Retinal Image Registration Through Simultaneous Camera Pose and Eye Shape Estimation

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What is (Retinal) Image Registration?

Image registration involves **a pair of images**: reference and test.

Spatial **warping** of the **test image** so that its points are imaged at the 2D coordinates of the **corresponding** points in the **reference image**.

The reference and test images may **differ** with respect to the **viewpoint**, the **time** and the image **acquisition device**.

Retinal Image registration consists on the registration of retinal images.

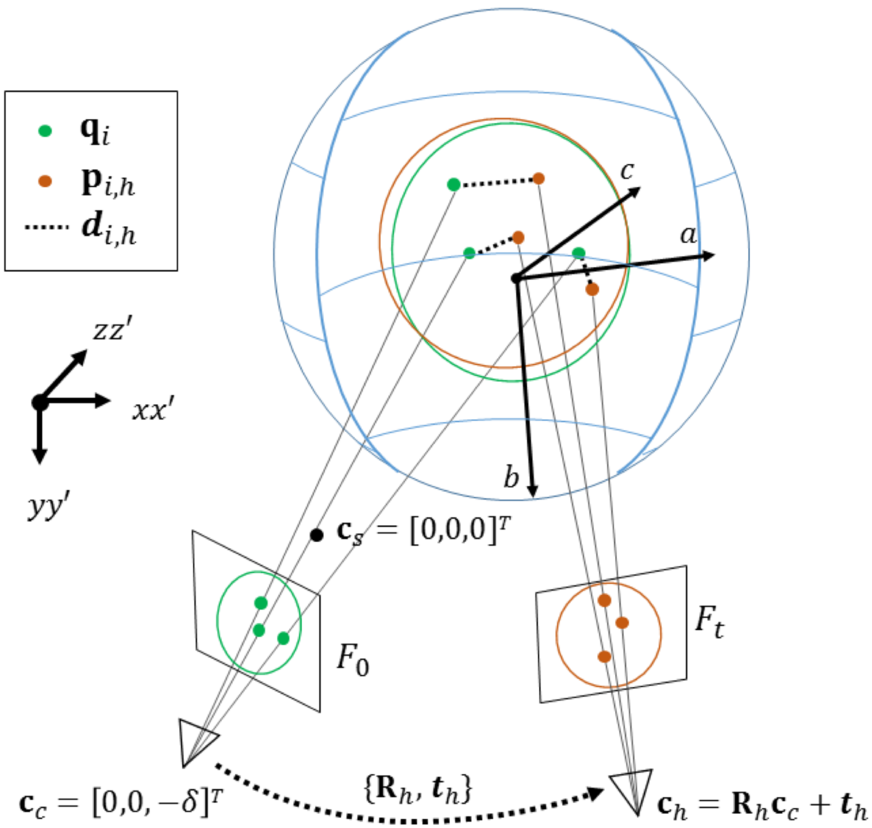
What do we propose?

Registration via **simultaneous** camera **pose** and eye **shape** estimation.

Camera pose {R, t}

General eye shape and rotation {A, Q}

Solution S = {R, t, A, Q}



Why do we propose it?

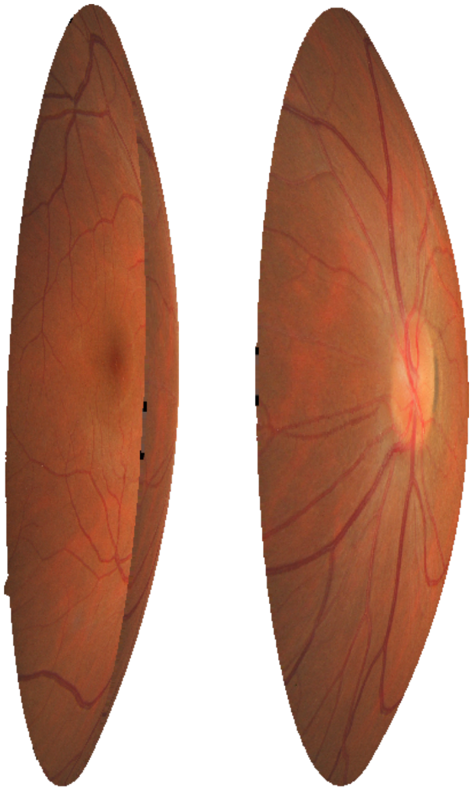
To account for 3D shape and provide **more accurate registration**

