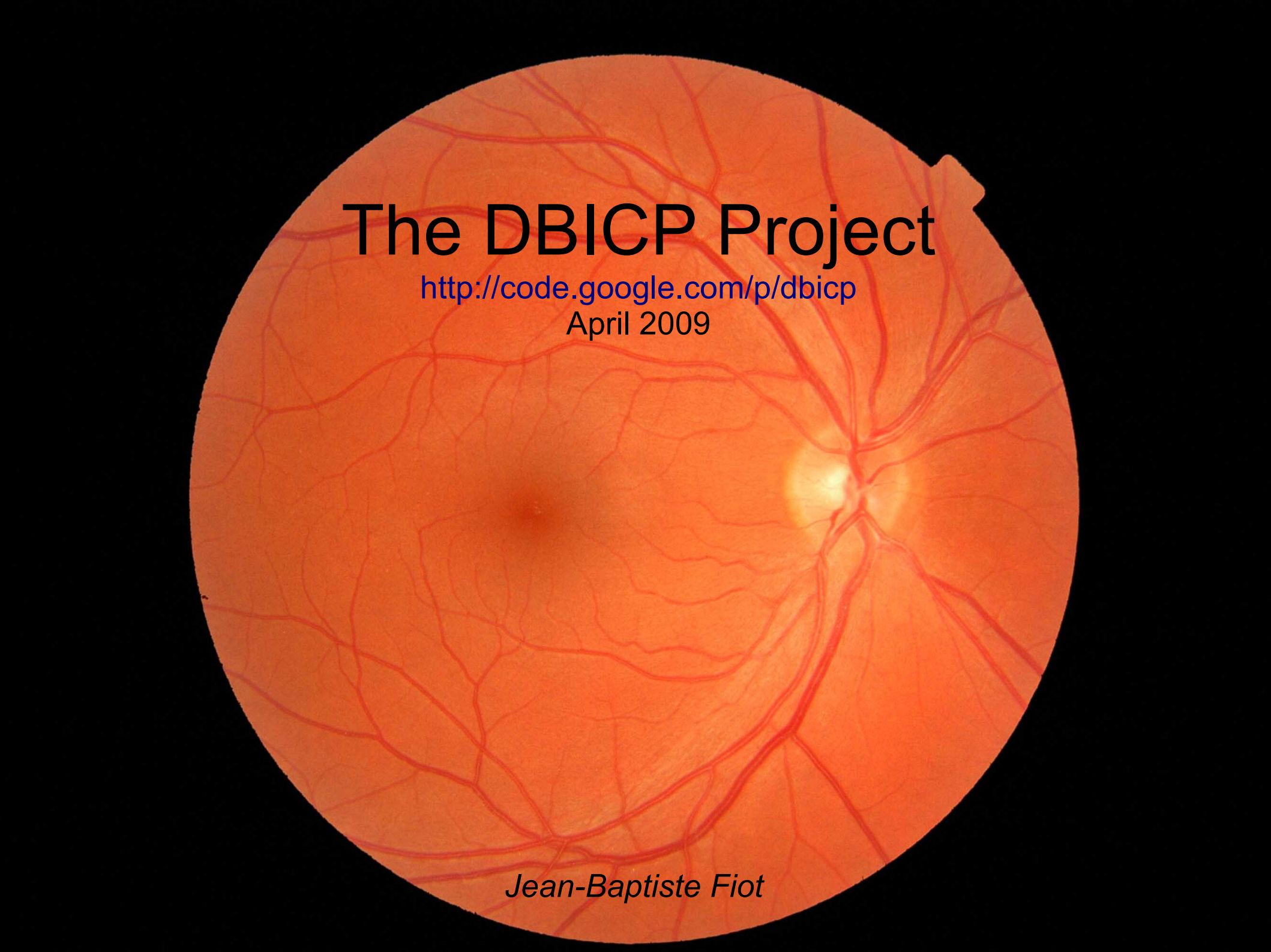


The DBICP Project

http://code.google.com/p/dbicp

April 2009

Jean-Baptiste Fiot

Position of the problem

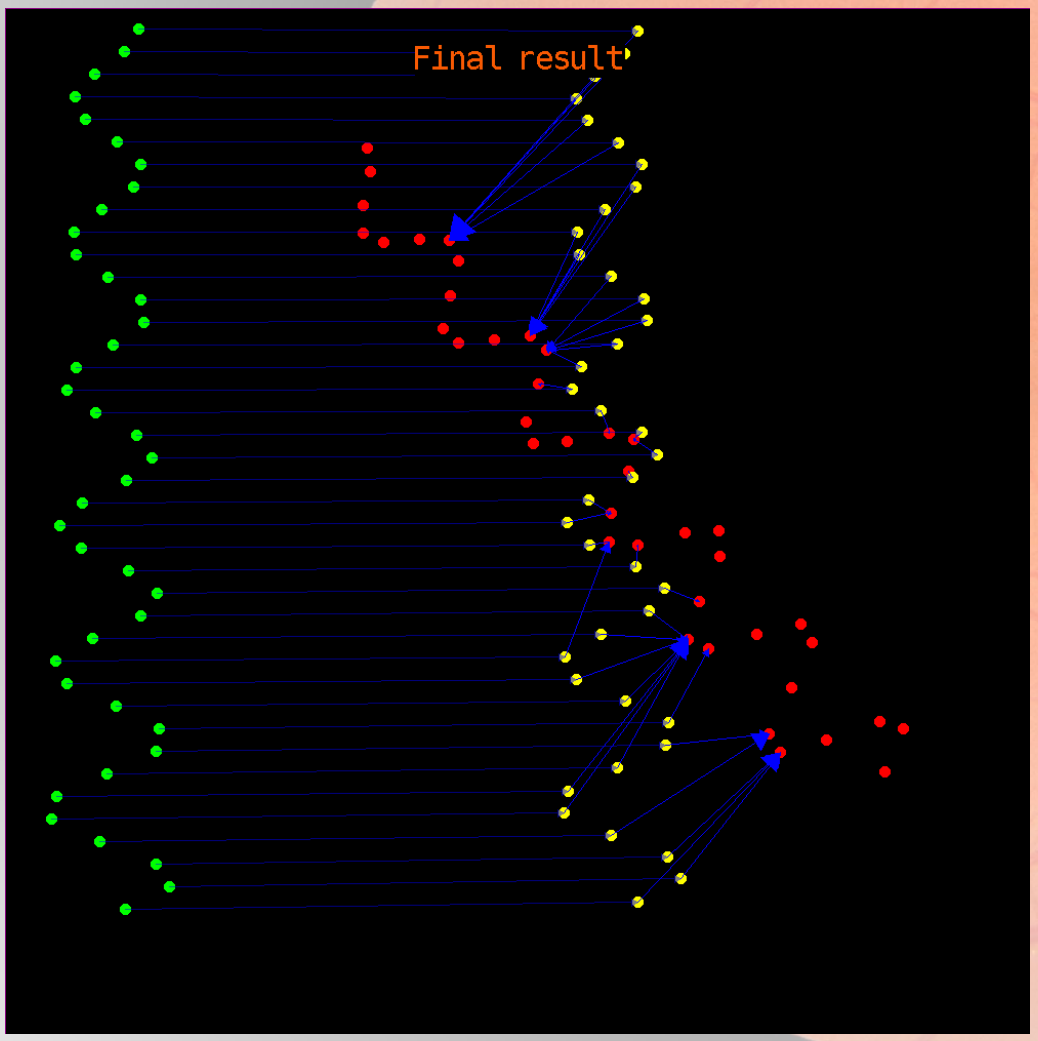
- Point-based registration
- Parametric transformations
- Unknown correspondences
- Conditions might be tough. Example:

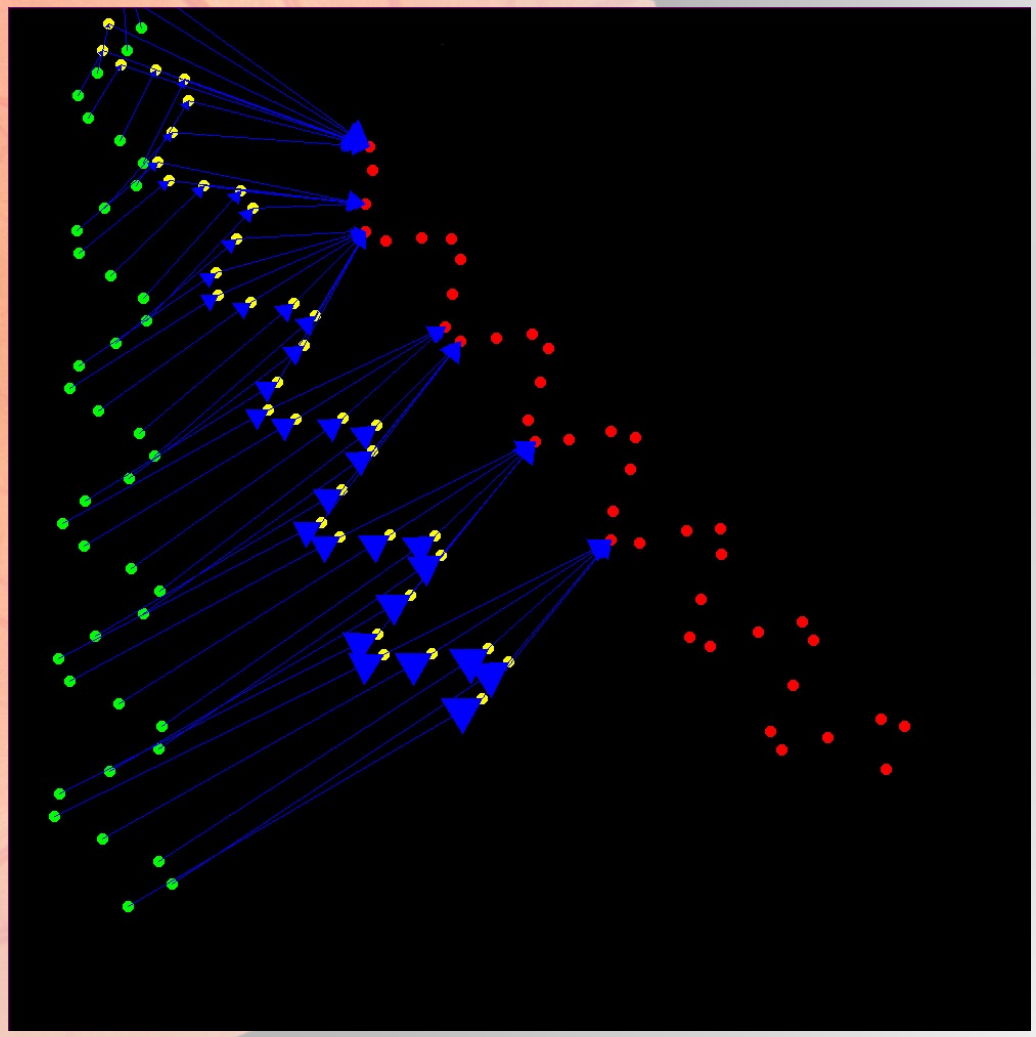
ICP algorithm

- Initialization
  - Initial transformation
- Iterations of 2 steps:
  - Matching step
    - Find the correspondences given the current transformation T
  - Optimization step
    - Optimize the parameters of the transformation T given the current correspondences

ICP – Matching Step

- Illustrated with the blue arrows:

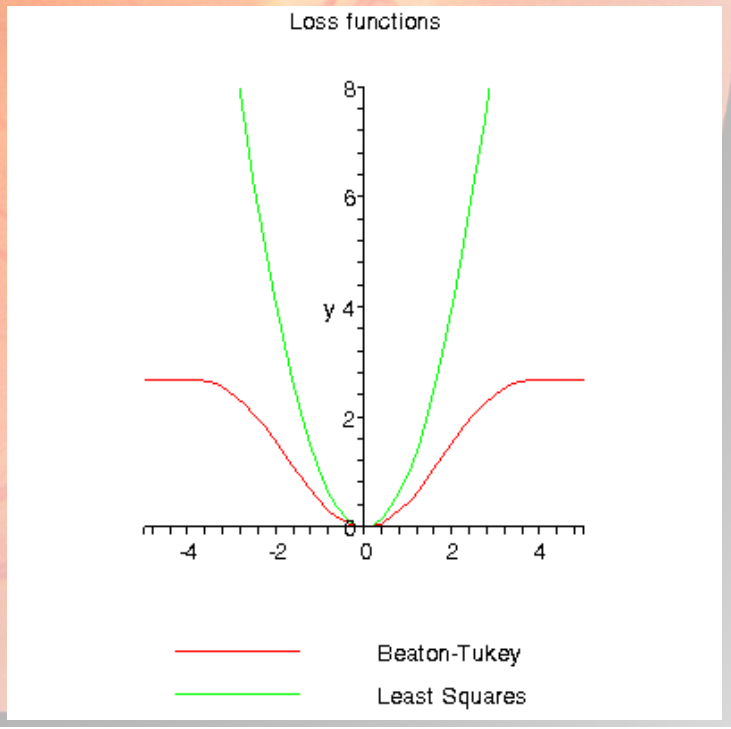




ICP – Optimization Step

$$E(\theta, \sigma, C) = \sum_{p_i, q_j \in C} \rho\left(\frac{d(T_\theta(p_i), q_j)}{\sigma}\right)$$

$$\text{with} \begin{cases} \theta & \text{parameters of the } T_\theta \text{ transformation} \\ \{p_i, q_j\} & \text{points in the images} \\ \sigma & \text{error scale} \\ \rho & \text{loss function} \end{cases}$$



ICP – Optimization Step

- Various possibilities (IRLS, Levenberg Marquadt, classic gradient descent...)
- Gradient descent with ρ constant, using finite differences:

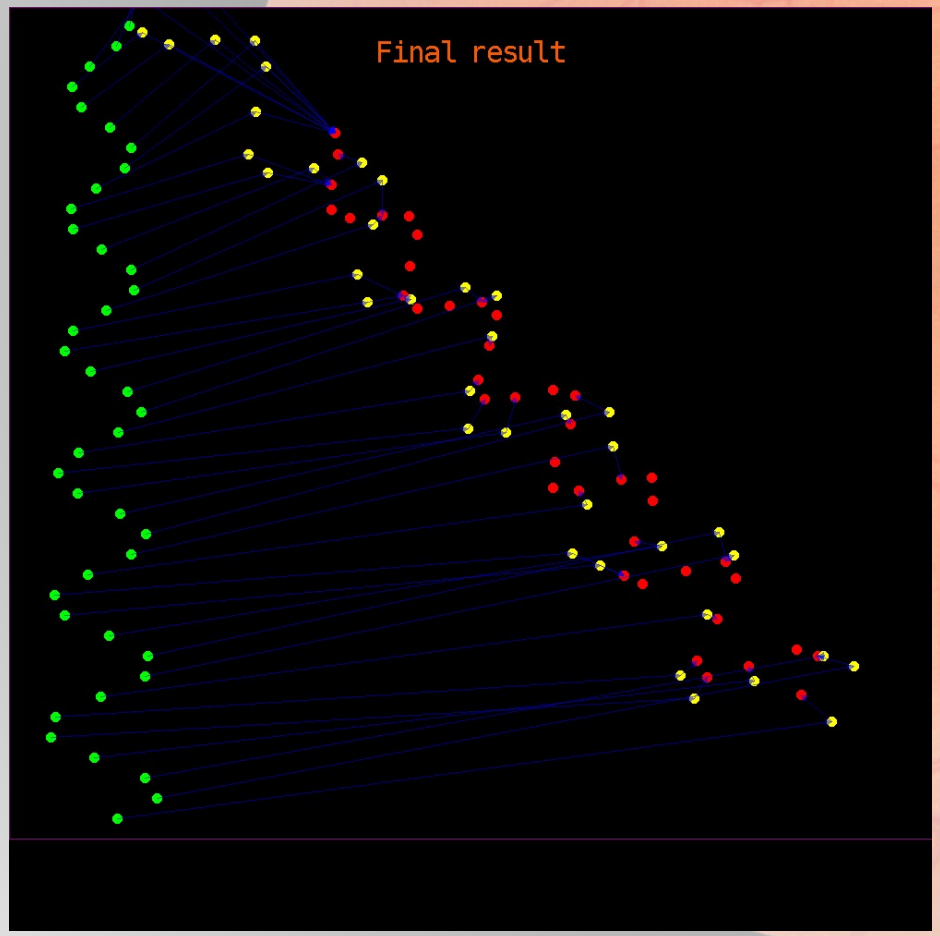
$$\theta_i \leftarrow \theta_i - \rho * \frac{E(\theta_i + \epsilon) - E(\theta_i)}{\epsilon} \approx \theta_i - \rho * \nabla E_i$$

(Note for E : other parameters remain constant in the finite difference)

