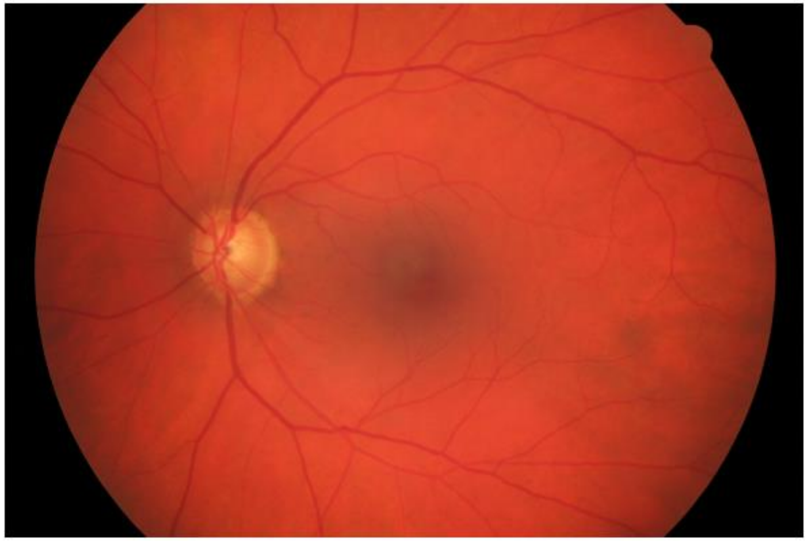

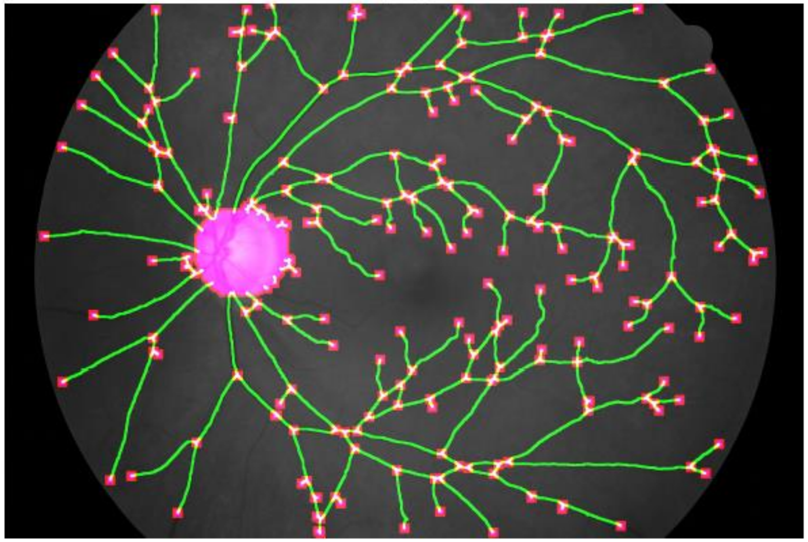

Application of network techniques to image analysis and outlier detection

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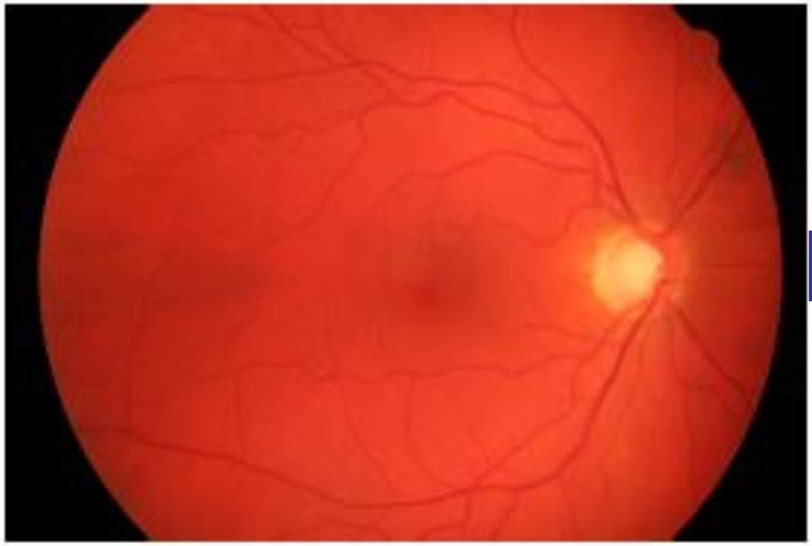
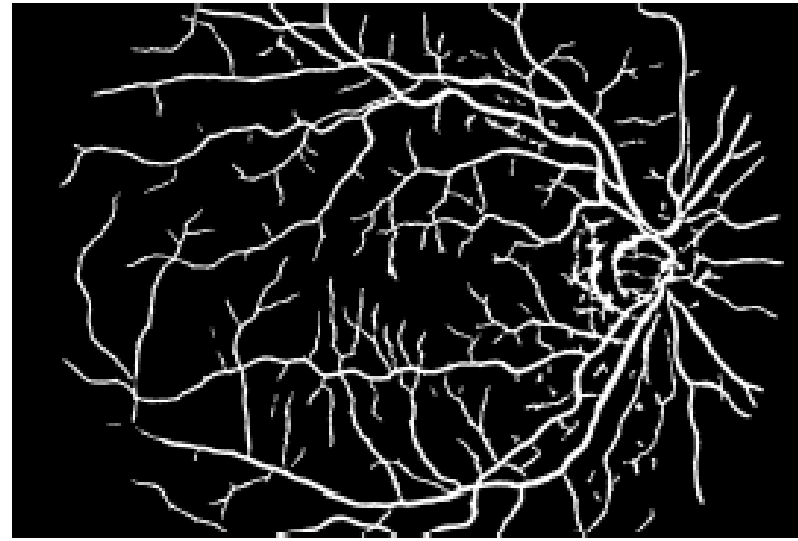
ICREA

A tree-like network can be extracted from a retina image





We used an unsupervised segmentation algorithm, originally developed for cultured neuronal networks.

