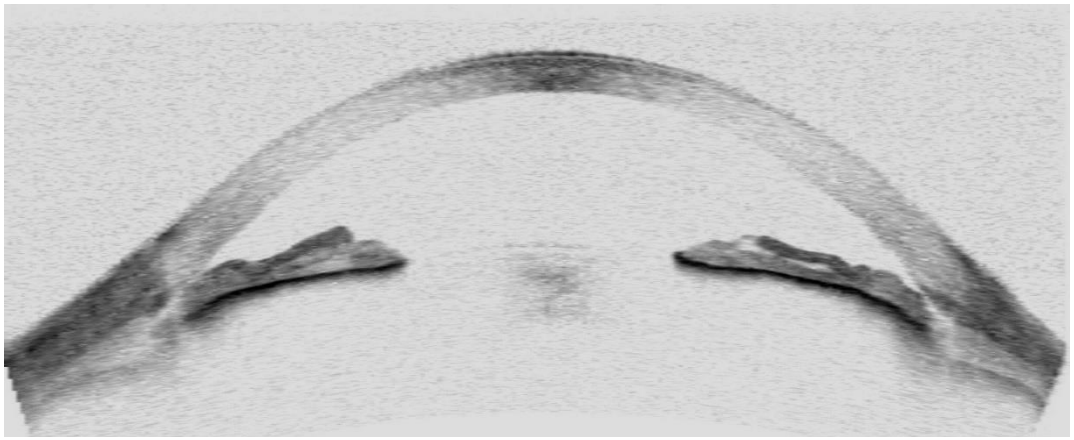


Unsupervised ordering of anterior chamber optical coherence tomography (OCT) images

Pablo Amil, Cristina Masoller, Ulrich Parlitz and others
Universitat Politècnica de Catalunya
Terrassa, Barcelona, Spain
www.fisica.edu.uy/~cris

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Campus d'Excel·lència Internacional

30+ Years of Chaos, Synchronization and Physiology
Workshop in honor of Prof. Parlitz, Gottingen, 20/8/19

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

BE-OPTICAL
Advanced Biomedical Optical Imaging and Data Analysis

ICREA

A long time ago…
Colonia, Uruguay, December 2002

BE-OPTICAL

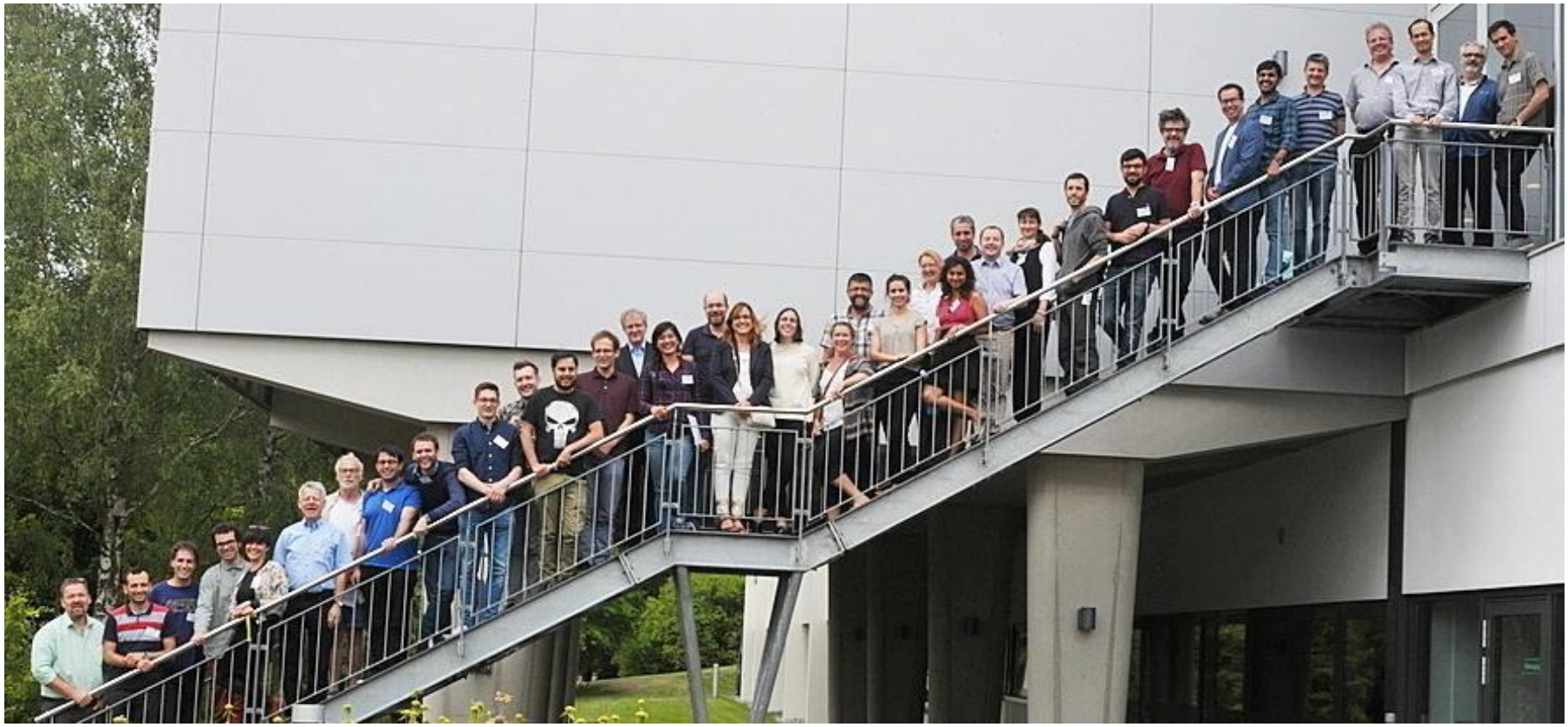
Advanced Biomedical Optical Imaging and Data Analysis

