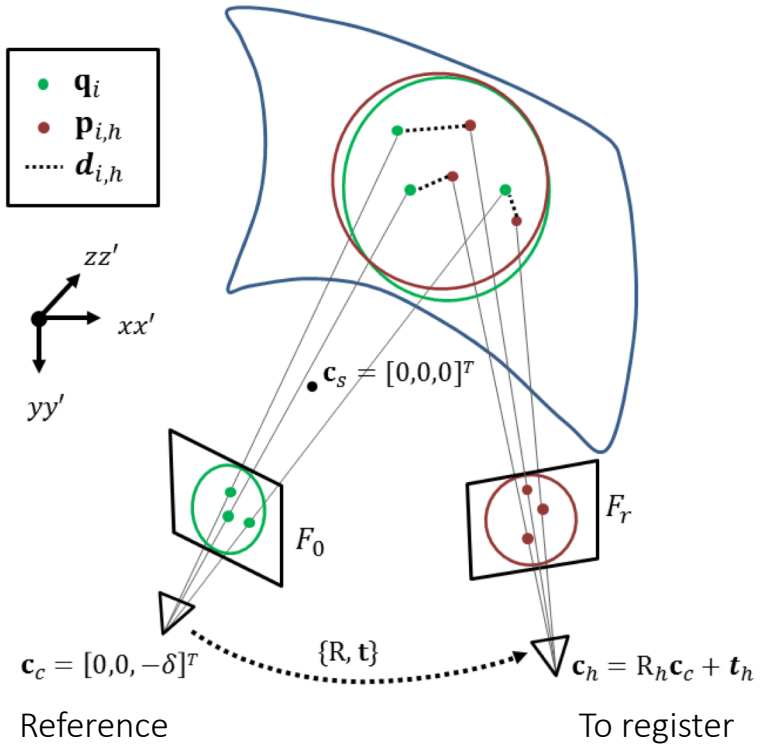


Pose Estimation

Method finds the **3D rotation and translation** linking the two images

A **candidate pose** for the camera of the image to register is set via **{R,t} transformation**

Objective function error is the sum of **errors, or otherwise, the sum of distances** of corresponding **keypoints after application of the candidate registration.**



Objective function optimization

- PSO [Poli 2007]
- Stochastic technique in which several **particles converge iteratively** towards the solution after several **generations**
- Better **robustness** to **local minima**
- **Simple, Parallelizable**

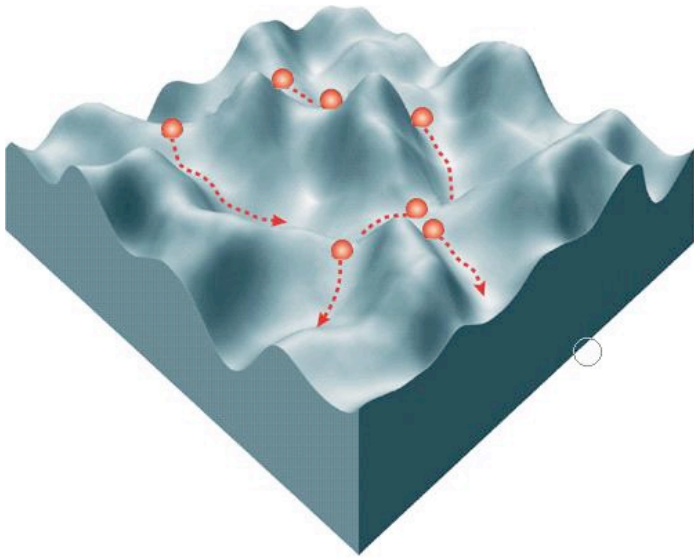
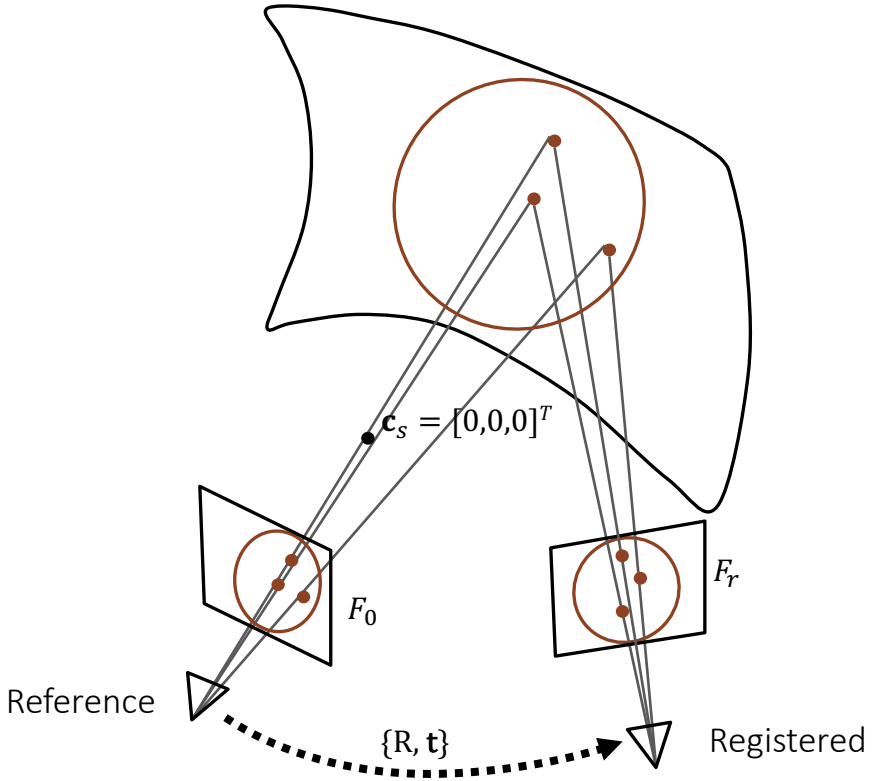


