Retinal Image Registration Through Simultaneous Camera Pose and Eye Shape Estimation

CARLOS HERNANDEZ-MATAS (1,2)
XENOPHON ZABULIS (1)
ANTONIS A. ARGYROS (1,2)

1- Institute of Computer Science – FORTH
2- Computer Science Department – University of Crete
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

<table>
<thead>
<tr>
<th>Dataset</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td># Image pairs</td>
<td>71</td>
<td>44</td>
<td>8</td>
</tr>
<tr>
<td>Examination session</td>
<td>Same</td>
<td>Same</td>
<td>Different</td>
</tr>
<tr>
<td>Overlap</td>
<td>&gt; 75%</td>
<td>&lt; 75%</td>
<td>&gt; 75%</td>
</tr>
<tr>
<td>Anatomical changes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Indicative application</td>
<td>Super resolution</td>
<td>Mosaicing</td>
<td>Longitudinal study</td>
</tr>
</tbody>
</table>

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

![Bar and Pie Chart Diagrams](image-url)
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 ellipsoidal 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!