First BE-OPTICAL school Gottingen, November 2016

BE-OPTICAL

Advanced Biomedical Optical Imaging and Data Analysis

Final BE-OPTICAL conference Gottingen, June 2019

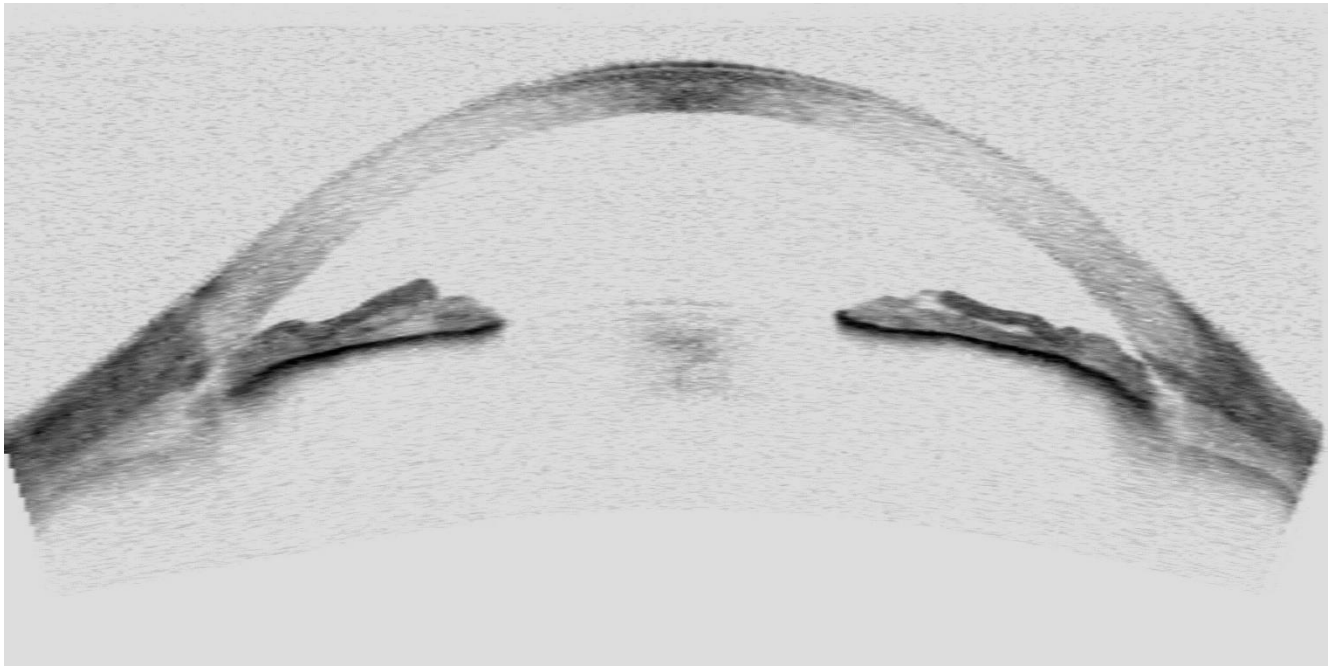


Inspiring discussions during many meetings (SIAM in Snowbird, US; DDays in Corfu, Greece, etc.)

Thanks Ulrich!!!

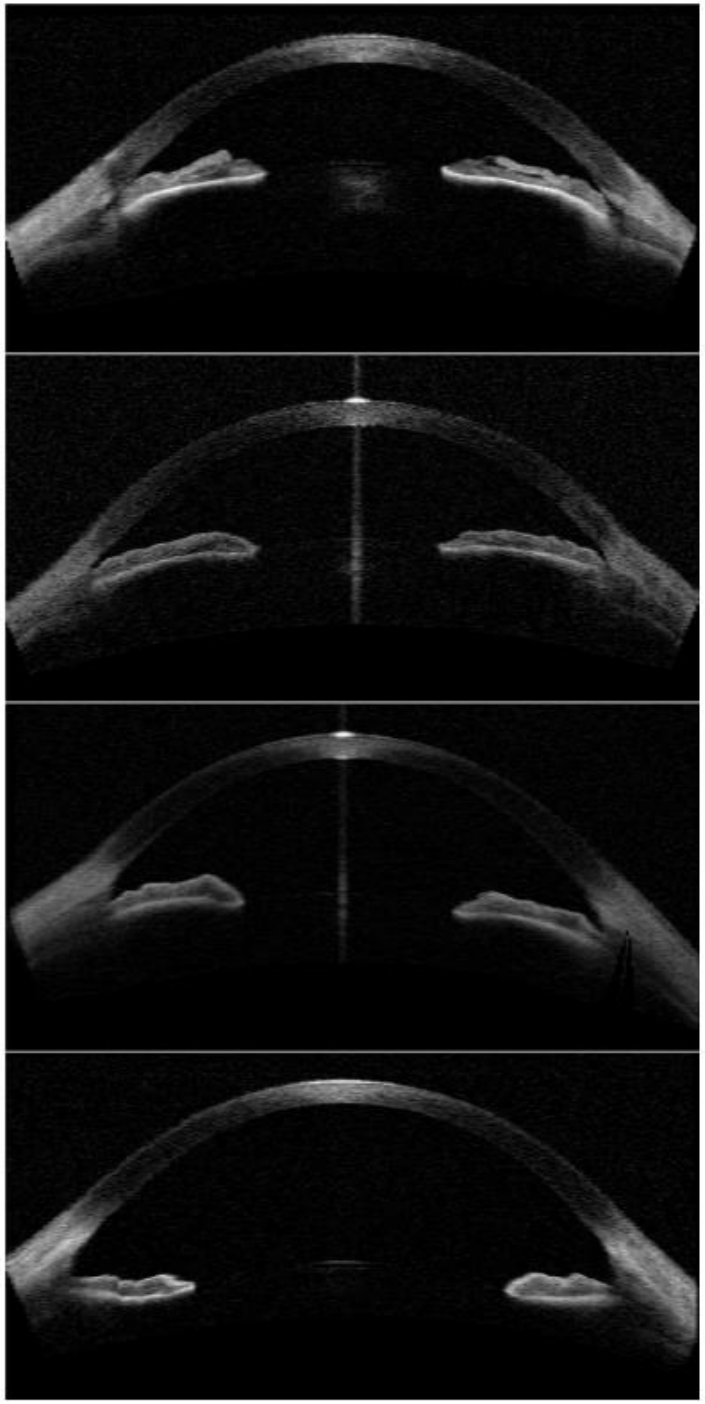
Unsupervised ordering of anterior chamber optical coherence tomography (OCT) images

- Used for diagnosis of glaucoma.
- More than 1000 images from patients of Instituto de Microcirugia Ocular (IMO, Barcelona).