Images with **large FOV** present large **distortion** around the **periphery**

To estimate the **approximate 3D eye model**

- Opens the door for **possible 3D measurements** in the model

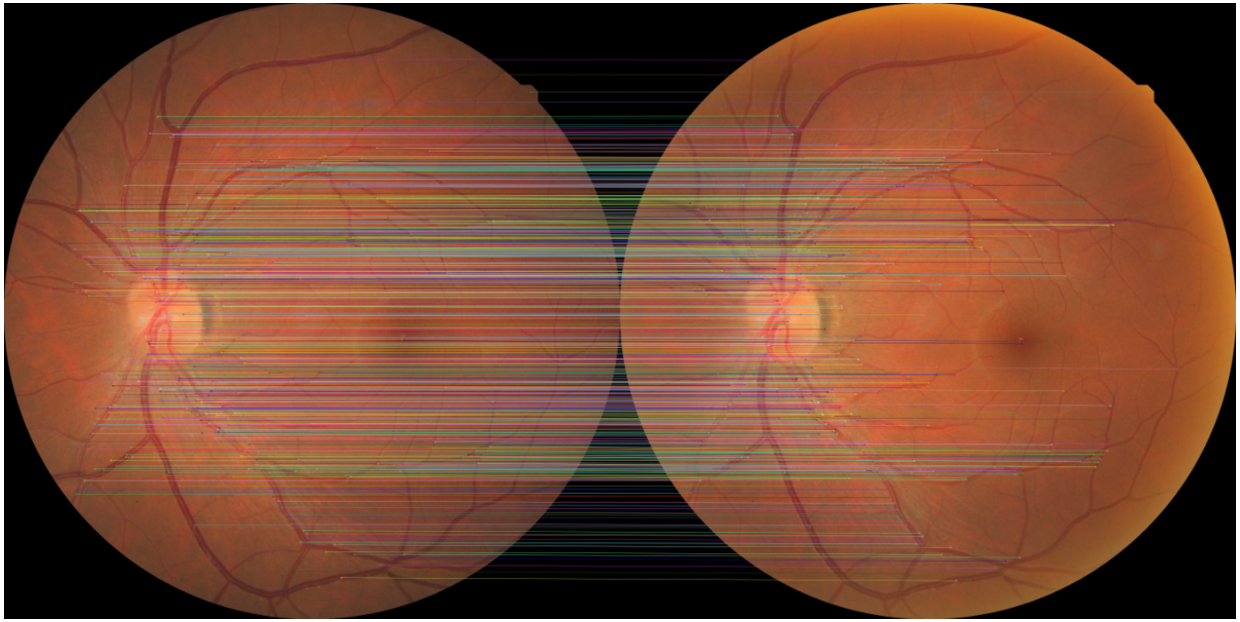
To obtain **3D registered images**



Feature detection and matching

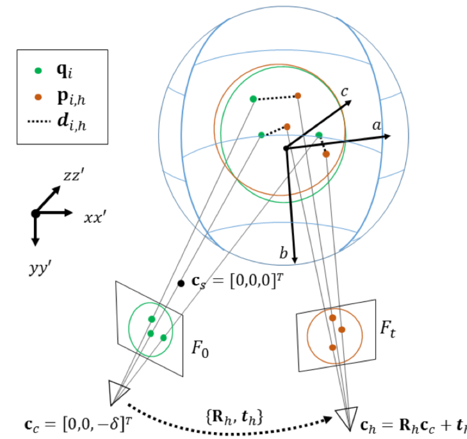
Detect **corresponding points** in both images