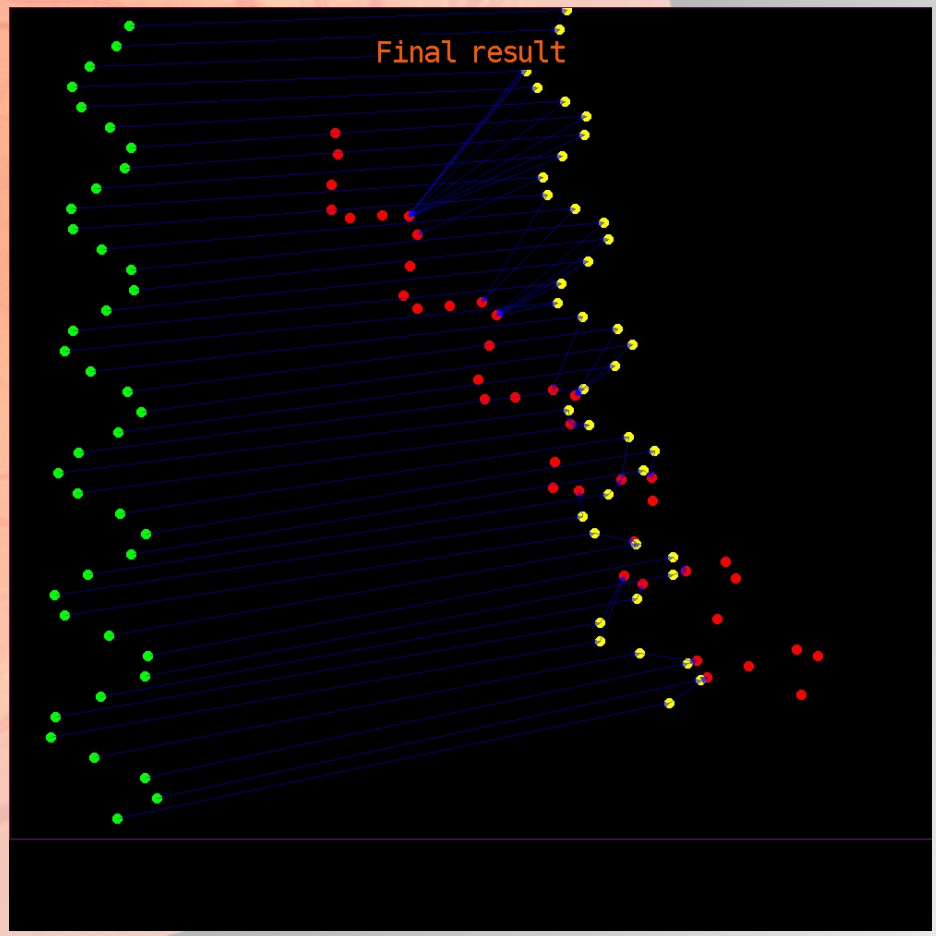
ICP Demo

- Videos of algo stuck in local minima:

Video 1

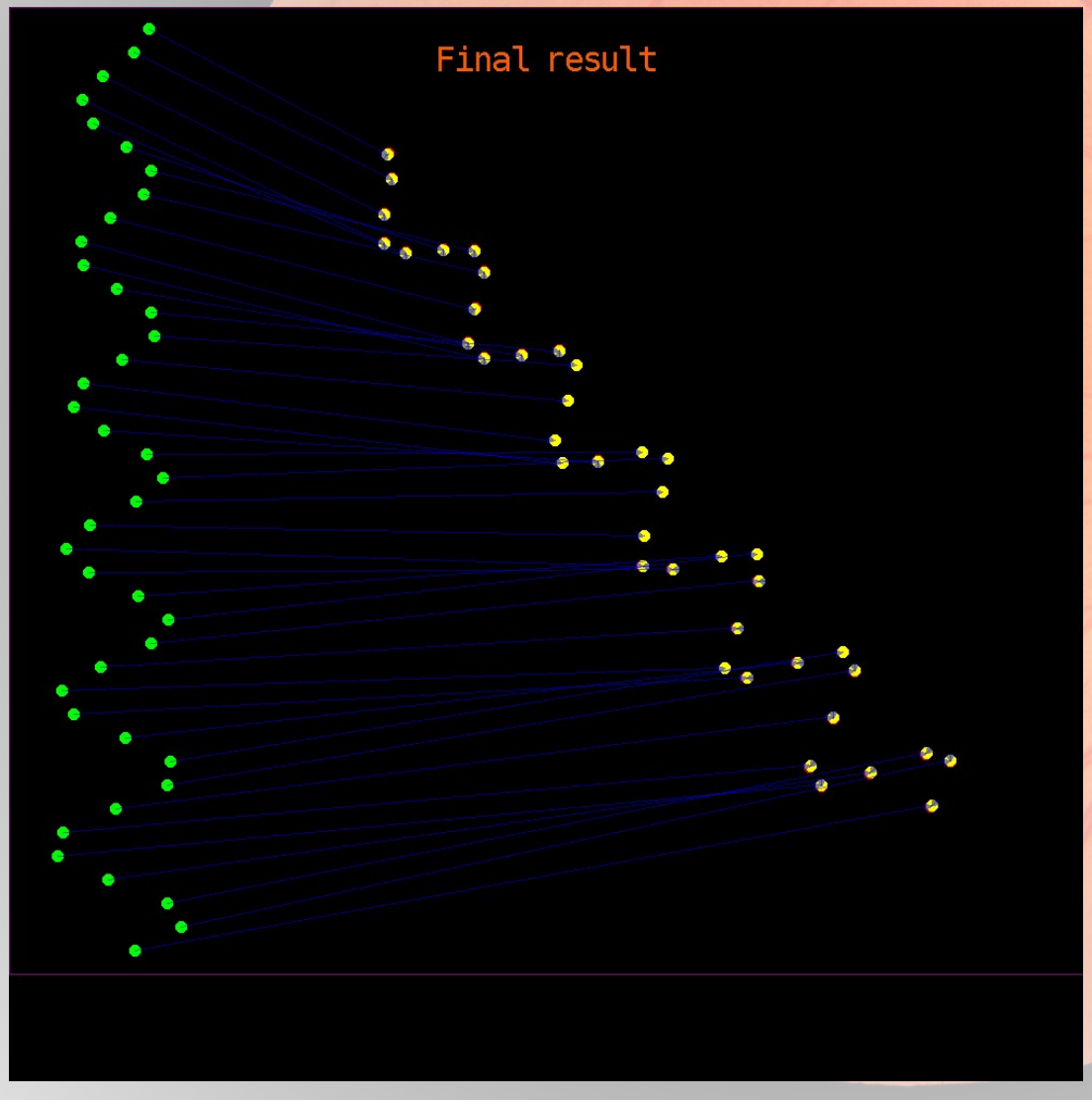


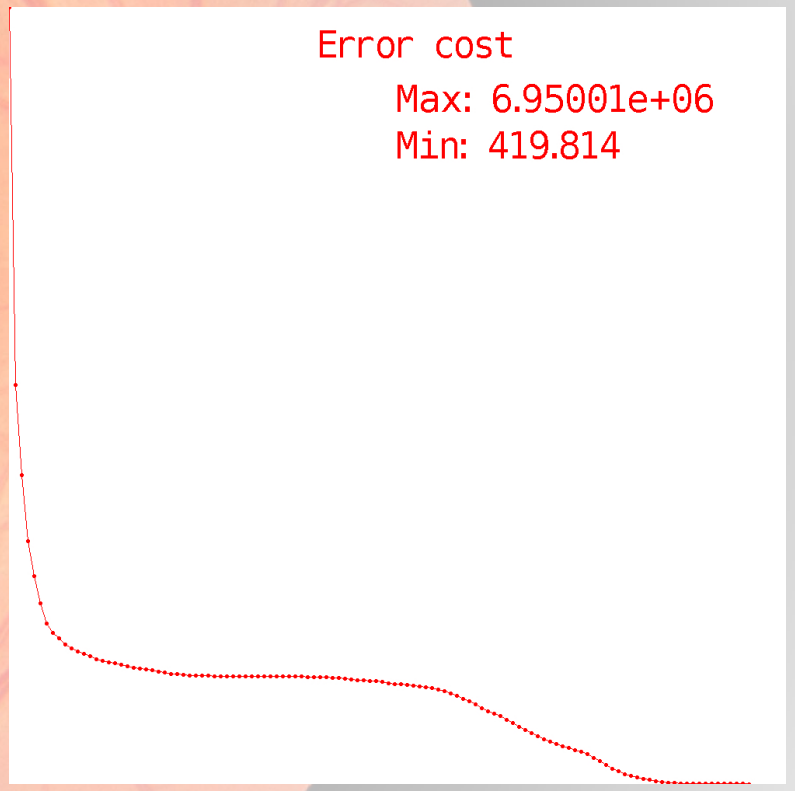
Video 2



ICP Demo

- Video of a successfull result





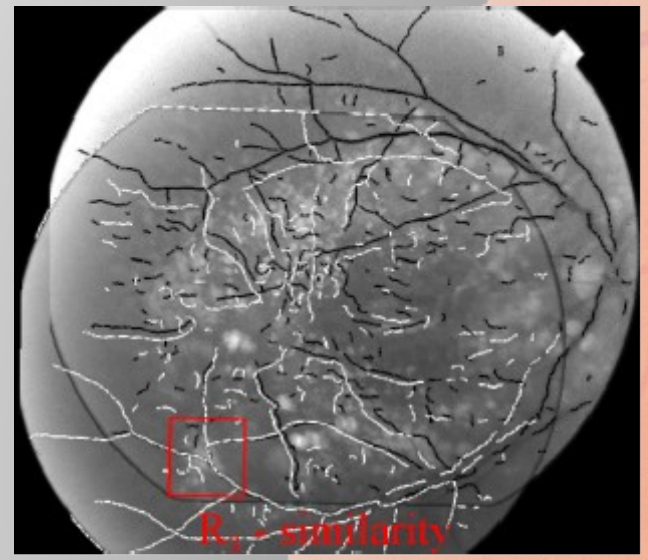
Conclusion on ICP

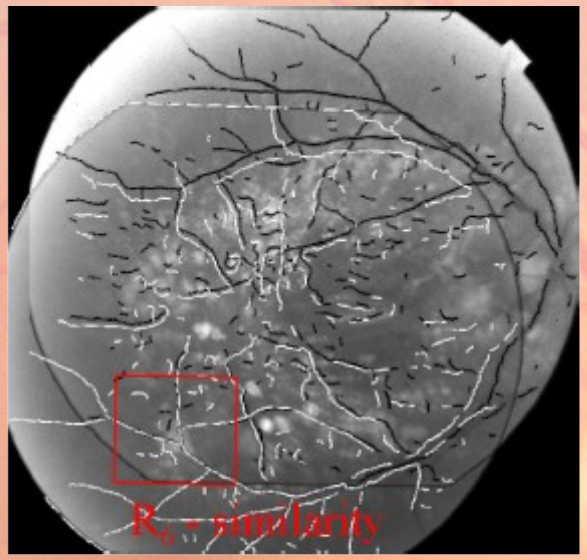
- Often stuck in a local minimum
- Very sensitive to initialization
  - Many papers on this issue
- Needs a large enough overlap
- Sensitive to outliers