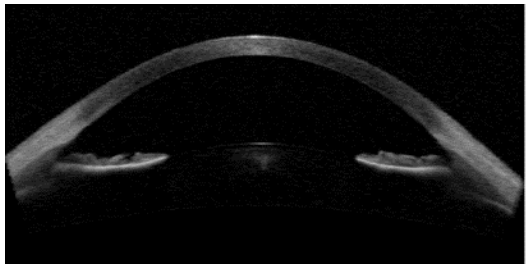
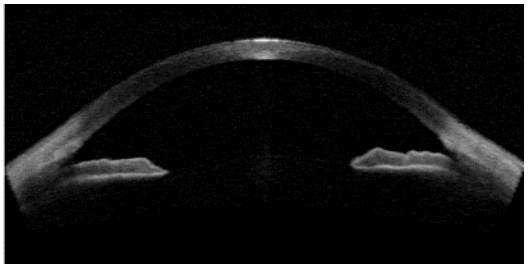


Examples

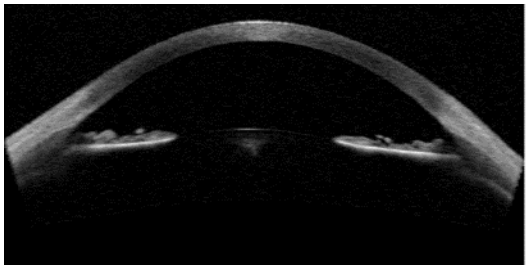
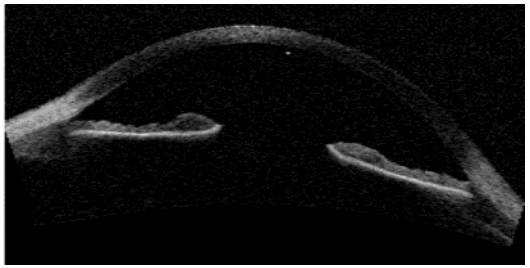
- Closed
- Narrow
- Open
- Wide open



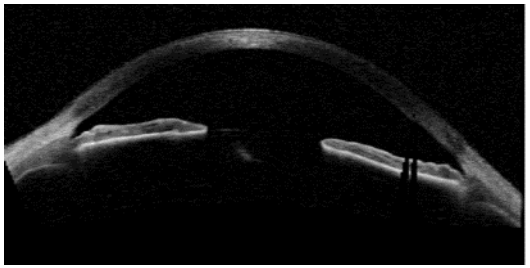
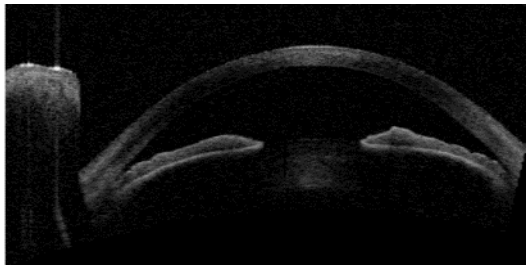
Using an appropriated distance (aligned Hellinger), we compare pairs of images

Small distance

Medium distance

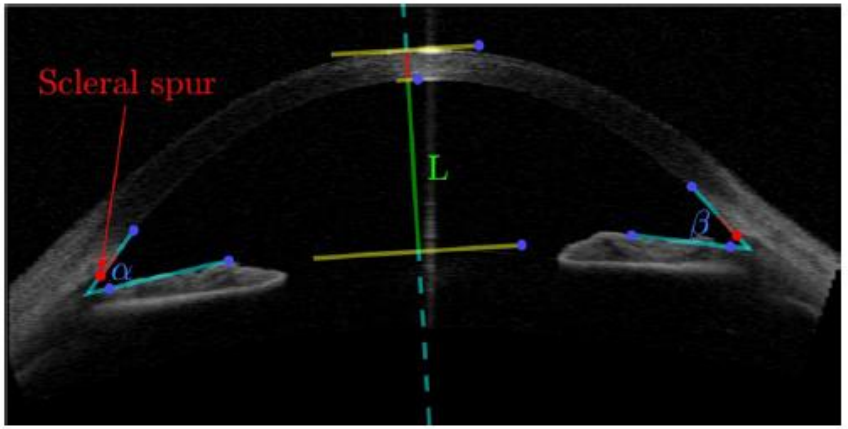
Large distance

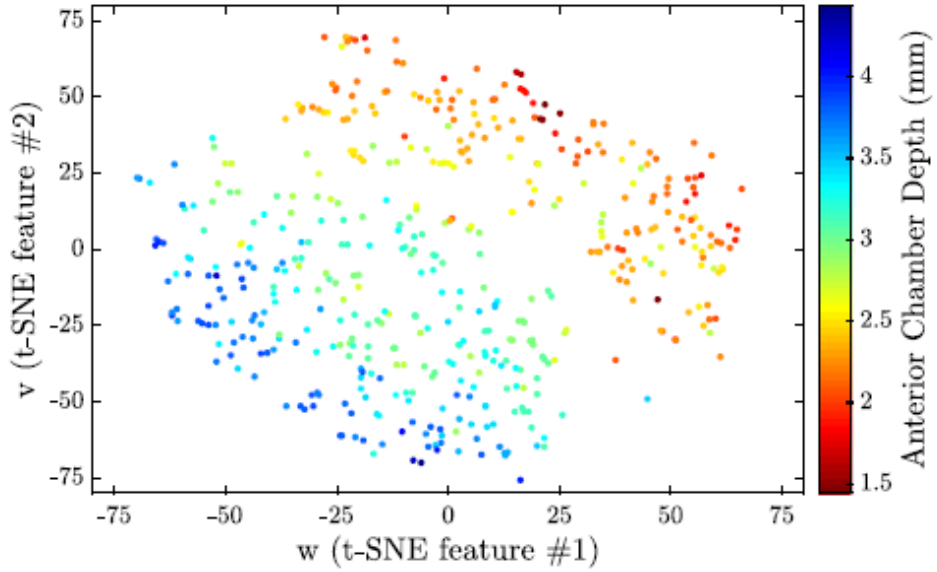
P. Amil, L. González, E. Arrondo, C. Salinas, J. L. Guell, C. Masoller, Ulrich Parlitz "*Unsupervised feature extraction of anterior chamber OCT images for ordering and classification*", Sci. Rep. 9, 1157 (2019).