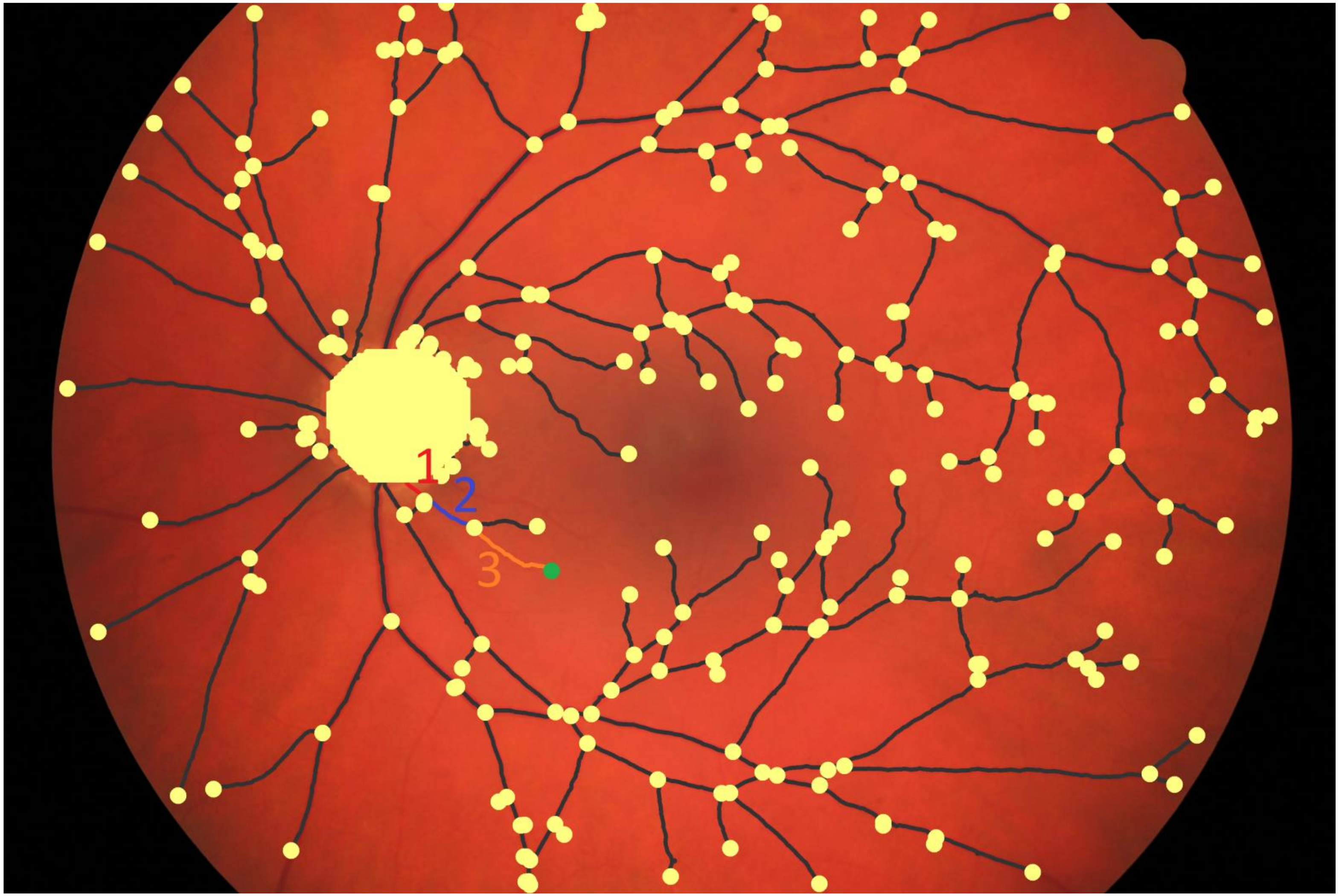
The obtained network is the superposition of the networks formed by arteries and veins.

Santos-Sierra D, Sendiña-Nadal I, Leyva I, et al. *Graph-based unsupervised segmentation