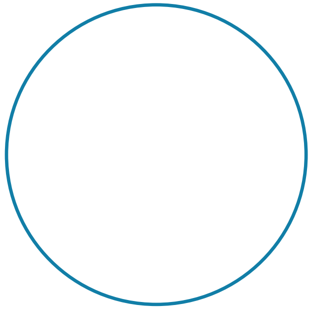
Currently utilizing **SIFT**



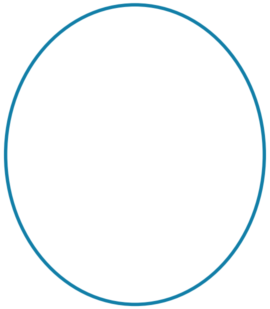
Eye model

Three models, with increasing level of complexity

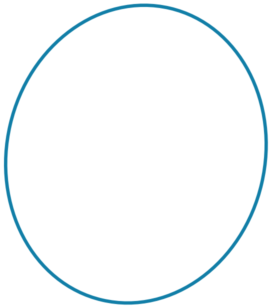




Sphere



Fixed orientation ellipsoid



Ellipsoid

Transform Model Estimation: Initialization

Solve Perspective-n-Point (PnP) problem utilizing Random Sample Consensus (RANSAC)

Pose is calculated through the **minimization** of the **projection error** between the 2D and projected 3D points on spherical eye model

Provides an **initial, coarse pose estimate**

… which is then refined by the proposed method

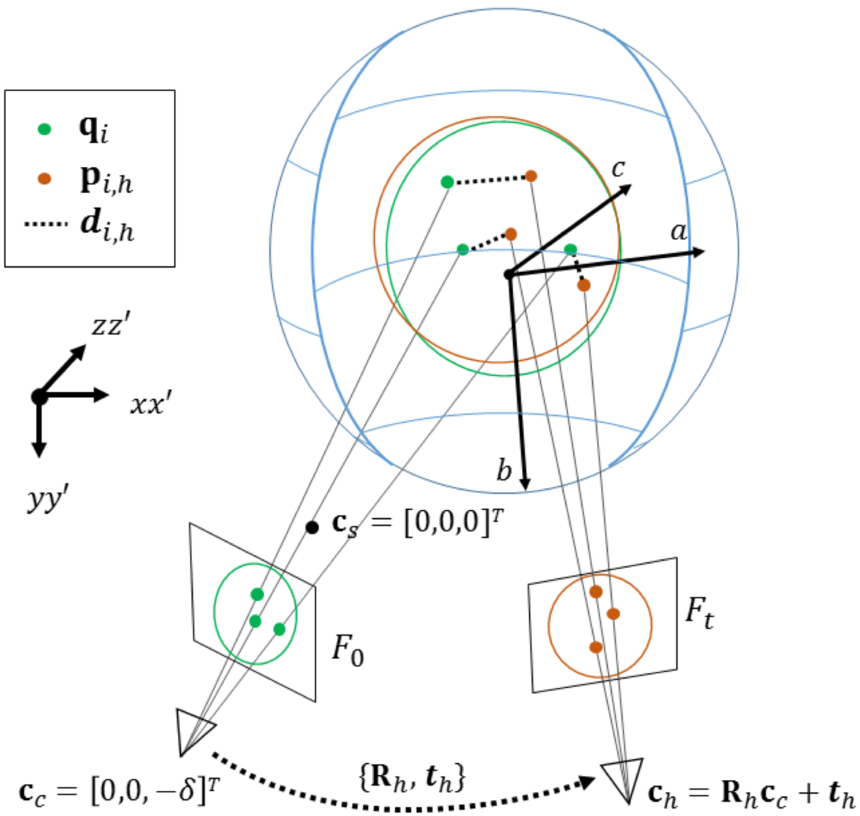
Transform Model Estimation: Objective function

An objective **function** whose **minimization** will provide the pursued pose **estimate**

Objective function **sums** the **distance** of **corresponding points** in the **eye model**:

$o(S_h) = \sum_j d_{j,h}$

j enumerates the smallest 80% values of $d_{j,h}$



Transform Model Estimation: Particle Swarm Optimization

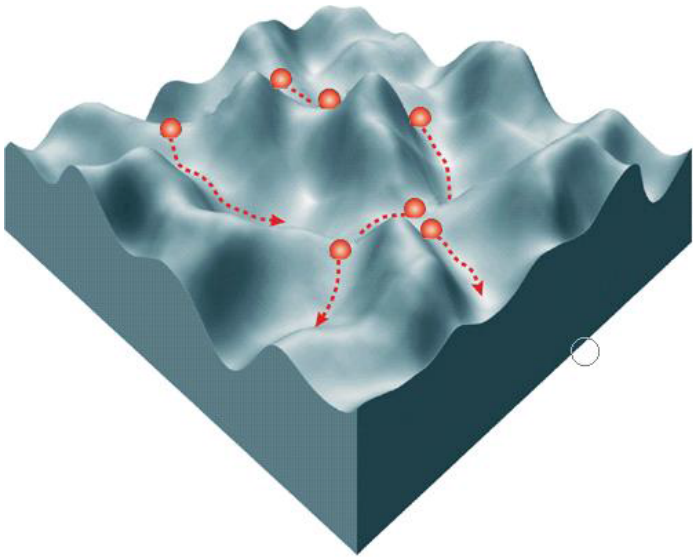
Stochastic technique in which **particles** search a multidimensional space, **converging iteratively** towards a global optimal **solution**

This **objective function**. The minimal is the pursued estimation.

This **avoids exhaustive** space search

No derivatives calculation (simple) due to **Robustness** to local minima

Parallelizable (CPU and GPU implementations)