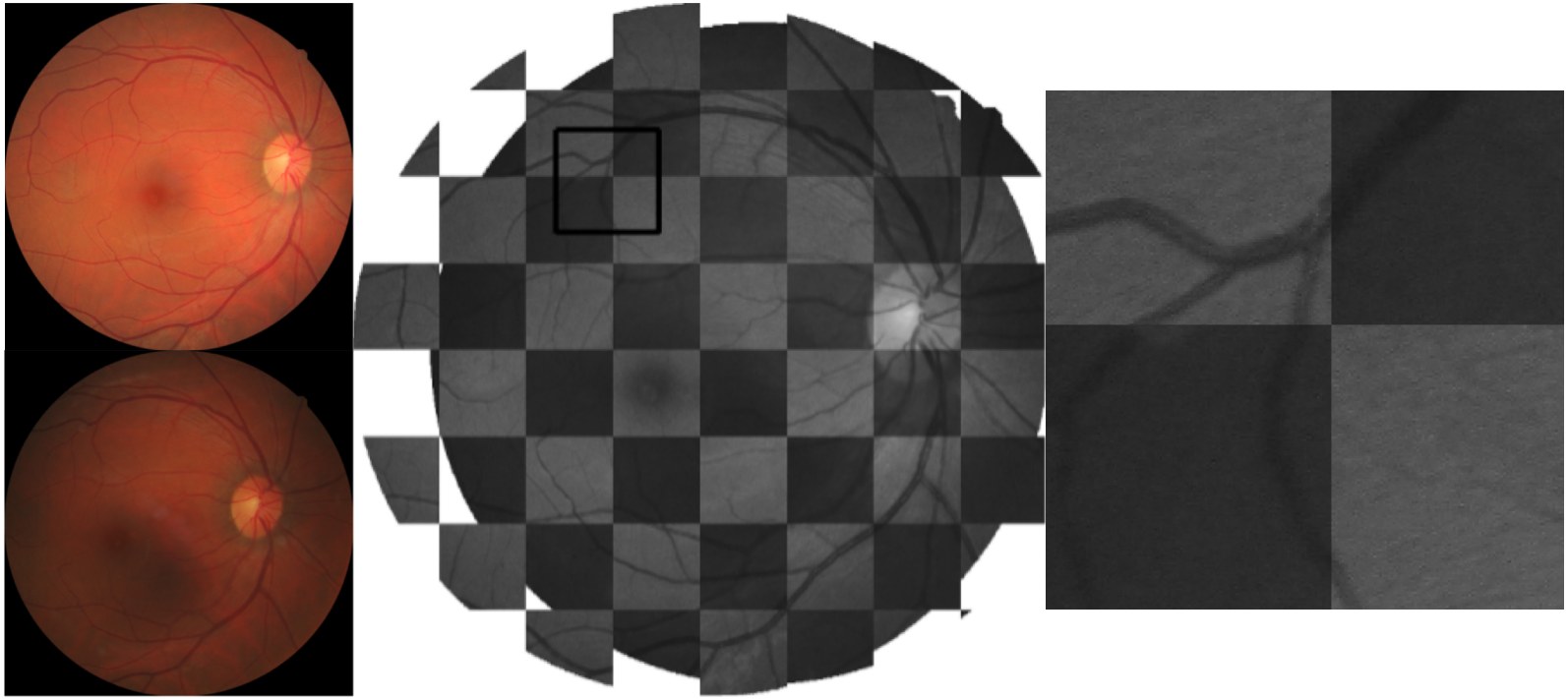
Image formation

Using {R, t} solution and the eye model, **pixels from** the test image can be projected **upon the reference image frame**