algorithm for cultured neuronal networks' structure characterization and modeling*. Cytometry Part A. 87, 513 (2015).

Process:

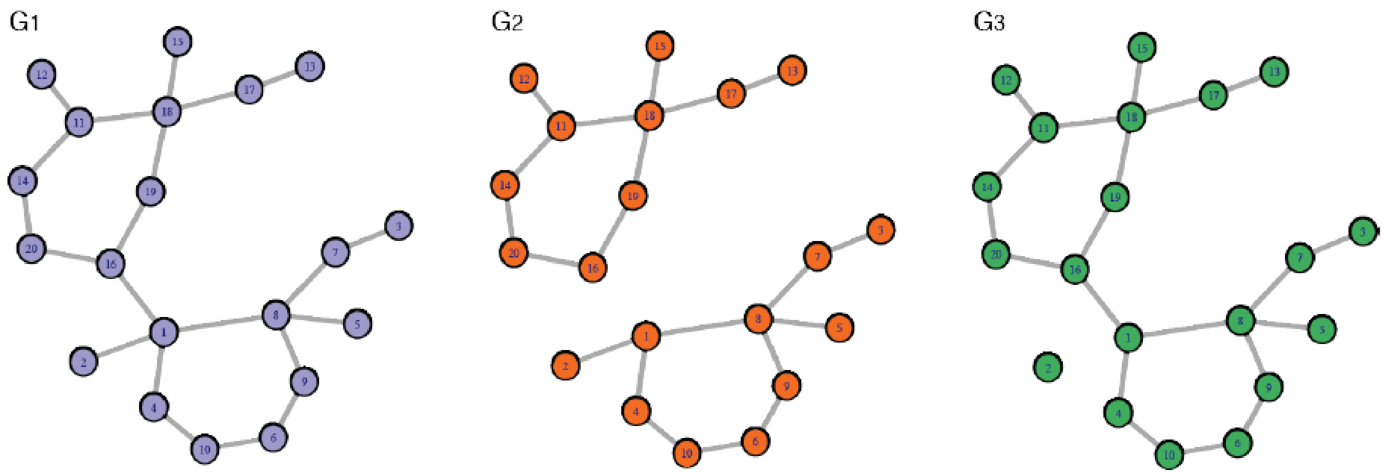
Step 1: Identification of nodes and links.

