EIGENFACES FOR RECOGNITON

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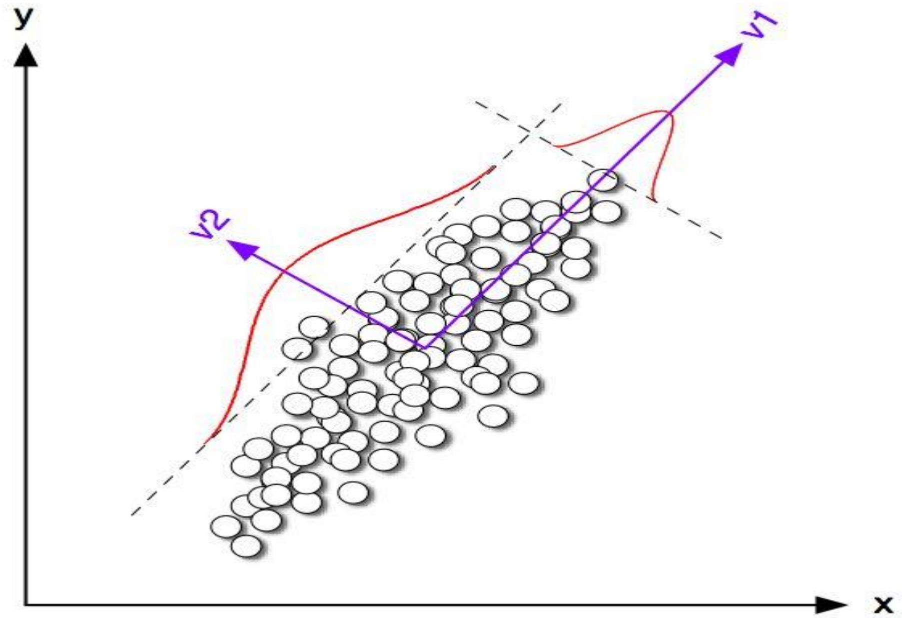
Overview

- Acquire training images.
- Calculate Eigenfaces.
- Project them to face space.
- Project test image to face space.
- Calculate the Euclidean distance and make a decision.

Principal Component Analysis

Find the dimensions of data with highest variance



http://web.media.mit.edu/

Principal Component Analysis

Finding patterns in many dimensions is hard. Mapping to a simpler domain is desirable.

$$n \rightarrow k \mid k \ll n$$

n, k number dimensions

Invented in 1901, by Karl Pearson.

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Acquire Training Images

Get M training samples with variances

I_1 I_2 I_3 I_4 … I_{M-1} I_M

(Olivetti - Att – ORL dataset, ‘94)

Images are in same size and equivalently framed.

Calculate EigenFaces

- Convert all the images in vector form.

I_i =

25	40	55
8	200	180
70	65	18

$N \times N$

$\Gamma_i{}'$ =

25	40	55	8	200	180	70	65	18

N^2

- Calculate the mean . (Average Face)

$$\Psi = \frac{1}{M} \sum_{n=1}^{M} \Gamma_n$$

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Calculate EigenFaces

- Normalize vectors.

$$\Phi_i = \Gamma_i - \Psi$$

- Form the covariance matrix

$$A = [\Phi_1, \Phi_2, .., \Phi_m]$$

$$C = \frac{1}{M} \sum_{n=1}^{M} \Phi_n \Phi_n^T = AA^T$$

Calculate EigenFaces

- We calculate the Eigen vectors of Covariance Matrix

$$C = AA^T \rightarrow N^2 \times M \,.\, M \times N^2 \rightarrow \boldsymbol{N^2} \times \boldsymbol{N^2} \quad !$$

- Do we need so many eigenvectors anyway ?

No, we don't ! Calculate eigenvectors of the Covariance matrix with reduced dimensionality.