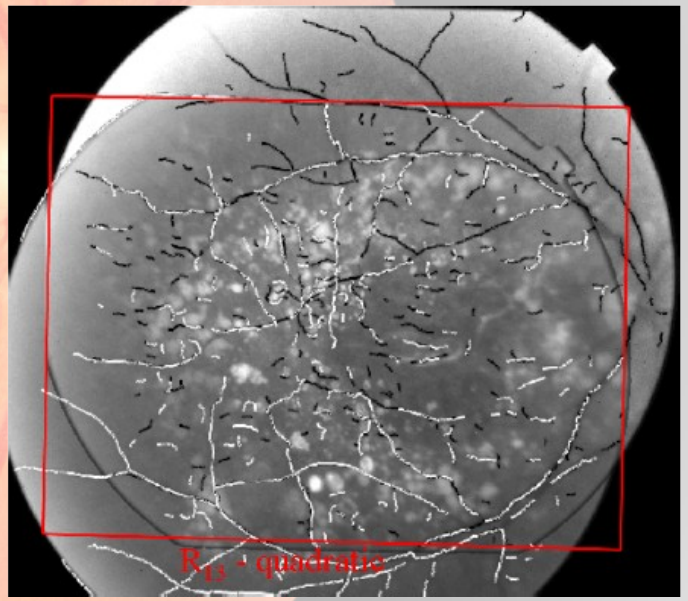
Dual Bootstrap ICP

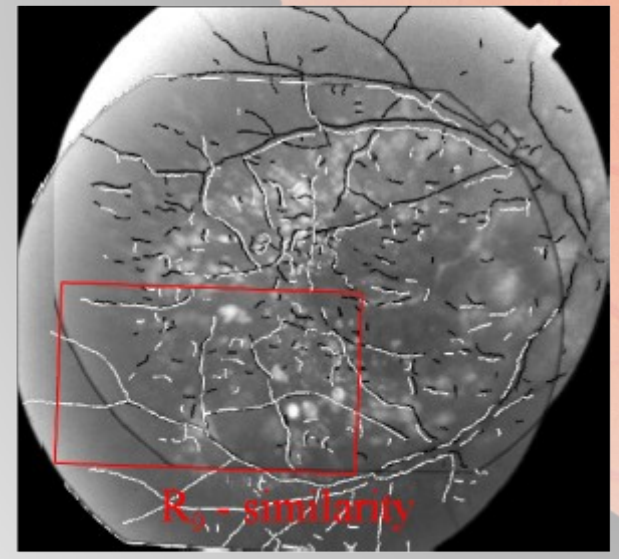
- Innovations in the structure
- Idea: Approximate the solution in a simpler case (relaxation), then refine it
- Goal: avoid being stuck in a local minimum
- Dual bootstrap: progressive enlargement of:
  - Bootstrap Region
  - Parametric Transformation Model