Step 2: Analysis of the connectivity paths to the central node (optical nerve)



To detect structural differences between networks we need a precise measure to compare them.

- Degree, centrality, assortativity distributions etc. provide *partial* information.
- Main problem: not all the links have the same importance.
- Example:



To compare networks we used a dissimilarity measure based on the distribution of distances between nodes (shortest paths)

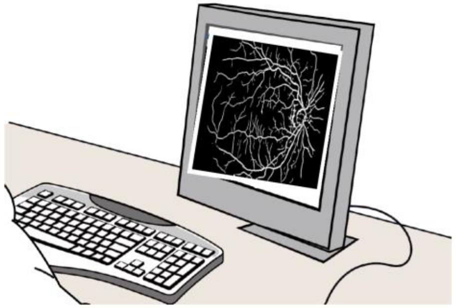
T. A. Schieber, L. Carpi, A. Diaz-Guilera, P. M. Pardalos, C. Masoller, M. G. Ravetti, "*Quantification of network structural dissimilarities*", Nat. Comm. **8**, 13928 (2017).

Data

- High-resolution public database with
  - 15 healthy subjects
  - 15 glaucoma
  - 15 diabetic retinopathy

- For every subject there is
  - fundus photography
  - manual segmentation of the vessels done by an expert.

- From each fundus photography $\Rightarrow$ automated segmentation.

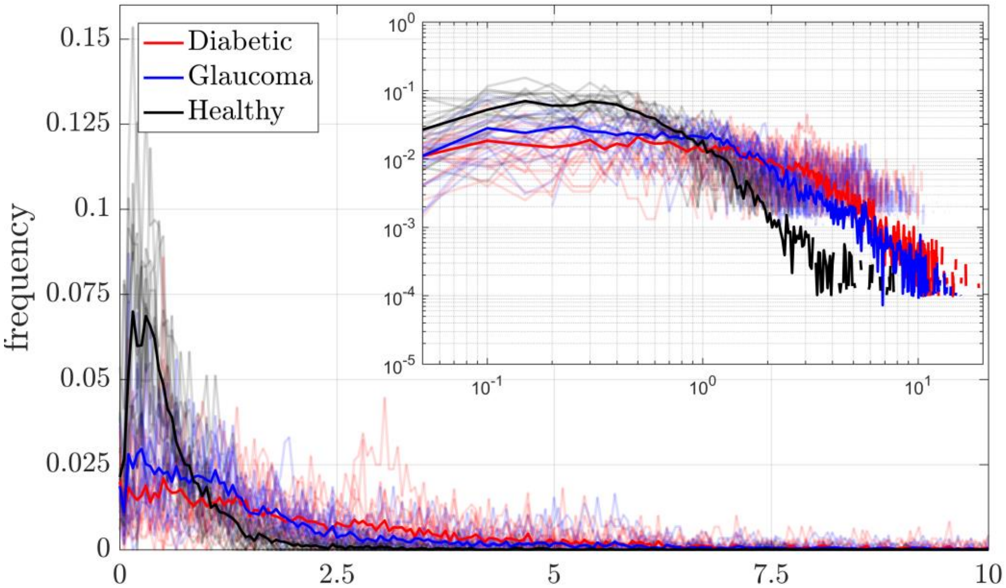


https://www5.cs.fau.de/research/data/fundus-images/

Methodology (1/2)

"Features" extracted from each image

- Fractal dimension (raw and skeletonized segmented images)
- Distribution of distances to the central node
- Distribution of average weights along the path to central node
- Distribution of weighted degrees



distribution of average weights

Methodology (2/2)

- We use the Jensen-Shannon (JS) divergence to compare distributions (image i with all other images)
- For each image i we obtain a vector

$$\{d_{i1}, d_{i2}, \ldots d_{iN}\} \text{ (N = number of images)}$$

whose elements are the distances between the distributions extracted from image i and image j (j in 1…N).