Calculate EigenFaces

$$C = A^T A \rightarrow M \times N^2 . N^2 \times M \rightarrow \boldsymbol{M} \times \boldsymbol{M}$$

v_i is an eigenvector of $A^T A$

$$\mu_i = A v_i$$

μ_i is an eigenvector of $A\,A^T$ (Eigen Face)

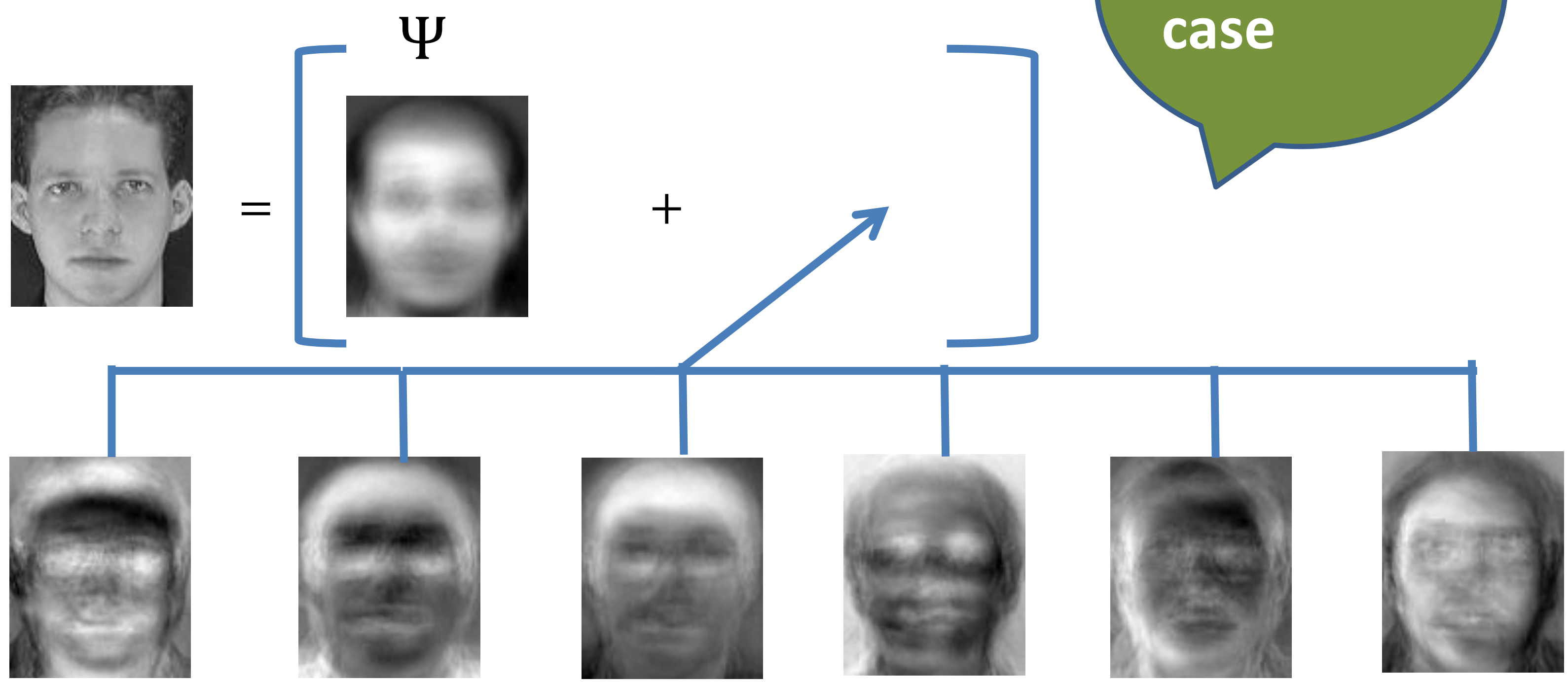
$$(A^T A) v_i = \lambda_i v_i$$

$$A A^T A v_i = \lambda_i (A v_i)$$

Calculate k eigenvectors and associate remaining to 0.