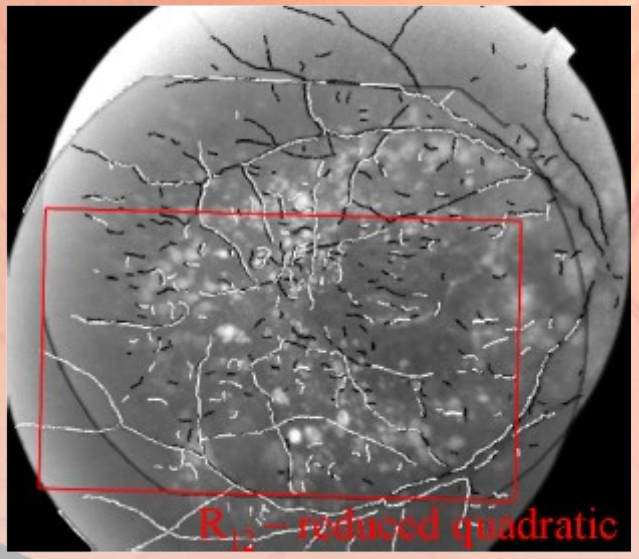
DBICP


R_4 - similarity


R_6 - similarity


R_{13} - quadratic


R_5 - similarity

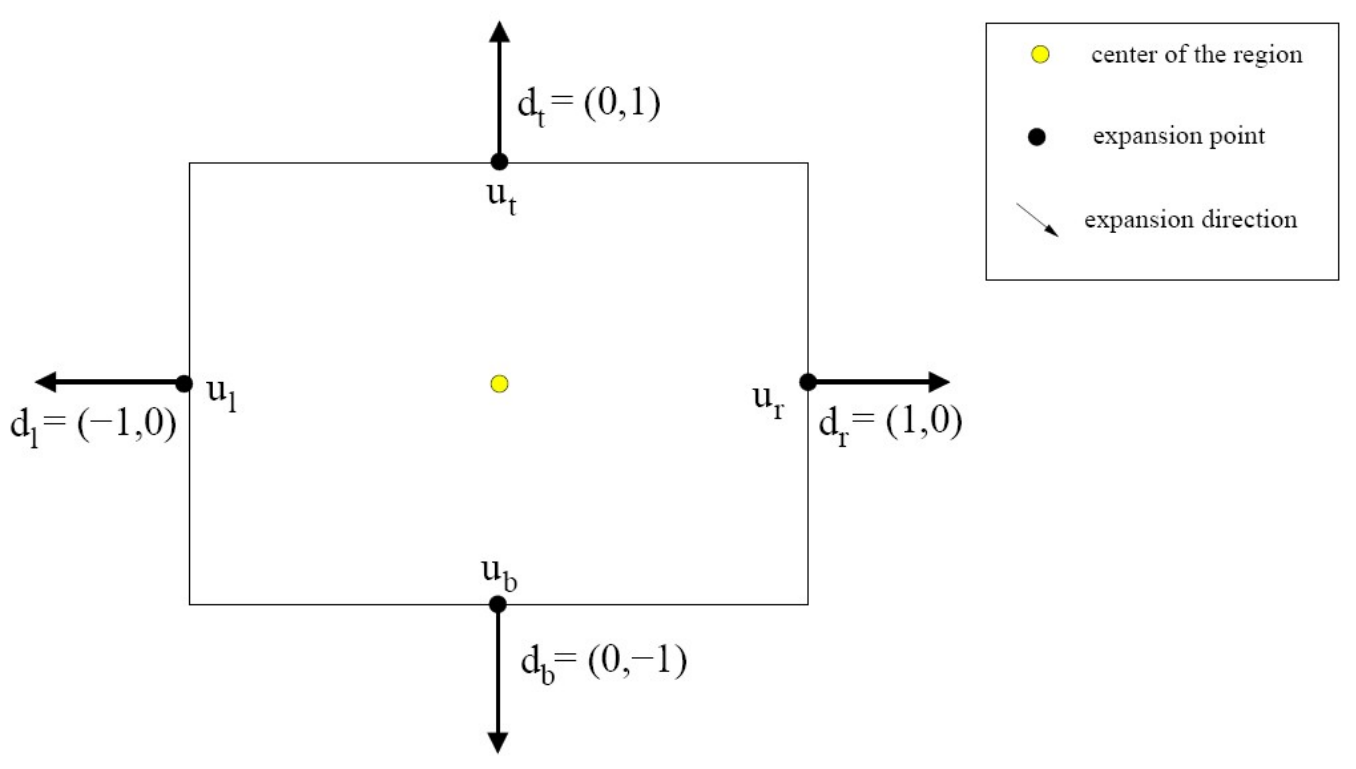

R_{12} - reduced quadratic

Algorithm outline

- Initialization
  - Bootstrap region
  - Initial transformation
- Iterations:
  - Compute correspondences
  - Optimize the transformation
  - Bootstrap the region
  - Bootstrap the model

Region Bootstrap

- Change based on the covariance matrix of the error, and thresholded with a max growth parameter



Model Bootstrap

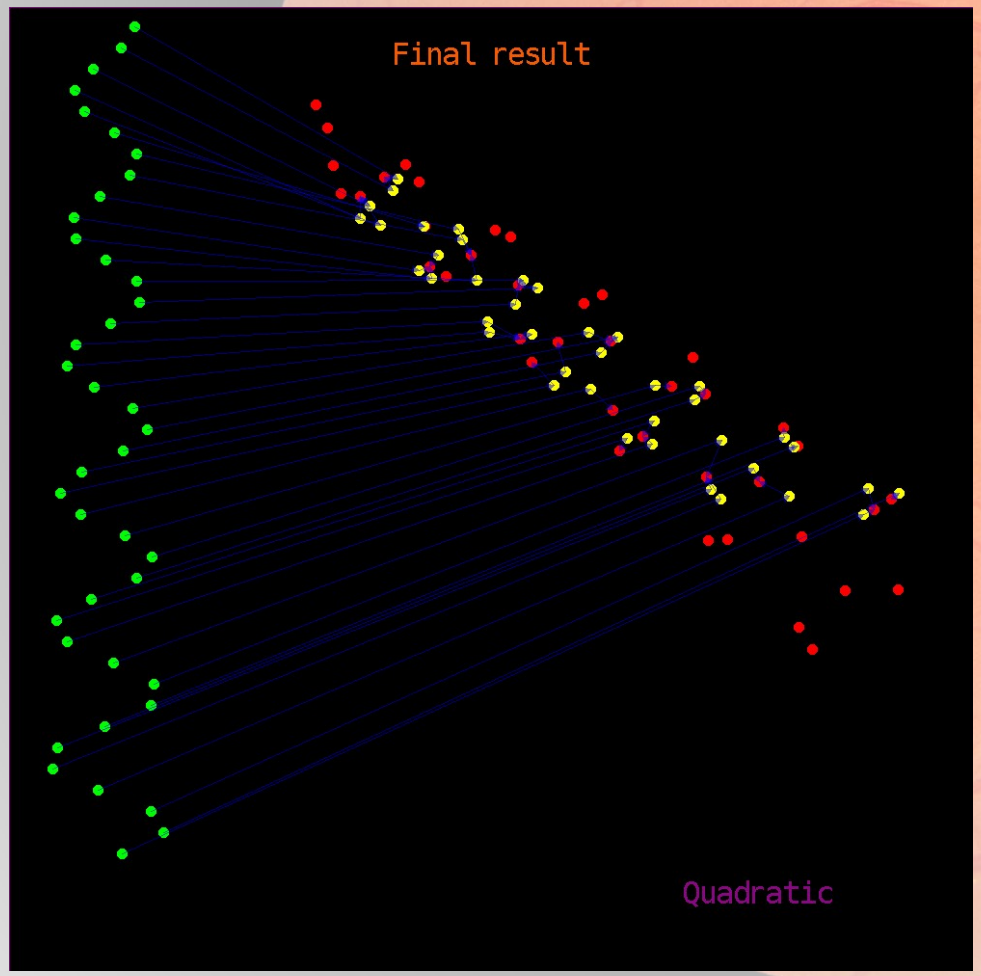
Transformation	Matrix	DoF
Similarity	$\begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & 0 & 0 & 0 \\ \theta_{21} & -\theta_{13} & \theta_{12} & 0 & 0 & 0 \end{pmatrix}$	4
Affine (not used)	$\begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & 0 & 0 & 0 \\ \theta_{21} & \theta_{22} & \theta_{23} & 0 & 0 & 0 \end{pmatrix}$	6
Reduced Quadratic	$\begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \theta_{14} & 0 & \theta_{14} \\ \theta_{21} & -\theta_{13} & \theta_{12} & \theta_{24} & 0 & \theta_{24} \end{pmatrix}$	6
Quadratic	$\begin{pmatrix} \theta_{11} & \theta_{12} & \theta_{13} & \theta_{14} & \theta_{15} & \theta_{16} \\ \theta_{21} & \theta_{22} & \theta_{23} & \theta_{24} & \theta_{25} & \theta_{26} \end{pmatrix}$	12

- Selection criterion based on the error and the degree of freedom (DoF)