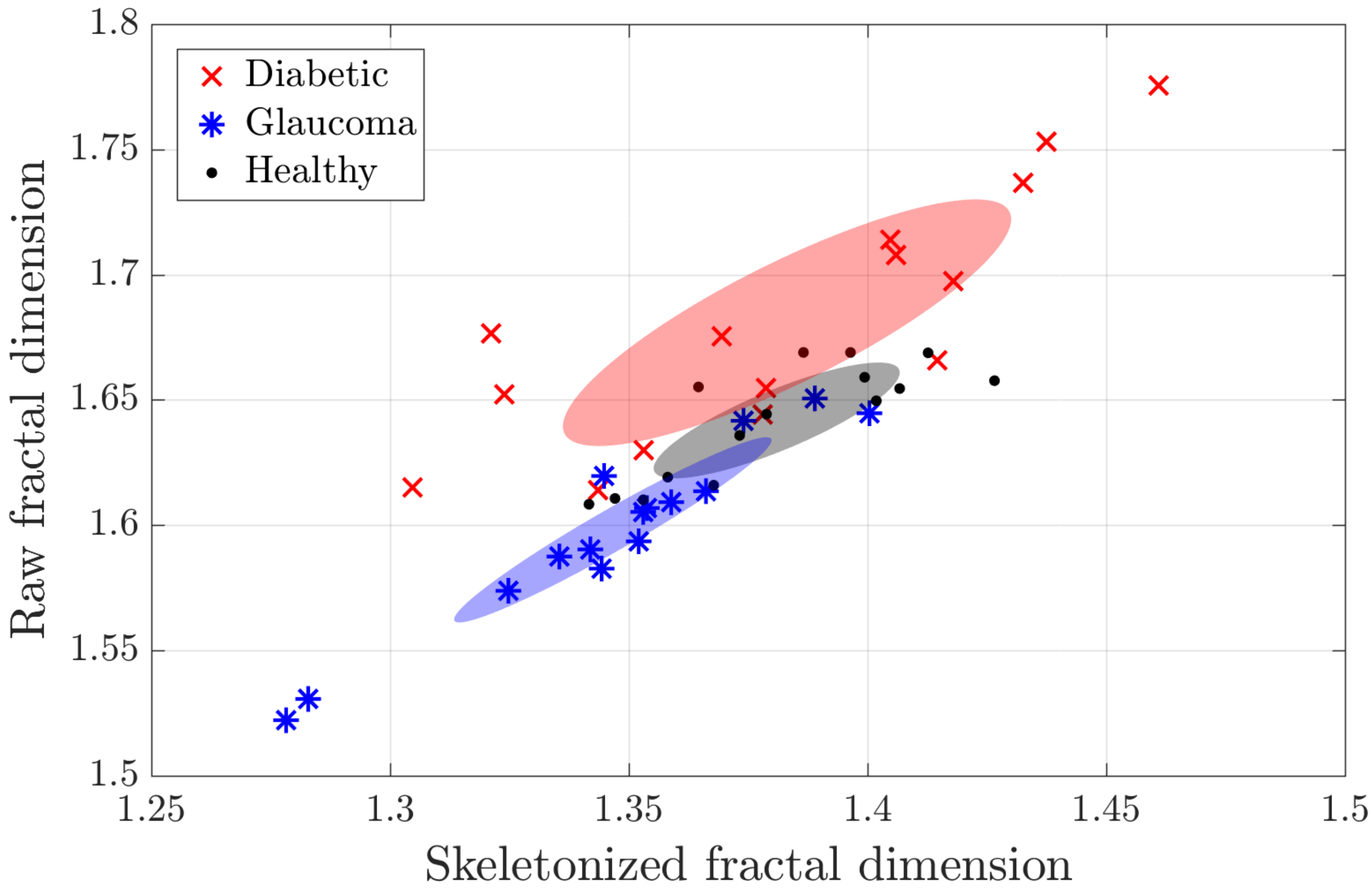
- This is a vector of N “features” that characterize image i.