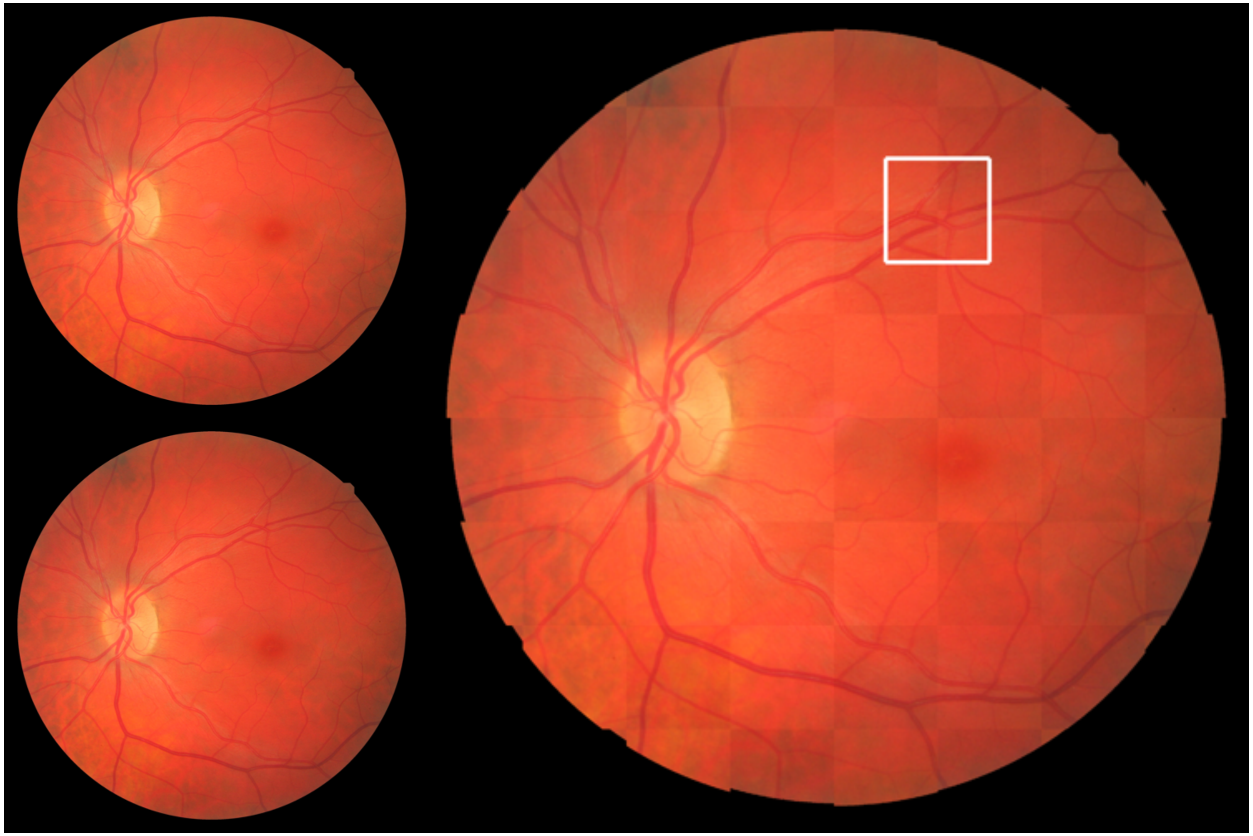


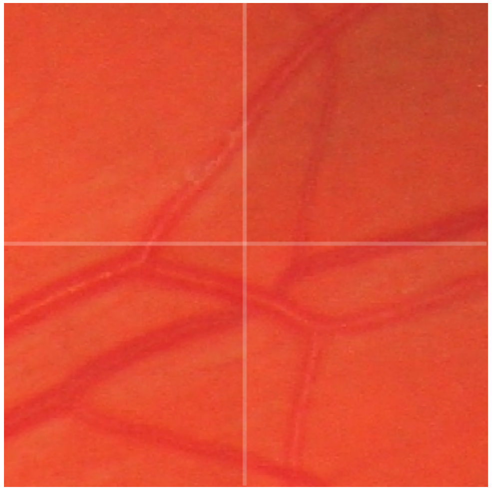
Data

Dataset	1	2	3
# Image pairs	71	44	8
Examination session	Same	Same	Different
Overlap	> 75%	< 75%	> 75%
Anatomical changes	No	No	Yes