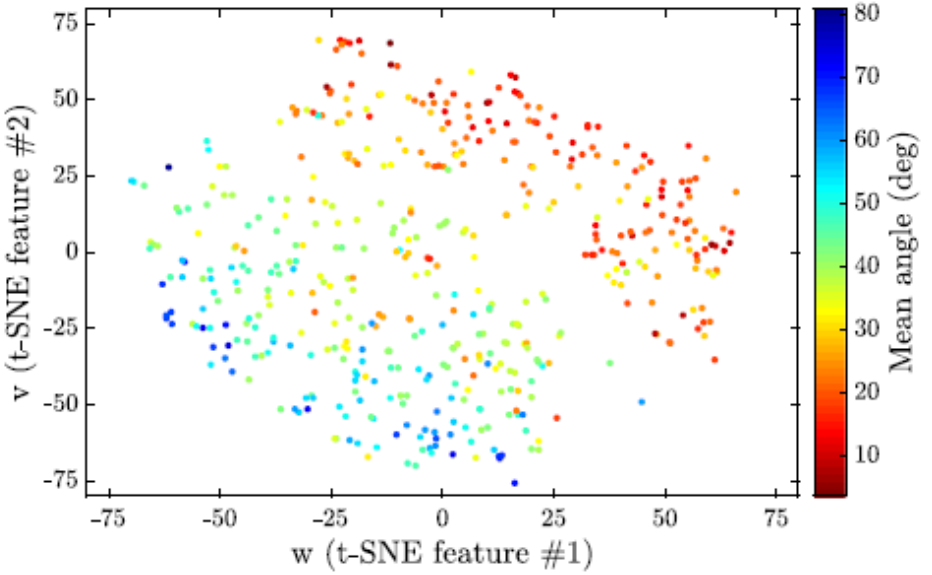
By using nonlinear dimensionality reduction, from the set of distances we extract, for each image, two features that allow ordering the images in a plane.

P. Amil et al., Unsupervised feature extraction of anterior chamber OCT images for ordering and classification, Sci. Rep. 9, 1157 (2019).

Correlation between unsupervised features and the “manual” feature from expert annotation.

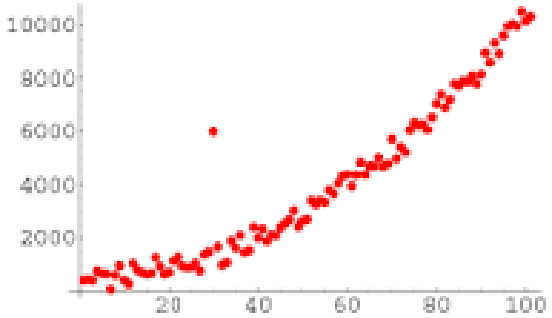






Can we improve the correlation if images with artifacts (outliers) are removed from the training set?

What is an outlier?



Practical definition: improved performance of machine learning algorithms when outliers are removed from the training set.

Two “network-based” & “distance based” outlier detection methods

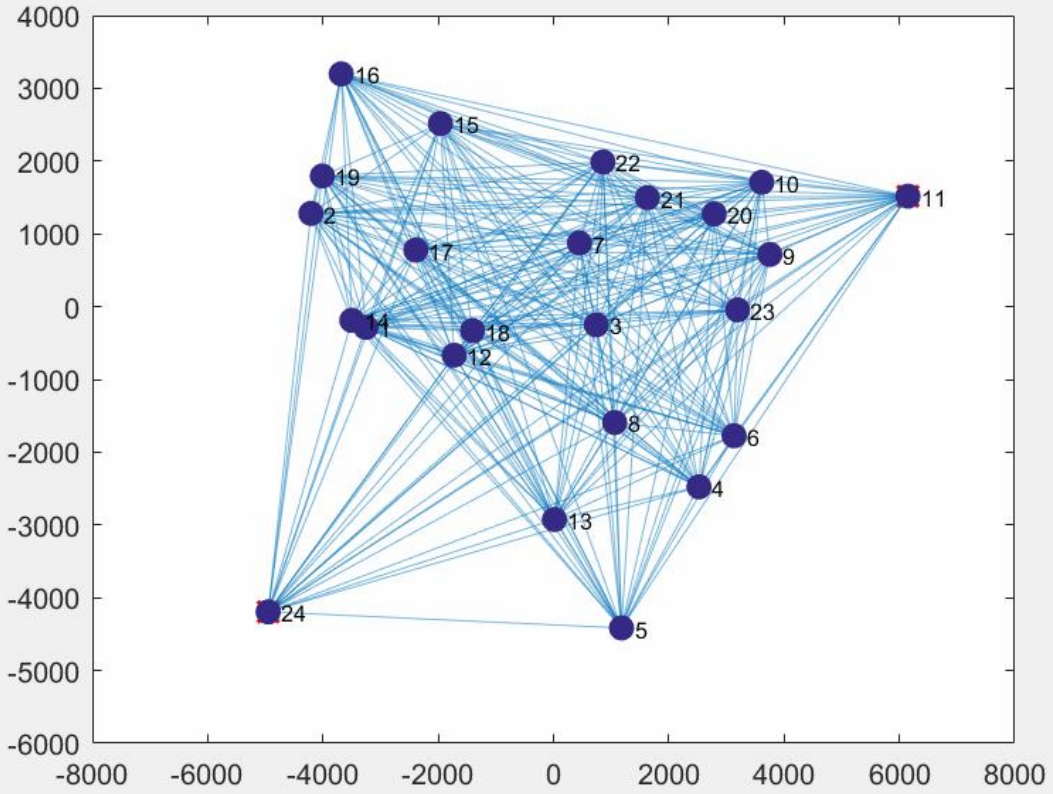
- percolation

- manifold learning

First method: Outlier detection using 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

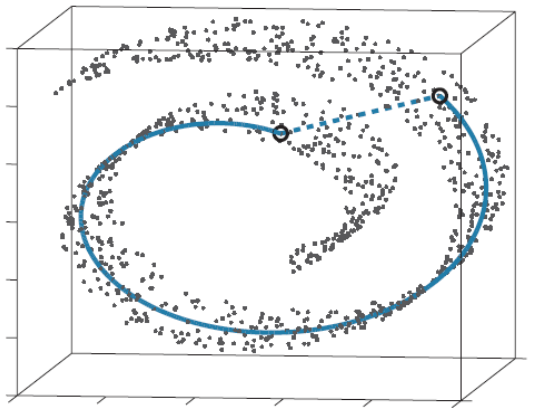


Outlier score = order in which elements disconnect from the giant component.