- We apply a nonlinear dimensionality reduction algorithm (*IsoMap*) to obtain only 2 features for each image.

J. B. Tenenbaum et al, A global geometric framework for nonlinear dimensionality reduction. Science 290, 2319 (2000).

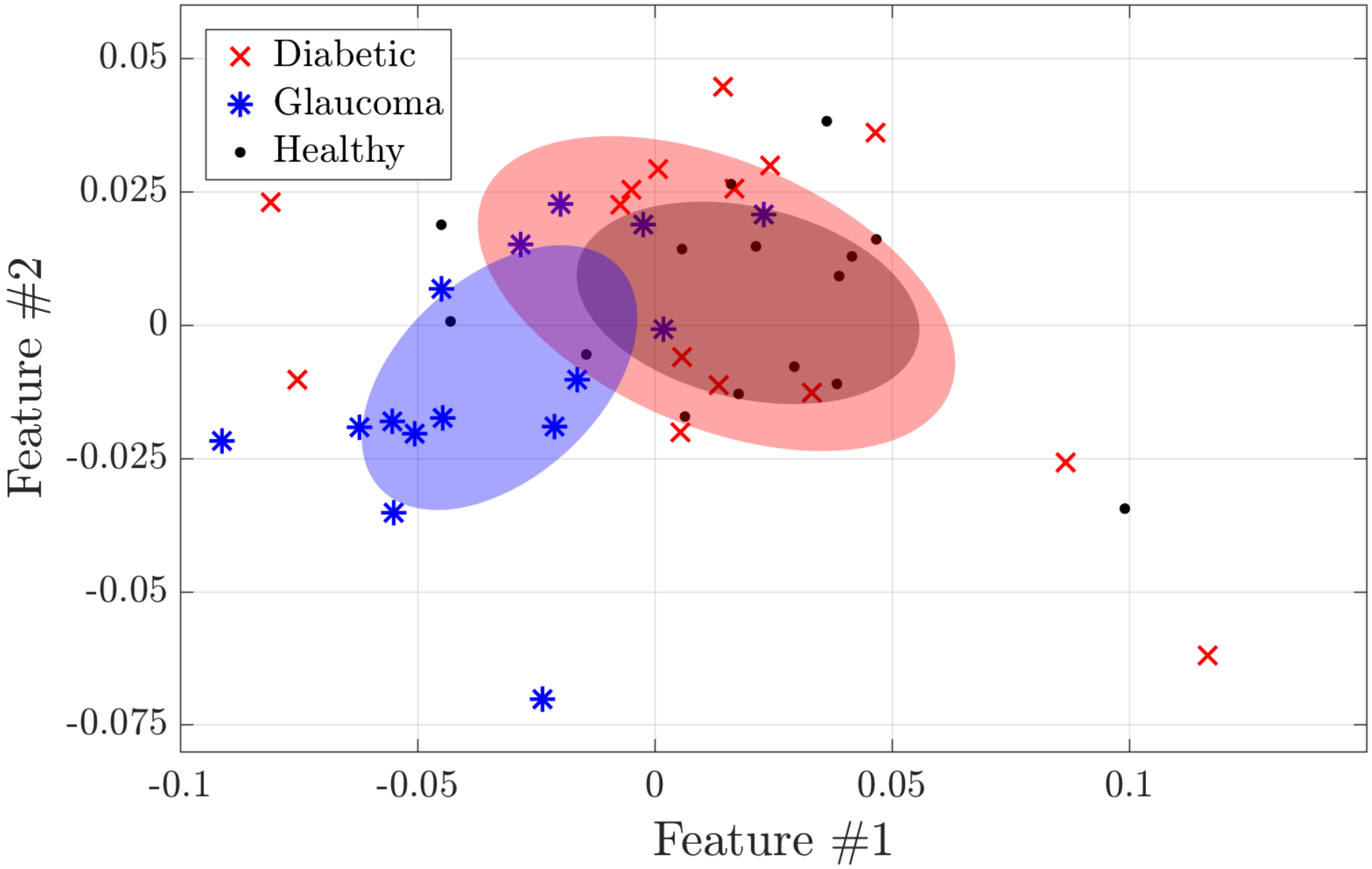
In the automated segmentation: fractal dimension separates the three groups