Training the system

6 eigenfaces case



$$\mu_1 * \omega_1 + \mu_2 * \omega_2 + \mu_3 * \omega_3 + \mu_4 * \omega_4 + \mu_5 * \omega_5 + \mu_6 * \omega_6$$

Training the system

- Images projected to face space.

$$\omega_k = \mu_k^T(\Gamma - \Psi)$$

- Images projected to face space.

$$\Omega_i = \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \dots \\ \omega_k \end{bmatrix} \qquad \Phi_f = \sum_{i=1}^{M'} \omega_i \mu_i$$

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Training the system

Testing a face has two cases:

- Find the nearest face with designated threshold θ_ϵ

  $\epsilon_k^2 = \|(\Omega - \Omega_k)\|^2$ compare with θ_ϵ

- Normalize and find out if it is a face according toθ_ϵ

  $\epsilon^2 = \left\|(\Phi - \Phi_f)\right\|^2$ compare with θ_ϵ

Additional Capabilities

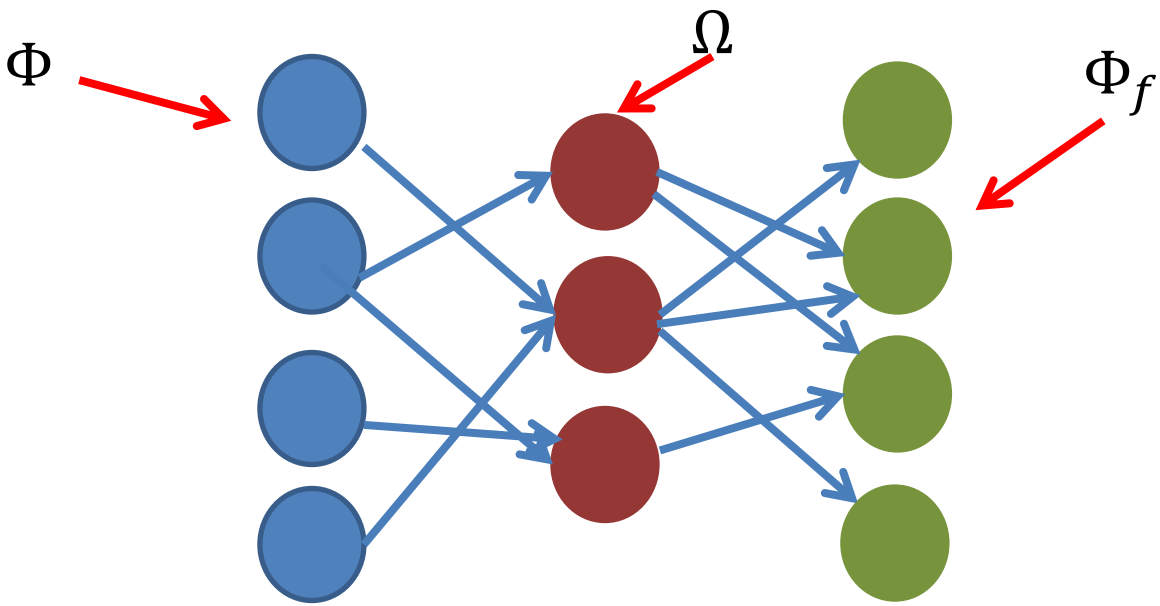
Detection and Tracking

- Check around every pixel for an image
- Try to classify faces using spatiotemporal filtering for a video
- Both methods can be combined

Additional Capabilities

Relation to Neural Networks

- Model the system as Neural Network.



Additional Capabilities

Increasing Robustness

- Multiply around the face with Gaussian for attenuating the effects of background.
- Try different scales of eigenfaces, estimate head pose.
- Up to 45^o turned faces with profile might be interpolated.

Summary

1. Acquire a set images with variations
2. Calculate eigenfaces and choose M' of them associated with highest eigenvalues.
3. By projecting each indivual's images to face space, train the system.
4. Given a test image; project it to face space and make decision according to threshold.