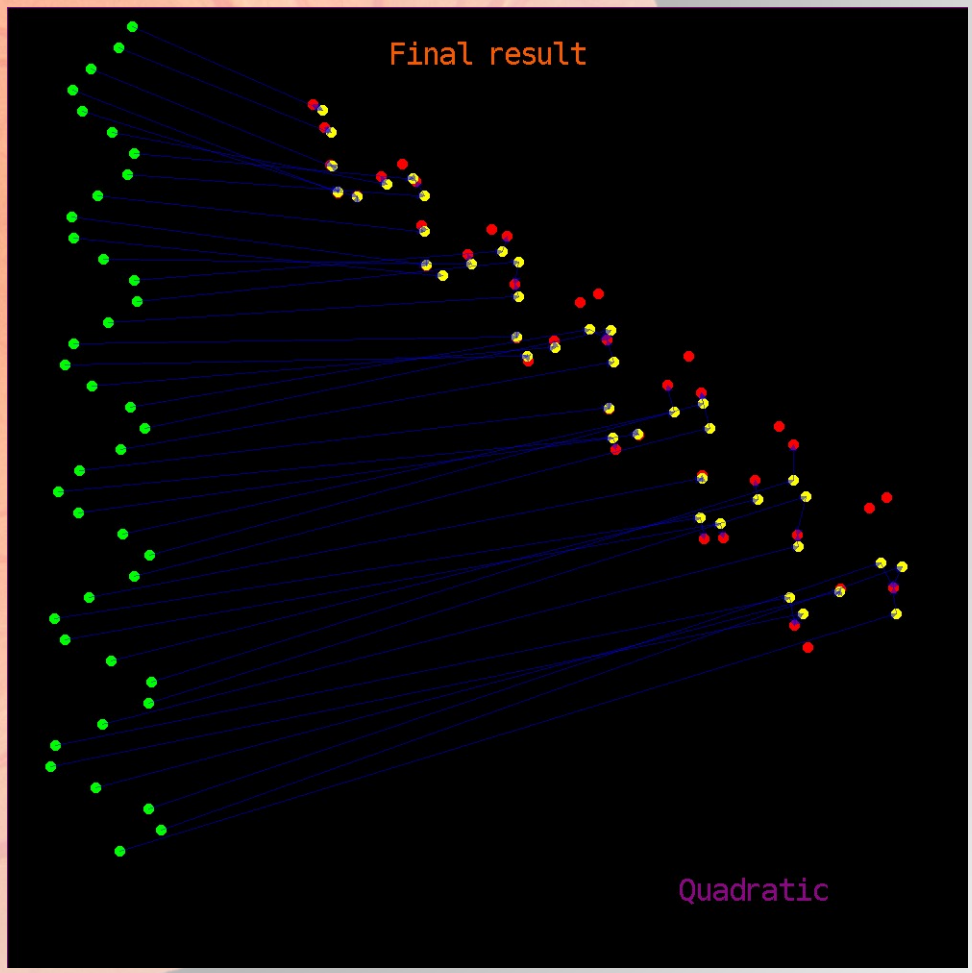
Model Bootstrap Demo

- 2 videos:

Without MB

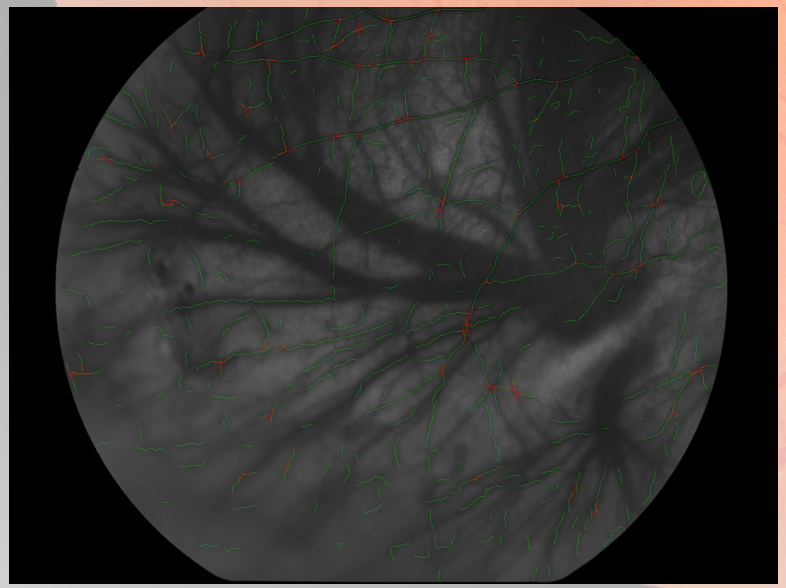


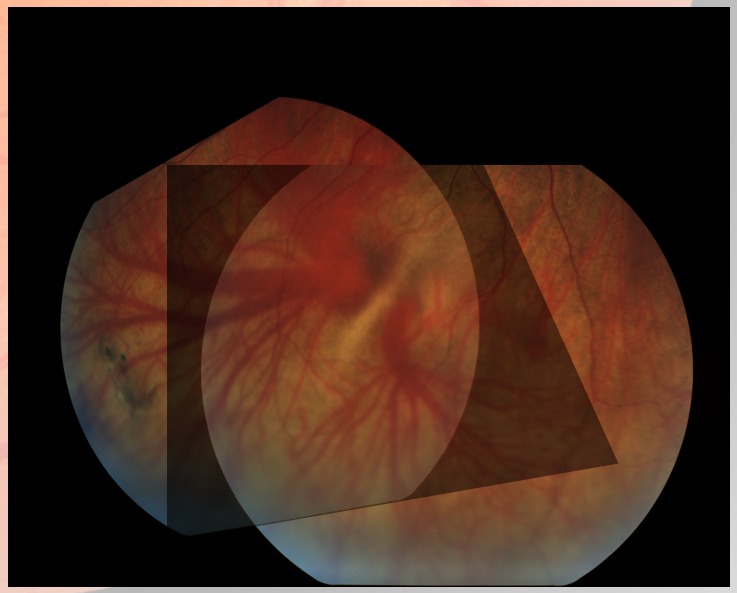
With MB



Further work

- Test on real data (eg human retina registration)
- Test with descriptors (not only points' positions)
- Test with other optimization techniques (Levenberg Marquardt, …)
- Test with other loss functions





Conclusion

- Great concept
- Efficient and flexible C++ implementation
- Mild enthusiasm with the results
- Source code available at
  http://code.google.com/p/dbicp