$$D = \lim_{\varepsilon \to 0} \frac{\log(N(\varepsilon))}{\log(1/\varepsilon)}$$

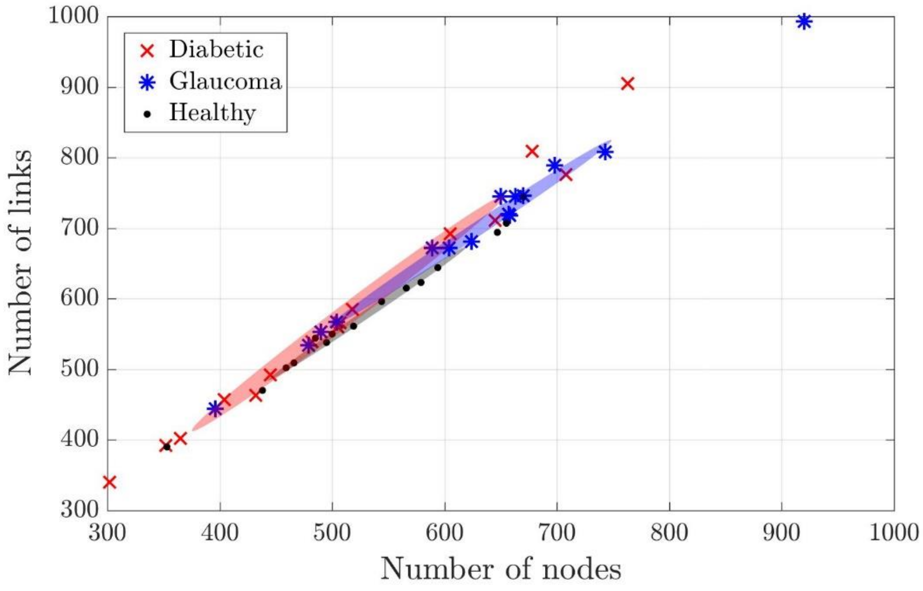


P. Amil et al, Network-based features for retinal fundus vessel structure analysis, PLoS ONE 14, e0220132 *(2019).*

Mean weight distribution (along the shortest path to central node) identifies glaucoma



Simple network features do not differentiate



Detecting images with artifacts and removing them from the training dataset allows to improve the performance of the algorithm.

Details in P. Amil et al., “*Outlier mining methods based on network structure analysis*”, Front. Phys. 7, 194 (2019).