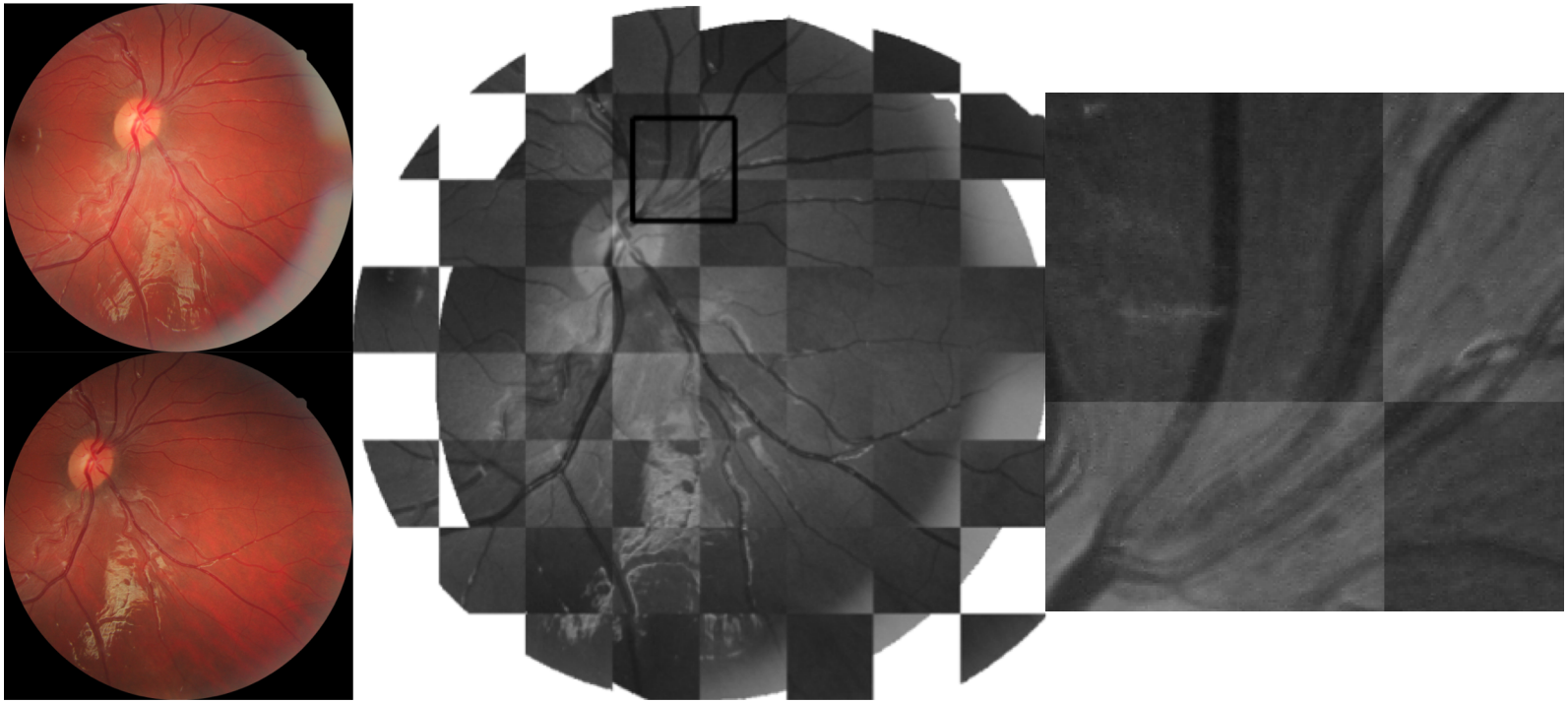
The **registered image** is formed by, inversely, **ray tracing** a pixel in the reference image, to **sample** its **color** from the test image.