Parameter free.

Second method: Outlier detection using manifold learning

- *IsoMap* is a method for manifold learning. We define the outlier level with a measure of how well an element fits in the manifold.
- Apply *IsoMap* to the distance matrix $\mathbf{D_{ij}}$ to obtain
  - a new set of features
  - a new distance matrix in the geodesic space, $\mathbf{D^G_{ij}}$
- With the new features, recalculate the distance matrix $\mathbf{D'_{ij}}$
- For each element, calculate correlation between $\mathbf{D^G_{ij}}$ and $\mathbf{D'_{ij}}$
- $AL_i = 1 - {\rho_i}^2$
- Two parameters (integers):
- Dimension of reduced space
- # of geodesic neighbors



Distance in the high dimensional space (dash) and geodesic distance in the low-dimensional manifold.

Tenenbaum et al., A global geometric framework for nonlinear dimensionality reduction. Science 290, 2319-2323 (2000)

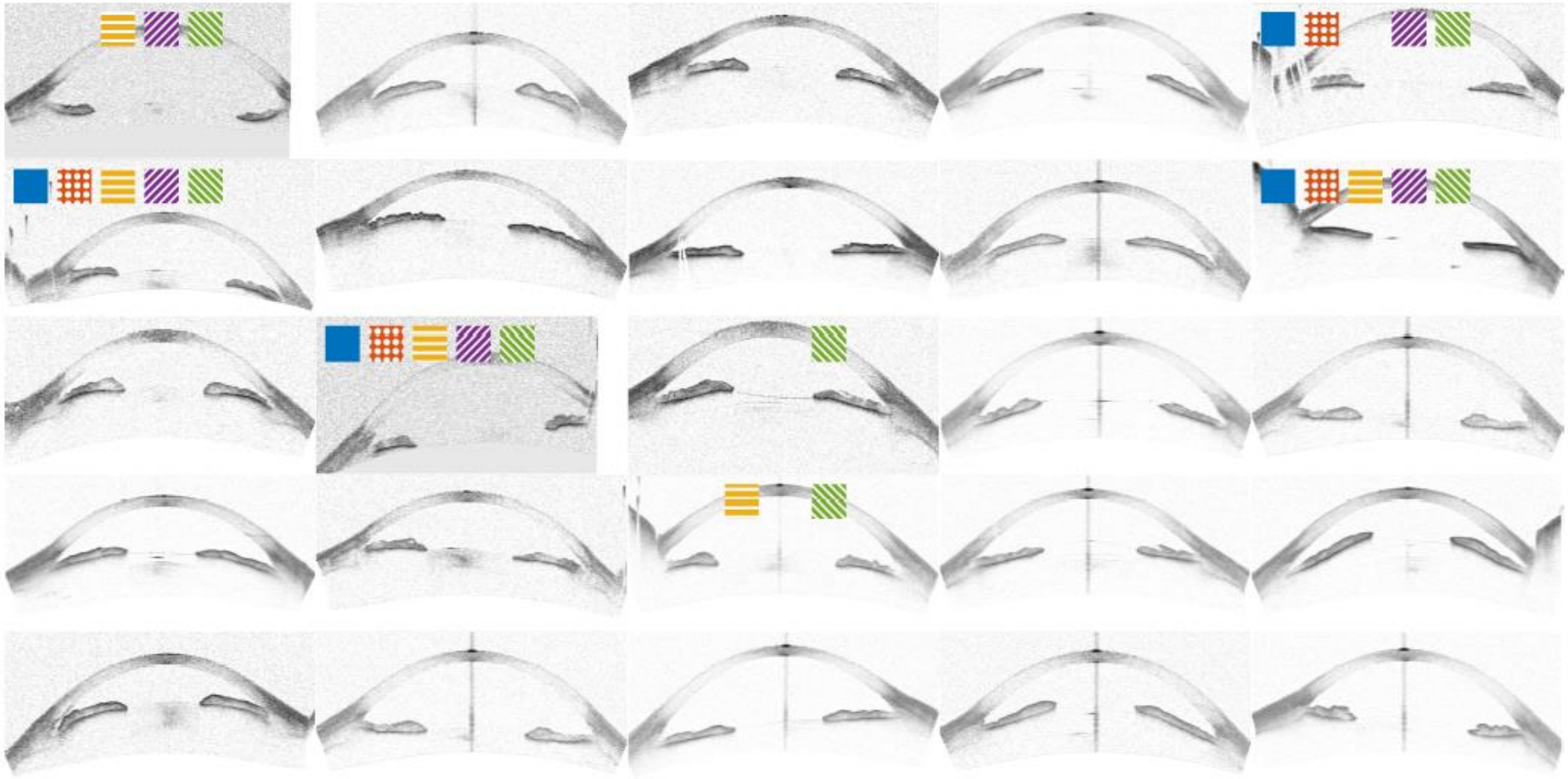
Comparison with other methods

- d2CM – Distance to center of mass. This method simple computes a “mean point” (center of mass) and computes the distance of each other point to this center of mass.
- Ramaswamy. A popular distance-based method. This method assigns an anomaly level to each point equal to its distance to its kth nearest neighbor.
- OCSVM - One Class Support Vector Machine. This method uses the inner product between the elements in the database to estimate a function that is positive in a subset of the input space where elements are likely to be found, and negative otherwise.

Ramaswamy et al., Efficient algorithms for mining outliers from large data sets. ACM Sigmod Record (Vol. 29, No. 2, pp. 427-438, 2000).

Schölkopf et al., Estimating the support of a high-dimensional distribution. Neural computation13, 1443-1471, 2001.