Indicative application	Super resolution	Mosaicing	Longitudinal study

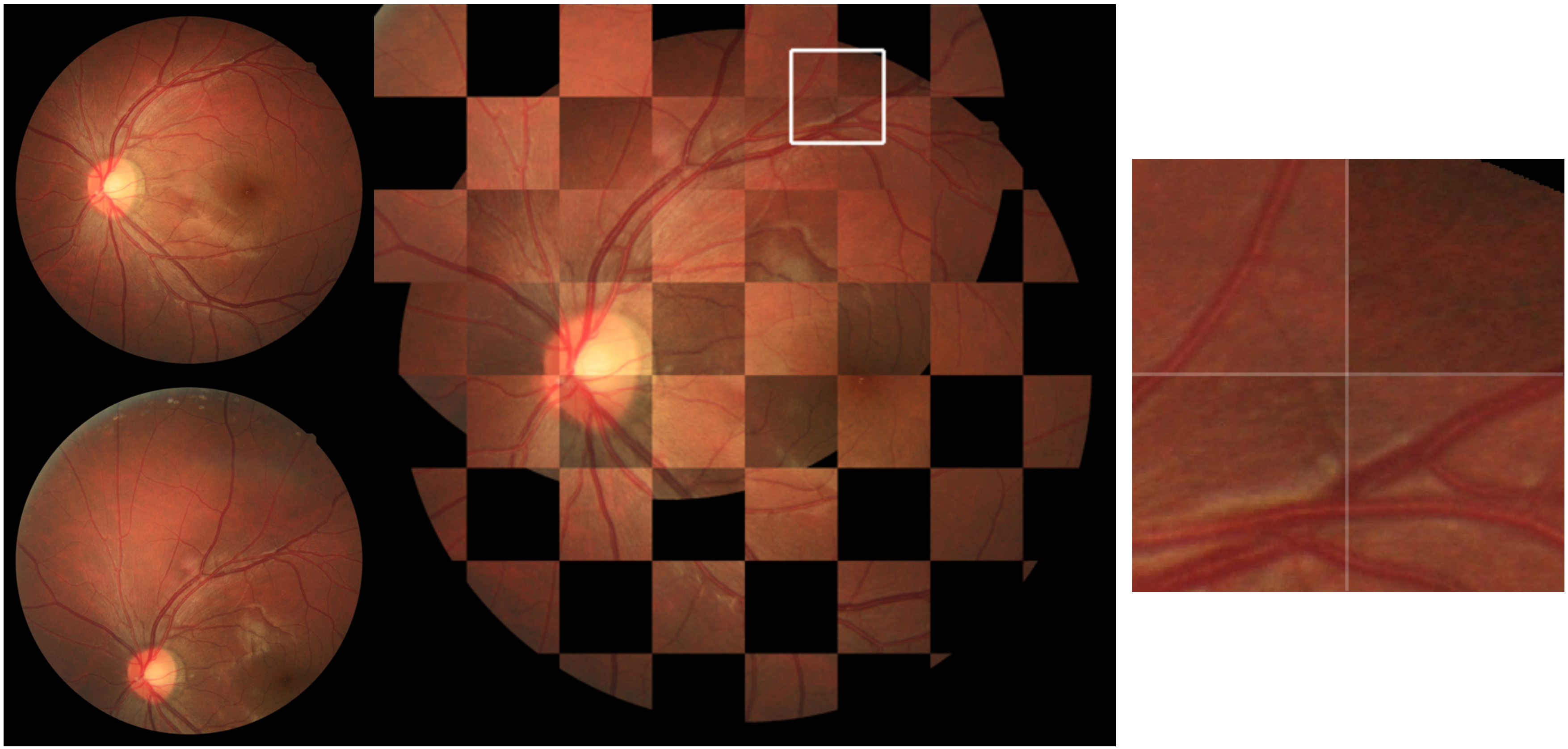
Ground truth: Manually supervised corresponding points (SURF) matched automatically