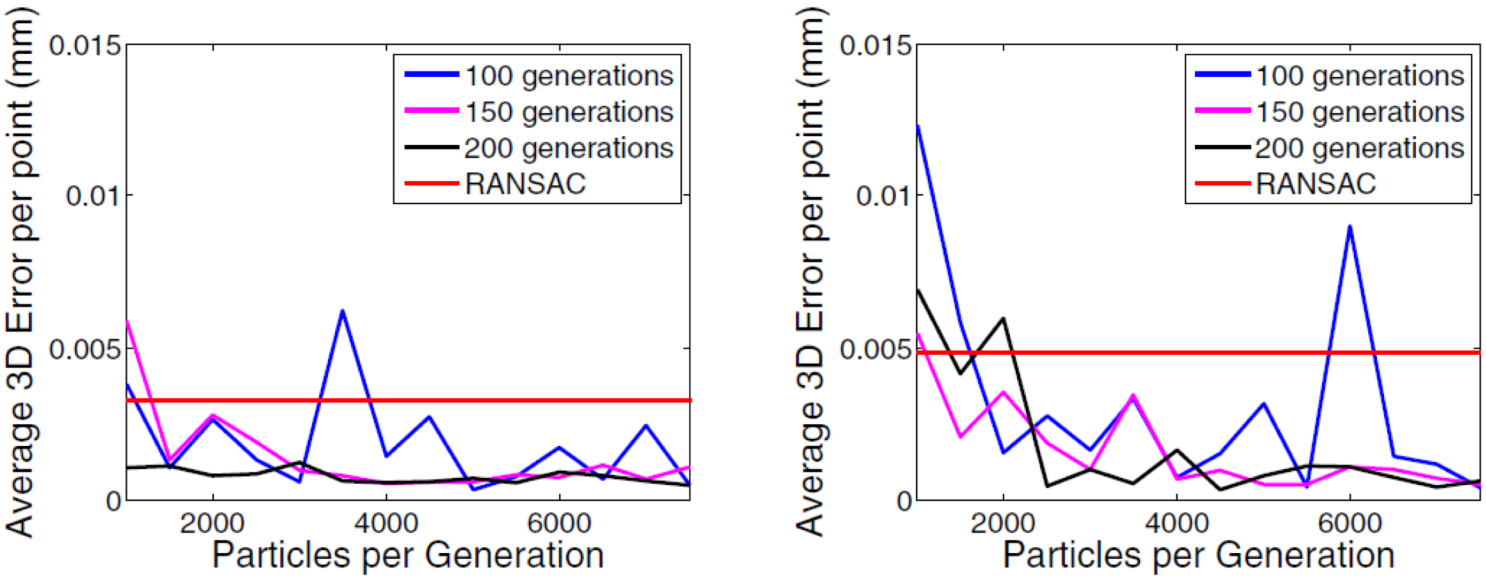
Registration Result I



Registration Result II



3D accuracy and budget study



Registration error for 3-stage PSO, for 100, 150 and 200 generations vs number of particles, for a small (left) and a large transformation (right) between the 2 images. RANSAC plot in red.

2D registration accuracy

Error (pixels)	This work	GDB-ICP
Mean and std (all)	0.4878 (0.2064)	0.5158 (0.2395)
Mean and std (periphery)	1.5002 (2.0587)	1.6082 (1.9087)

Proposed method is a 5.43 % more accurate than GDB-ICP for all pixels, and 6.72 % for pixels located in the periphery.

Conclusion

- Method for **retinal image registration** for fundoscopy images was proposed.
- **Increased accuracy** and **robustness** compared to state-of-the-art approaches.
- Large **computational cost justified** by the offline and critical nature of targeted applications.
- **Future work** warrants **more sources** of information, **increase** of **optimized dimensions** to include the shape and size of the retina as well as the camera parameters.

Thank you for your attention!