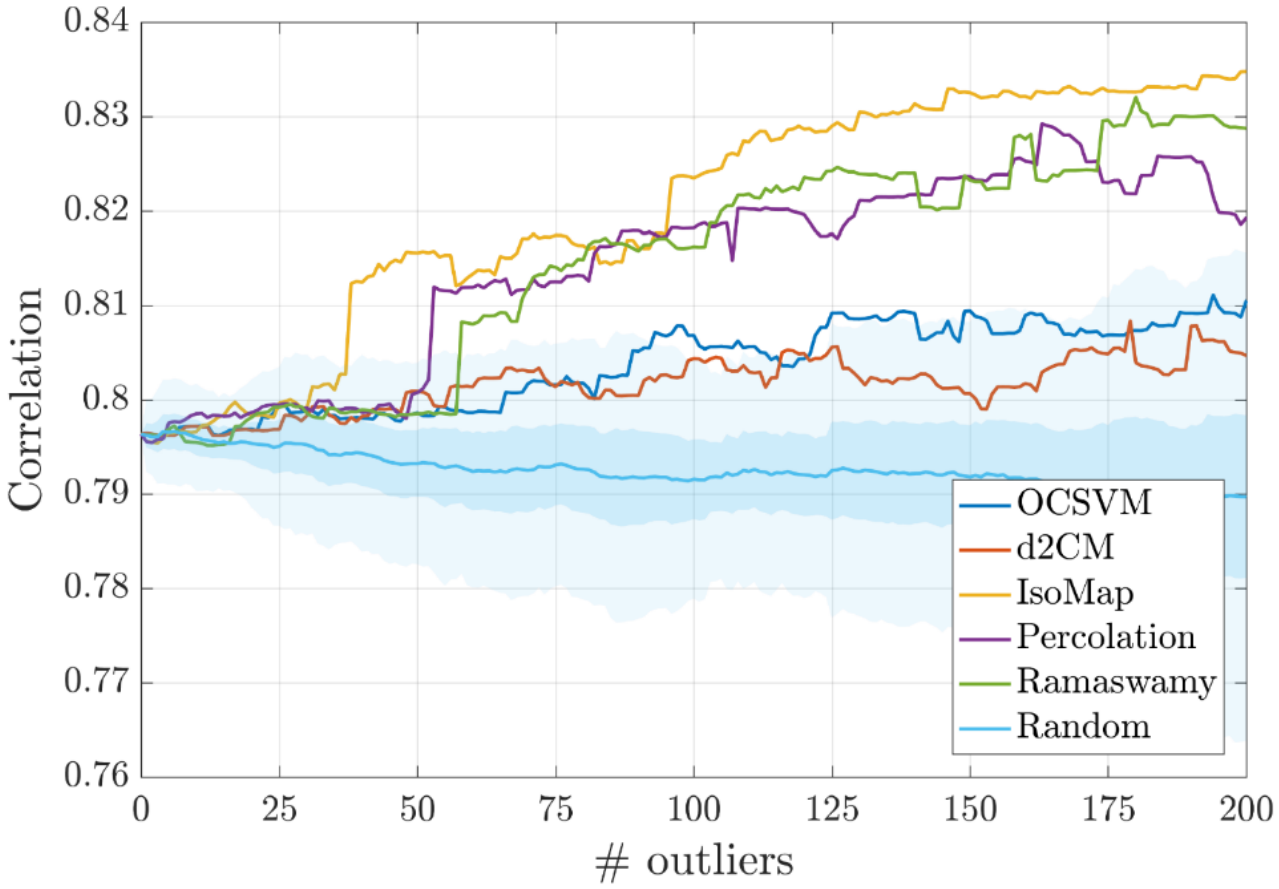
Results with OCT images (1/2)



All except the first one were randomly sampled. Marked images correspond to top 15% outlier score for OCSVM (Blue), distance to center of mass (Orange), IsoMap (Yellow), Percolation (Purple), and Ramaswamy (Green)

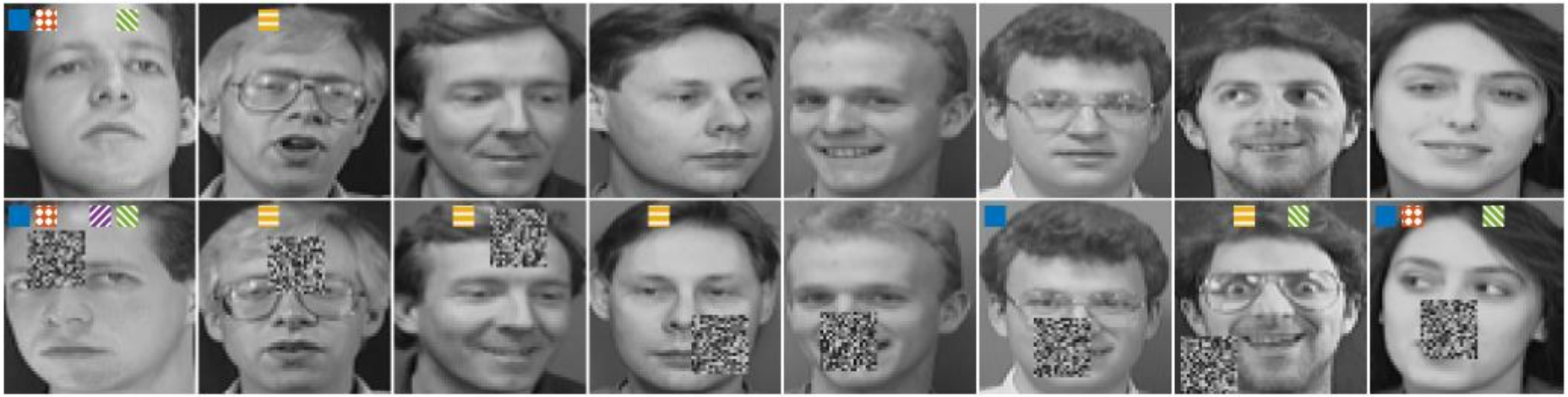
Results with OCT images (2/2)

Correlation between unsupervised features and the “manual” feature (mean angle) obtained from expert annotation.