Dataset 1

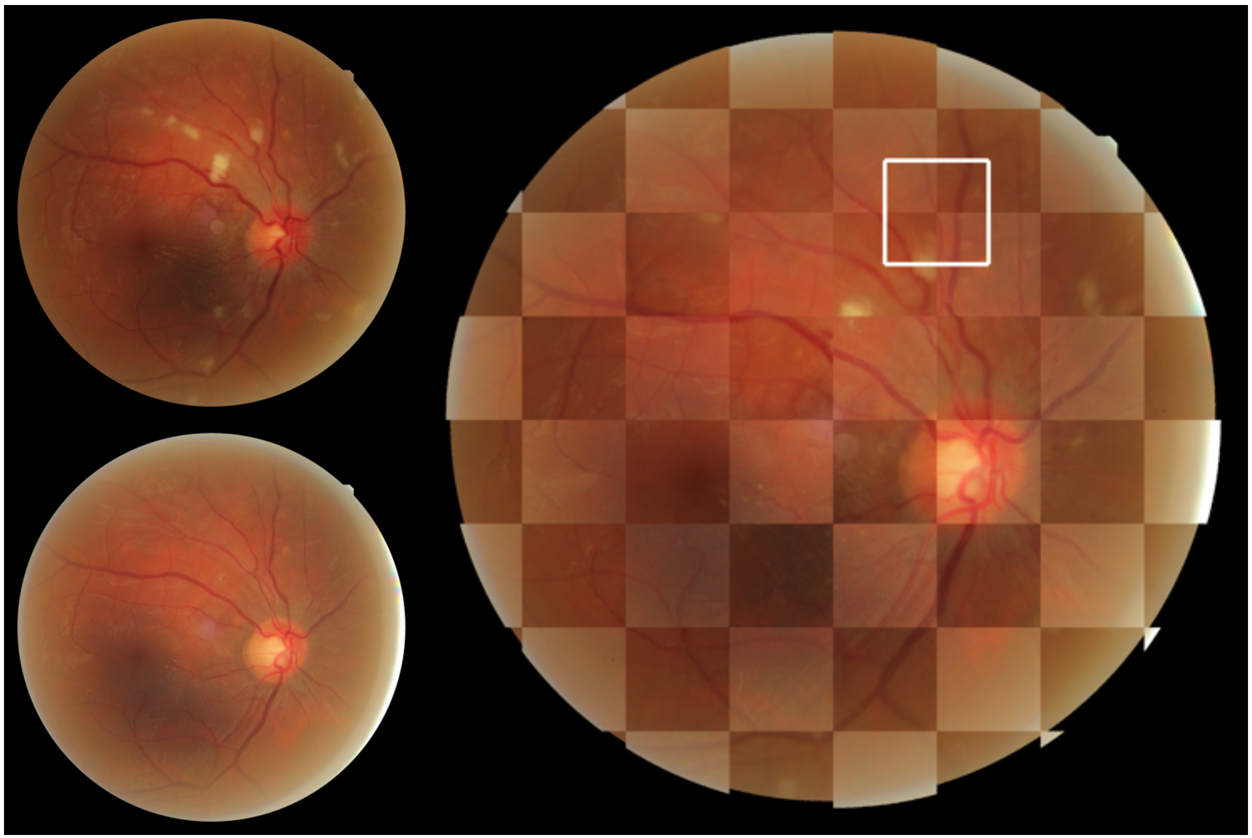


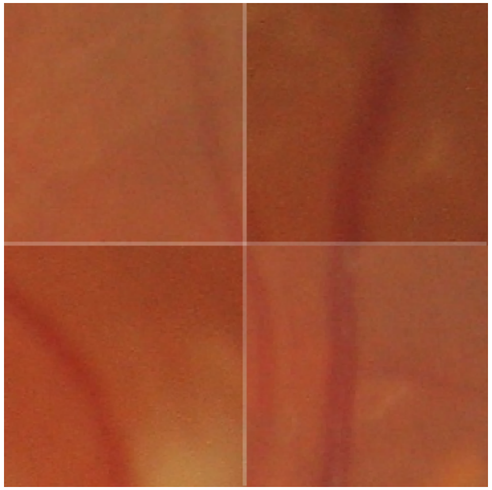


Dataset 2

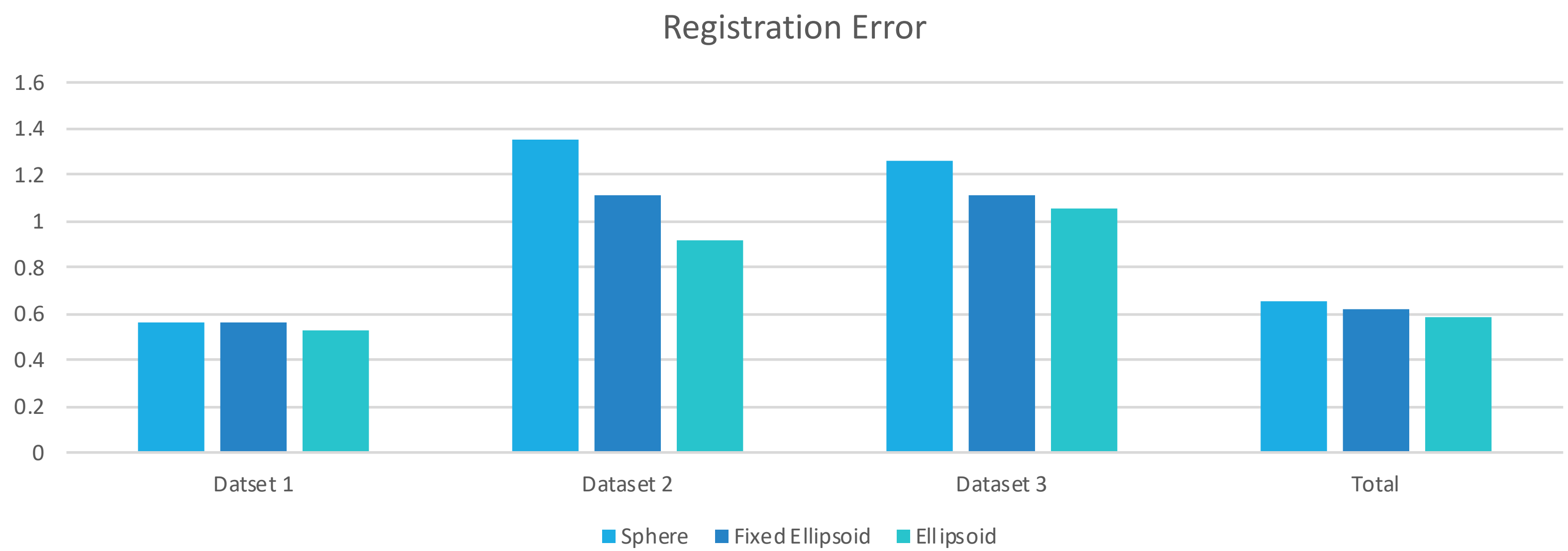


Dataset 3



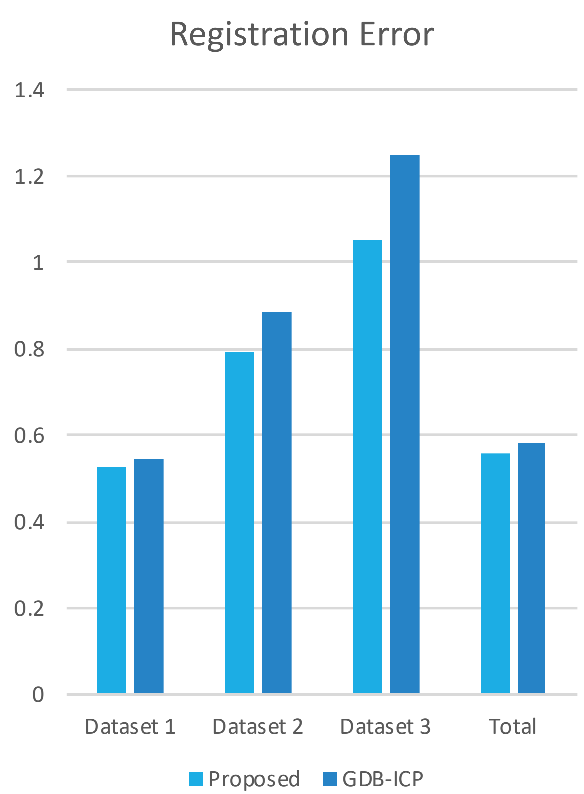


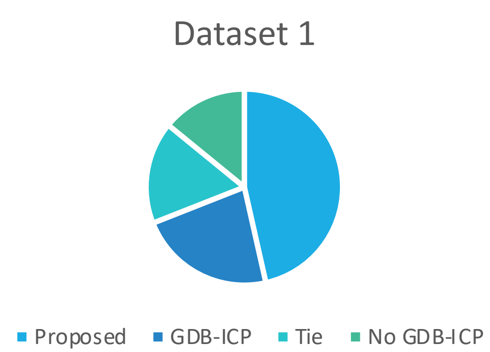
Comparative results: model

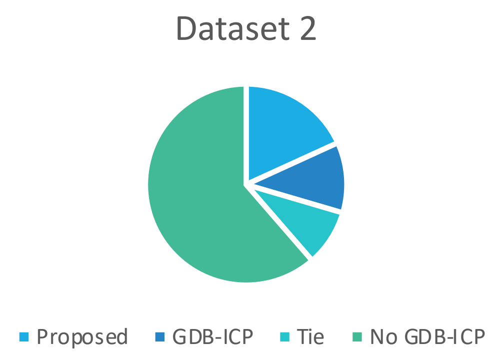


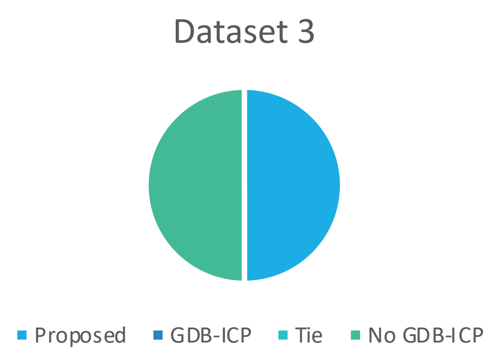
The higher the complexity of the model, the more accurate the registration

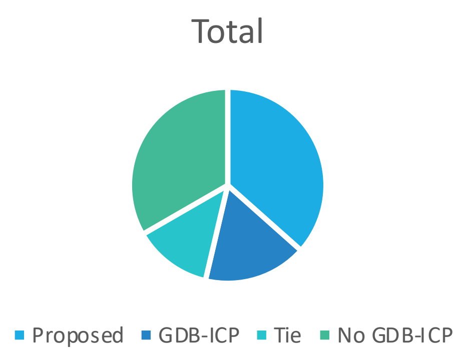
Comparative results: methods











Conclusion

Retinal image registration method.

Simultaneous estimation of

- (a) **the relative 3D pose** of the **cameras** that acquired the
- (b) the **parameters** and the **orientation** of an e**llipsoidal model** of the **eye**.

The performed experimental evaluation shows that the **better** the model **approximates** the eye, the **more accurate** the registration.

Proposed method is more **robust** and **accurate** than **GDB-ICP**, a **widely employed method** for retinal image registration

Dataset available

Dataset soon publicly available at

http://www.ics.forth.gr/cvrl/fire

Thank you for your attention!