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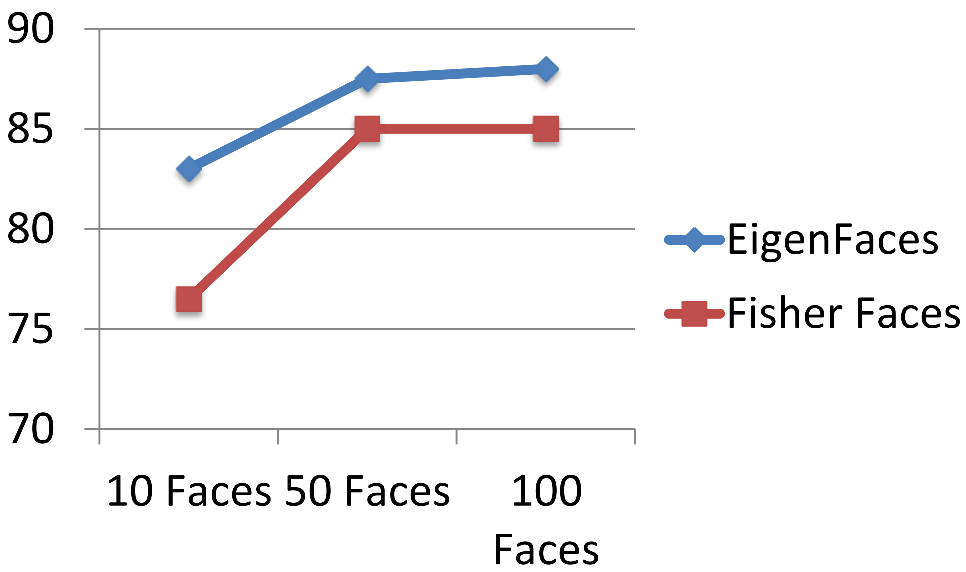
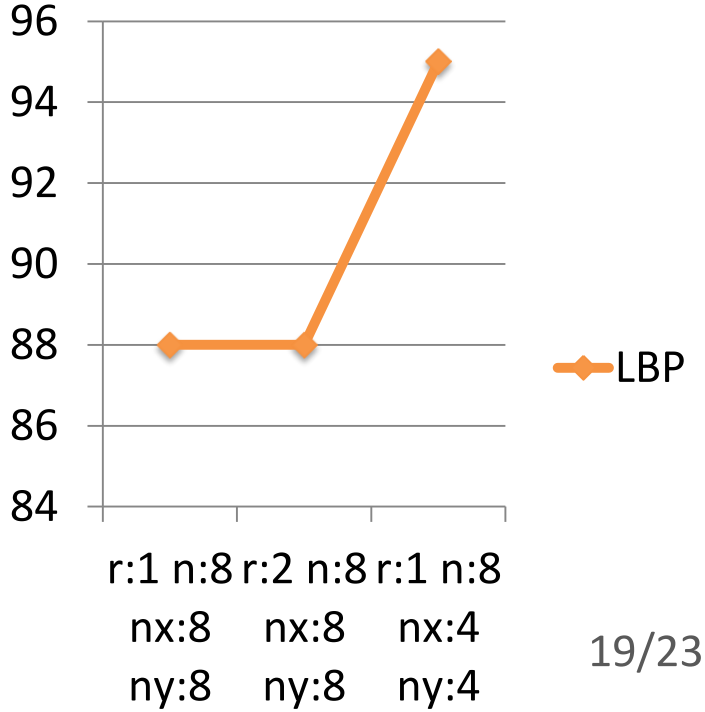
Results

Percentage results for Recognition from AT&T dataset, equal number of training and test images.





Results

Speed of Eigenfaces, 200 images for training and testing.

Eigenfaces	Training+Test	Test
10	0.52 seconds	0.02 seconds
50	0.7	0.11
100	0.92	0.25

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Results

(Caltech Face Dataset,’99)

Selection of 150 images from Caltech Faces(Converted to Grayscale);
45 Training, 105 test and 10 eigenfaces selected. Eigenfaces used directly and..

Only 7 (!) are correctly classified.

References

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[2]L. Sirovich and M. Kirby, Low-dimensional Procedure for the Characterization of Human Faces, Journal of the Optical Society of America A, 4:519--524, 1987

[3]Belhumeur, P.N.; Hespanha, J.P.; Kriegman, D., "Eigenfaces vs. Fisherfaces: recognition using class specific linear projection," *Pattern Analysis and Machine Intelligence, IEEE Transactions on* , vol.19, no.7, pp.711,720, Jul 1997   doi: 10.1109/34.598228

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[4] Anil K. Jain and Stan Z. Li. 2005. Handbook of Face Recognition. Springer-Verlag New York, Inc., Secaucus, NJ, USA.

Thank you for listening

Questions ?