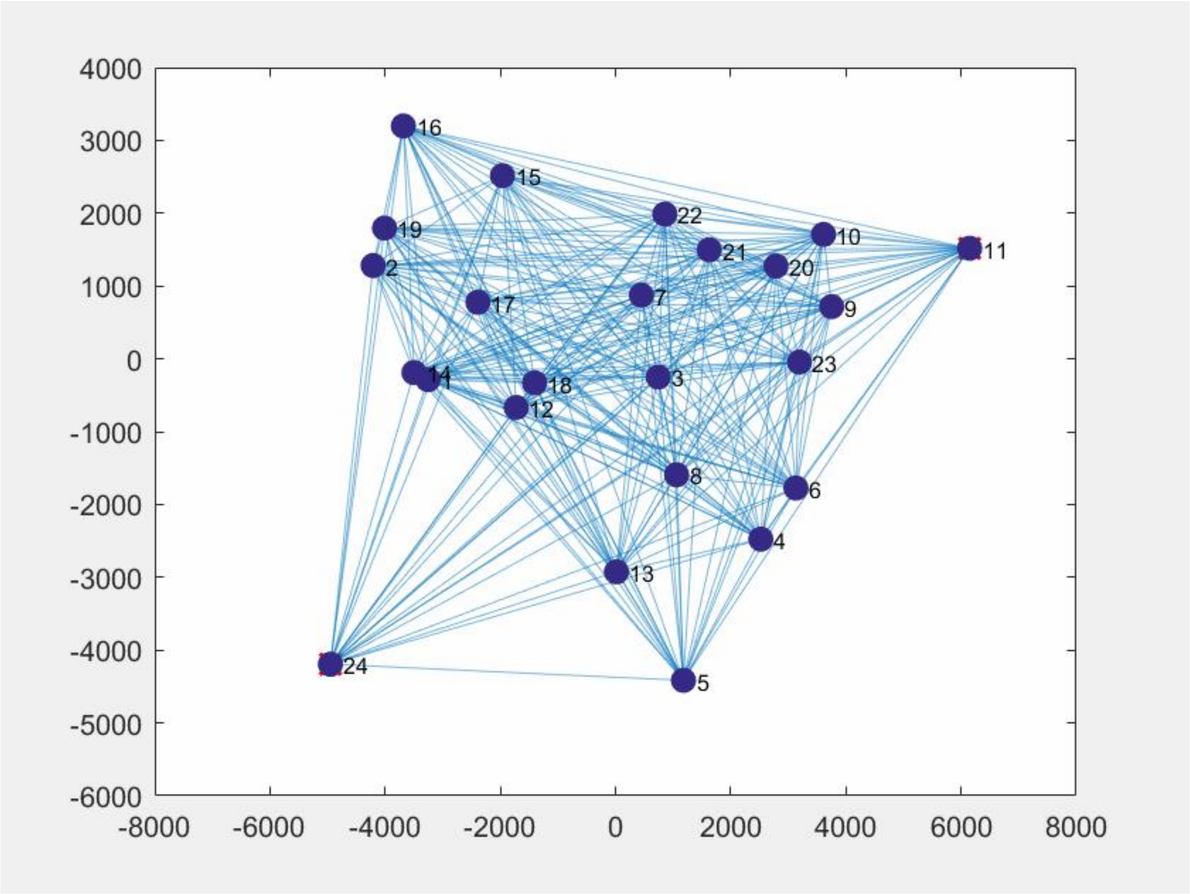
Outlier detection using network percolation

$$V_i = \{v_1^i \dots v_m^i\}$$

Feature vector describing each element of a dataset

$$D_{ij} = \left(\sum_k \left| v_k^i - v_k^j \right|^p \right)^{1/p}$$

Distance between any two elements of the dataset



Outlier score = order in which elements disconnect from the giant component.

Parameter free.

Summary

- A dissimilarity measure between two graphs (that have different size, unlabeled nodes and undirected links) was used to analyze a database of retina fundus images

- Good separation between healthy and non-healthy patients was obtained when applying automated segmentation to *high resolution* images.

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References

- T. A. Schieber et al., "*Quantification of network structural dissimilarities*", Nat. Comm. 8, 13928 (2017).
- P. Amil et al., "*Network-based methods for retinal fundus image analysis and classification*", PLoS ONE 14, e0220132 (2019).
- P. Amil et al., "*Outlier mining methods based on network structure analysis*", Front. Phys. 7, 194 (2019).

Thank you for your attention !