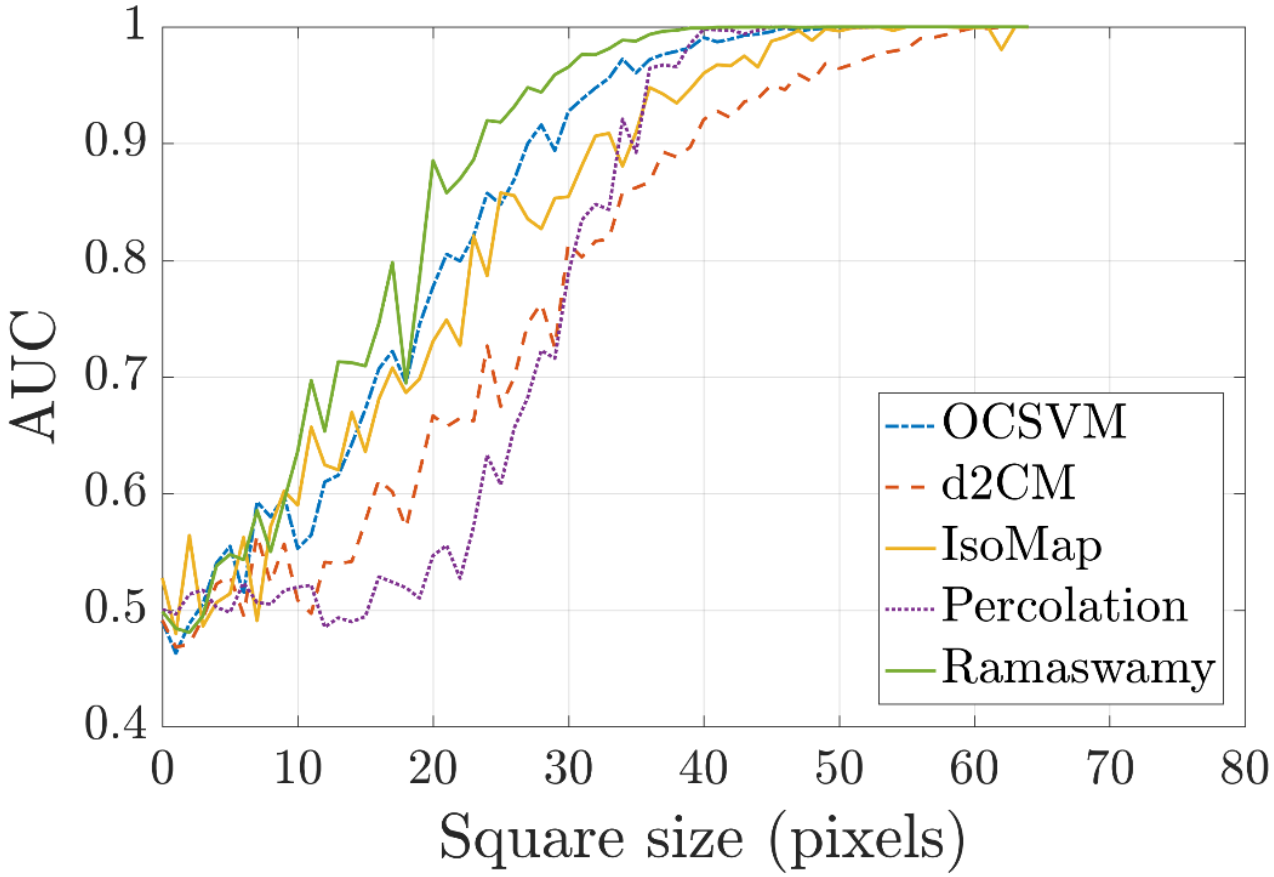
Can these methods work with other images?

- Freely available face database
- Added to some random images a square with gray-scale pixels whose color distribution is the same as that of the image.
- Measure success with the area under the ROC curve.



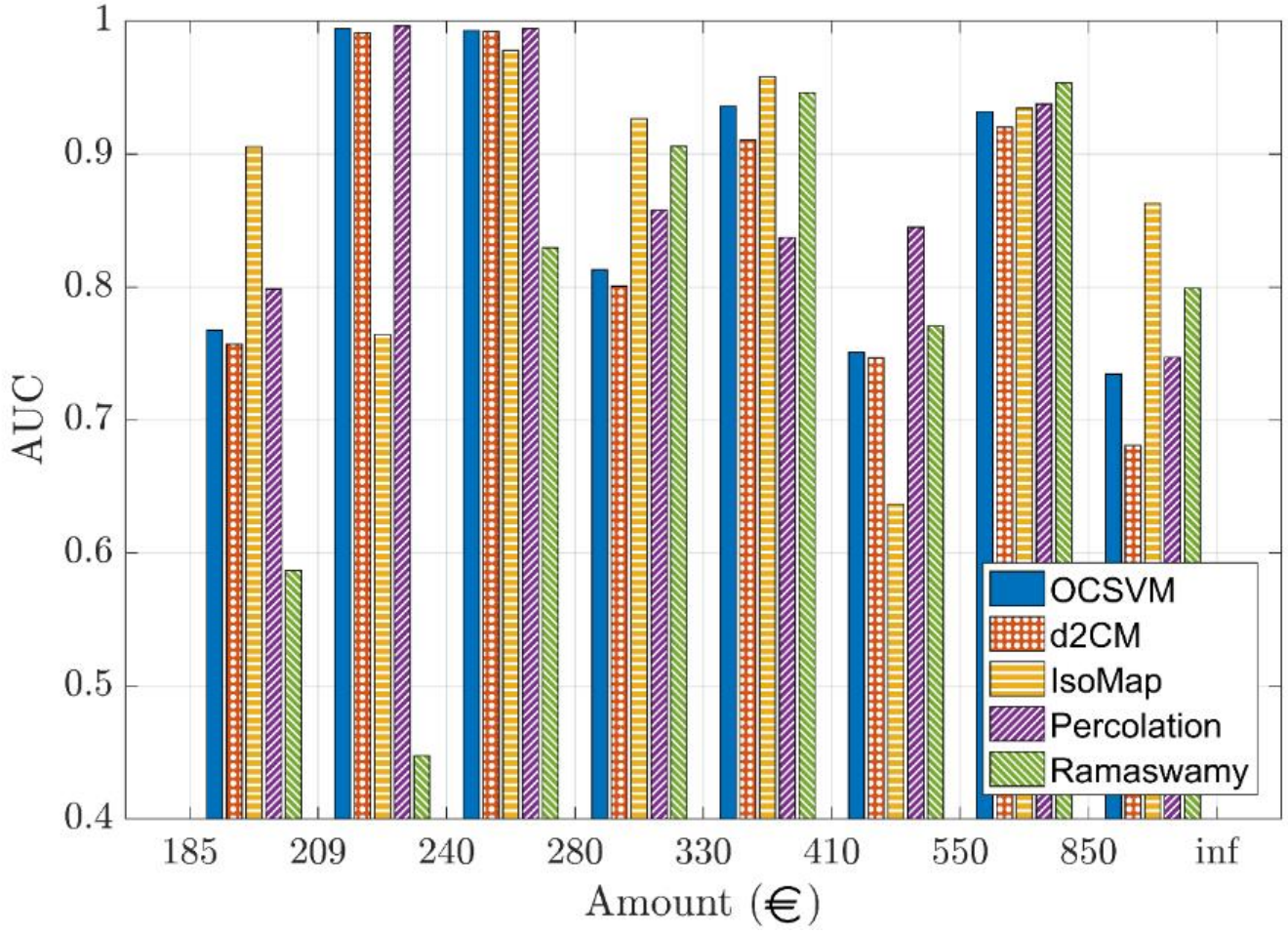
http://www.cl.cam.ac.uk/research/dtg/attarchive/facedatabase.html

Results from the face database



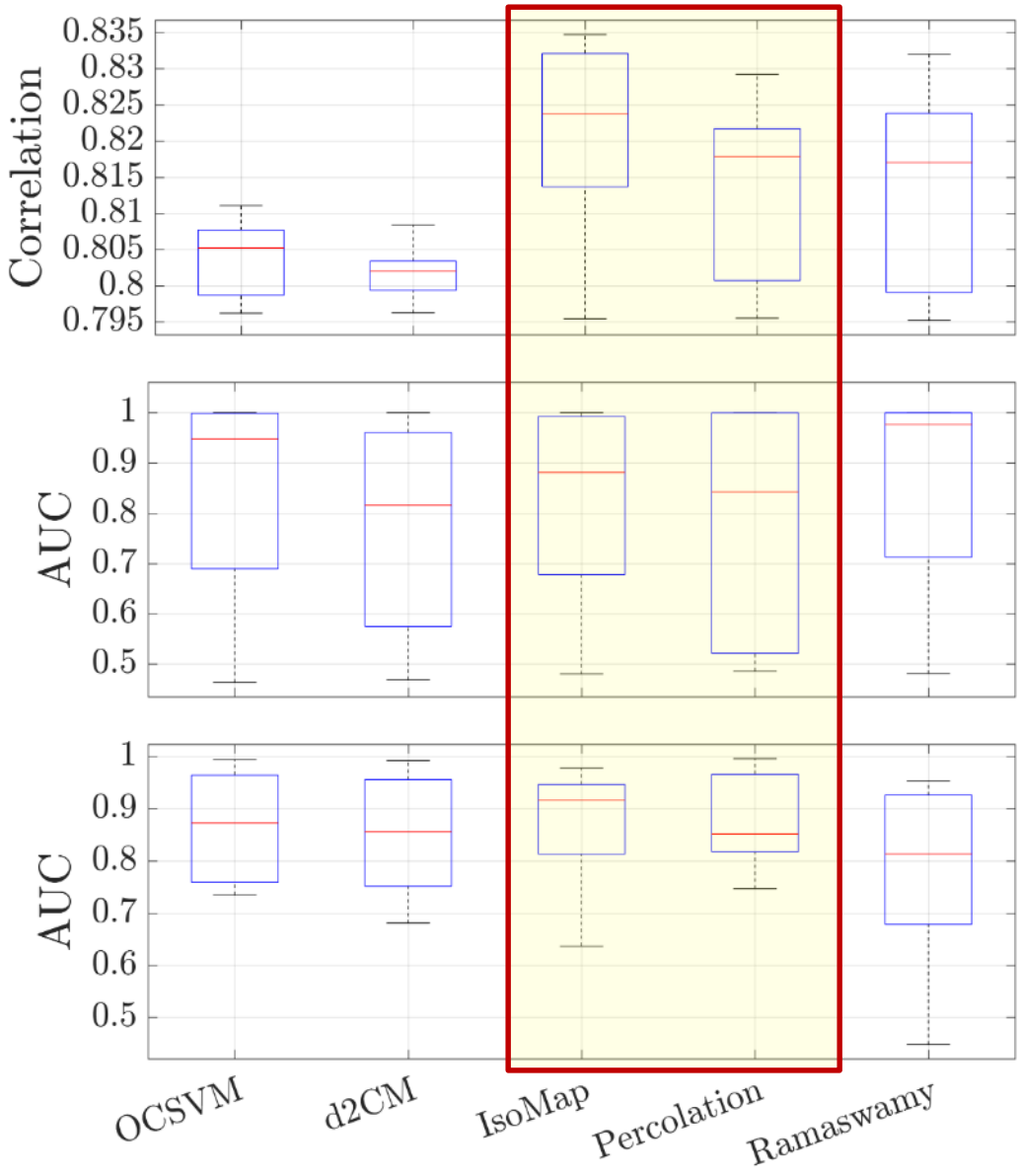
How about other types of elements?

Results from freely available credit card transactions (some identified as frauds)



https://www.kaggle.com/mlg-ulb/creditcardfraud

Summary of results



OCT database

Face database

Credit card database

Summary

- Fully unsupervised method for ordering anterior chamber OCT images.
- The performance of the method improves when images with artifacts (outliers) are removed from the training set.
- Two methods for outlier detection proposed, with results competitive with other methods in the literature.
- The *percolation* method is parameter free, which makes it perfect for blind outlier finding.
- The *IsoMap* method has 2 parameters that when set properly can greatly outperform other methods, but is very sensitive to such parameters.
- Patent pending.

Thanks to

- Pablo Amil (UPC Barcelona)
- Ulrich Parlitz (Max Plank Institute for Dynamics and Self-organization)
- Laura González, Elena Arrondo, Cecilia Salinas, Jose Luis Guell (Instituto de Microcirugia Ocular de Barcelona)
- Nahuel Almeira (Universidad Nacional de Córdoba, Argentina)

Thank you for your attention !

- P. Amil et al., "*Unsupervised feature extraction of anterior chamber OCT images for ordering and classification*", Sci. Rep. 9, 1157 (2019).
- P. Amil et al., "*Outlier mining methods based on network structure analysis*", submitted (2019).

GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD

BE-OPTICAL Advanced Biomedical Optical Imaging and Data Analysis

ICREA

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH