Eigenfaces for Recognition
(Turk, Pentland; 1991)

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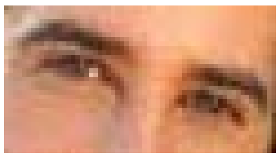
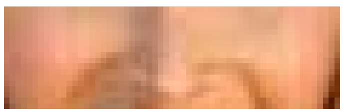
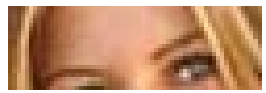
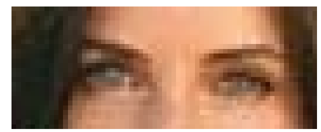
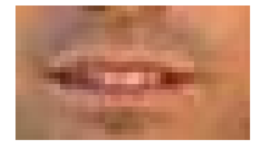
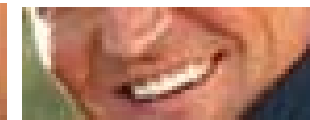
Outline

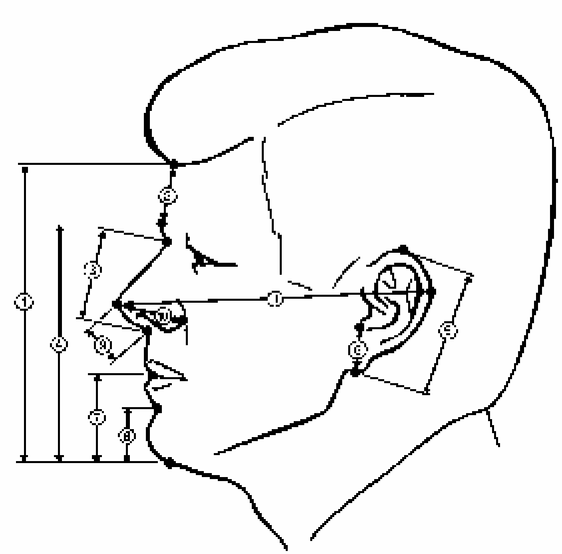
- Background
- PCA (Eigenfaces)
- Issues
- Face Detection
- Experiments / Tests
- Comments / Conclusion

Face Recognition Background

- “Traditional” approaches use bottom-up Feature analysis and geometric measurements

- Additional methods include
  - Deformable templates
  - Multiresolution templates
  - Connectionists approaches



Piecemeal Approach

Eigenface Approach

- GOAL:
  - Develop a fast, simple, and accurate face recognition computational model
- Assumptions
  - 2-D images,
  - Centered frontal portrait
- Method
  - Use Information Theory to analyze data
  - Encode images through Principal Components Analysis (PCA)

Holistic Approach

Eigenface training (1 of 2)

- M=16 images (255x255 pixels)
  - Each image vector Γ is 65536x1
  - Input images: S = [Γ1, Γ2, … , Γ16] (16x65536)

- Average Face is Ψ (65536x1)

- Each Image differs from mean $\Phi=\Gamma - \Psi$

Valentine's Norm-based coding in high dimensional face space

- Input faces A = [Φ_1, Φ_2, Φ_3, … ,Φ_{16}] (16x65536)

Eigenface training (2 of 2)

- Covariance Matrix to find Eigenvalues $L = A^TA$ (16x16)
- Calculate eigenvectors v=eig(L) (16x16)
- Obtain EigenFaces u=v*A (16x65536)

$$\mathbf{u}_l = \sum_{k=1}^{M} \mathbf{v}_{lk}\mathbf{\Phi}_k, \qquad l = 1, \ldots, M$$

- Determine significant Eigenvalues/Eigenvectors to utilize M' eigenfaces with most information
- Encode input faces into low dimensional space through "weights"

$$\omega_k = \mathbf{u}_k^T(\mathbf{\Gamma} - \mathbf{\Psi}) \qquad k = 1, \ldots, M'$$

$$\Omega^T = [\omega_1, \omega_2 \ldots \omega_{M'}]$$

Each Image is only represented by a vector of size M' (7) instead of N^2 (65536)

Recognition using Eigenfaces

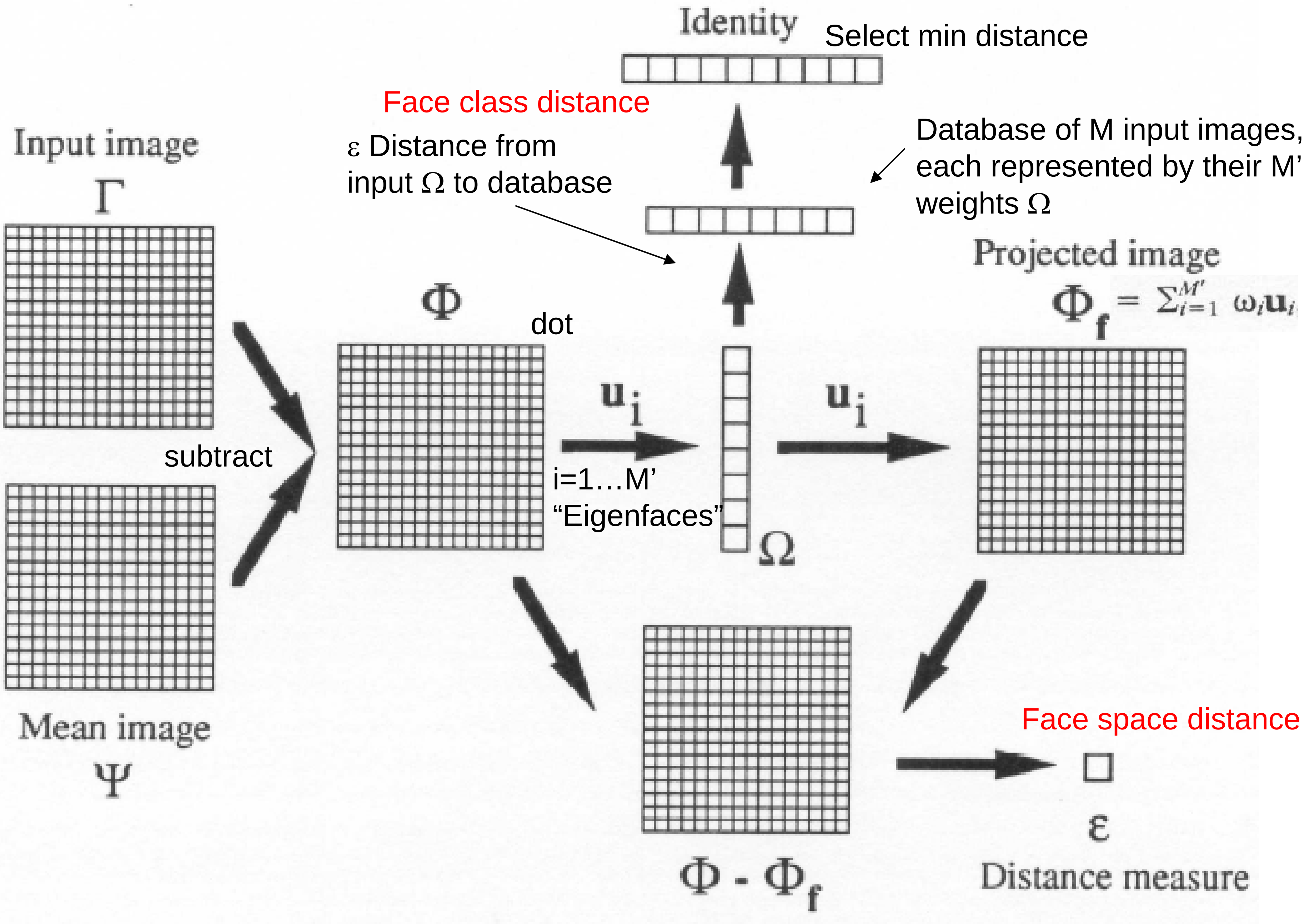
- Calculate ‘weights’ of unknown Input face (Γ)

$$\omega_k = \mathbf{u}_k^T(\Gamma - \Psi) \qquad k = 1, \ldots, M'$$

$$\Omega^T = [\omega_1, \omega_2 \ldots \omega_{M'}]$$

- Compute Euclidean Distance from input face ‘weights’ to training images. Closest match wins!

Eigenfaces Overview



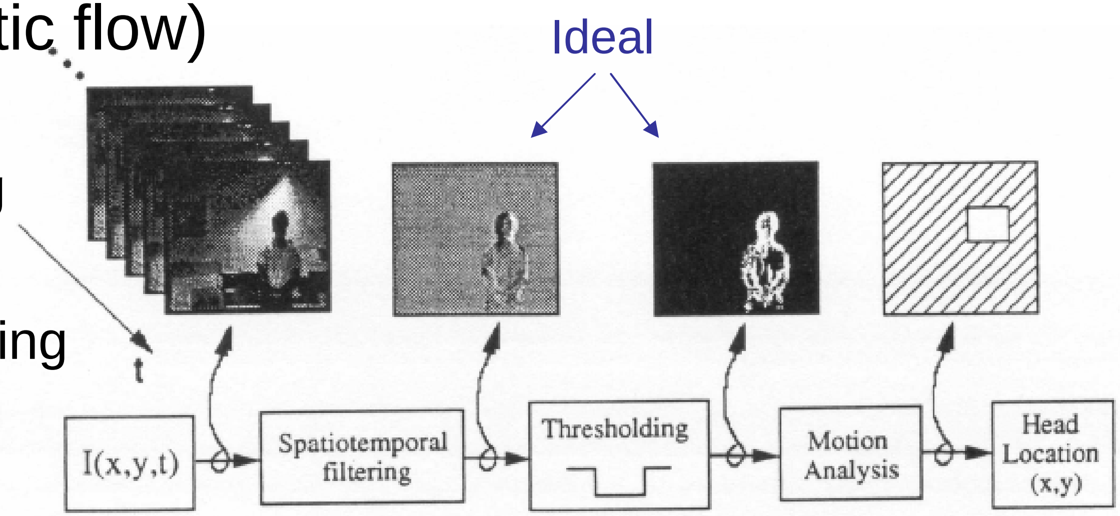
Adaptive Learning

- Eigenfaces Bonus Feature
  - If an unknown input face is both
    - Close to face-space and
    - Not Close to any face in the database
  - Then
    - It is a potentially new face
    - The new face can be added to the database

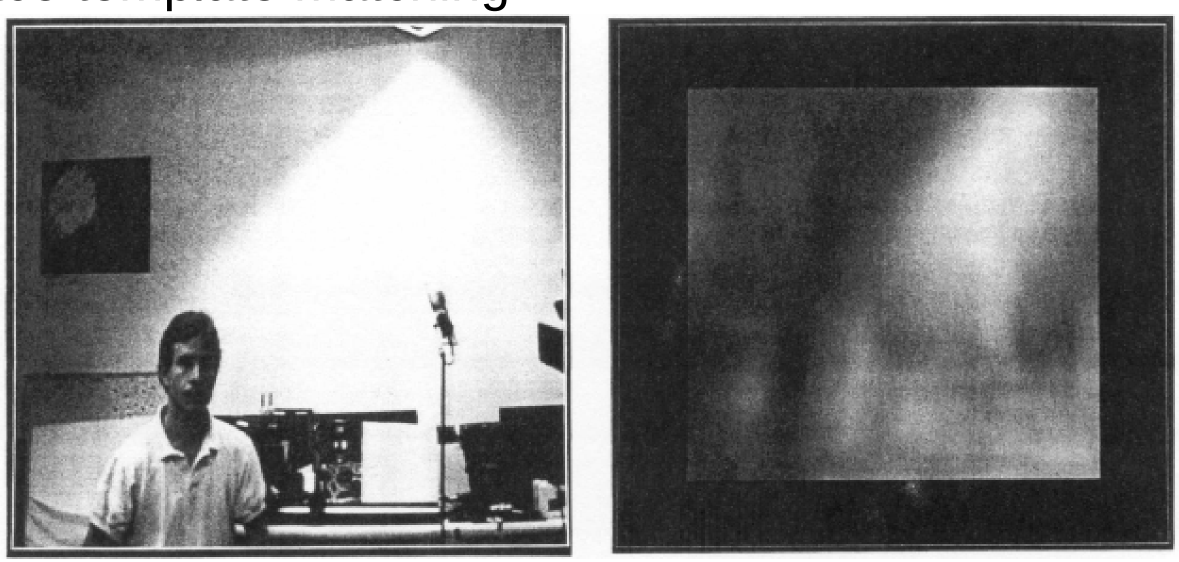
Unsupervised Operation

Face Detection (not recognition)

- 1 – Motion Analysis (optic flow)
  - nothing to do with PCA
  - Fails with various moving objects
  - Fails without people moving



- 2 – Face Space
  - Eigenface template matching

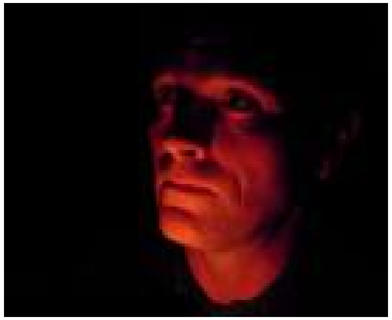


Issues

- Background
- Scale/Size
- Orientation/rotation
- 3d Viewpoint
- Expressions
- Lighting
- Makeup

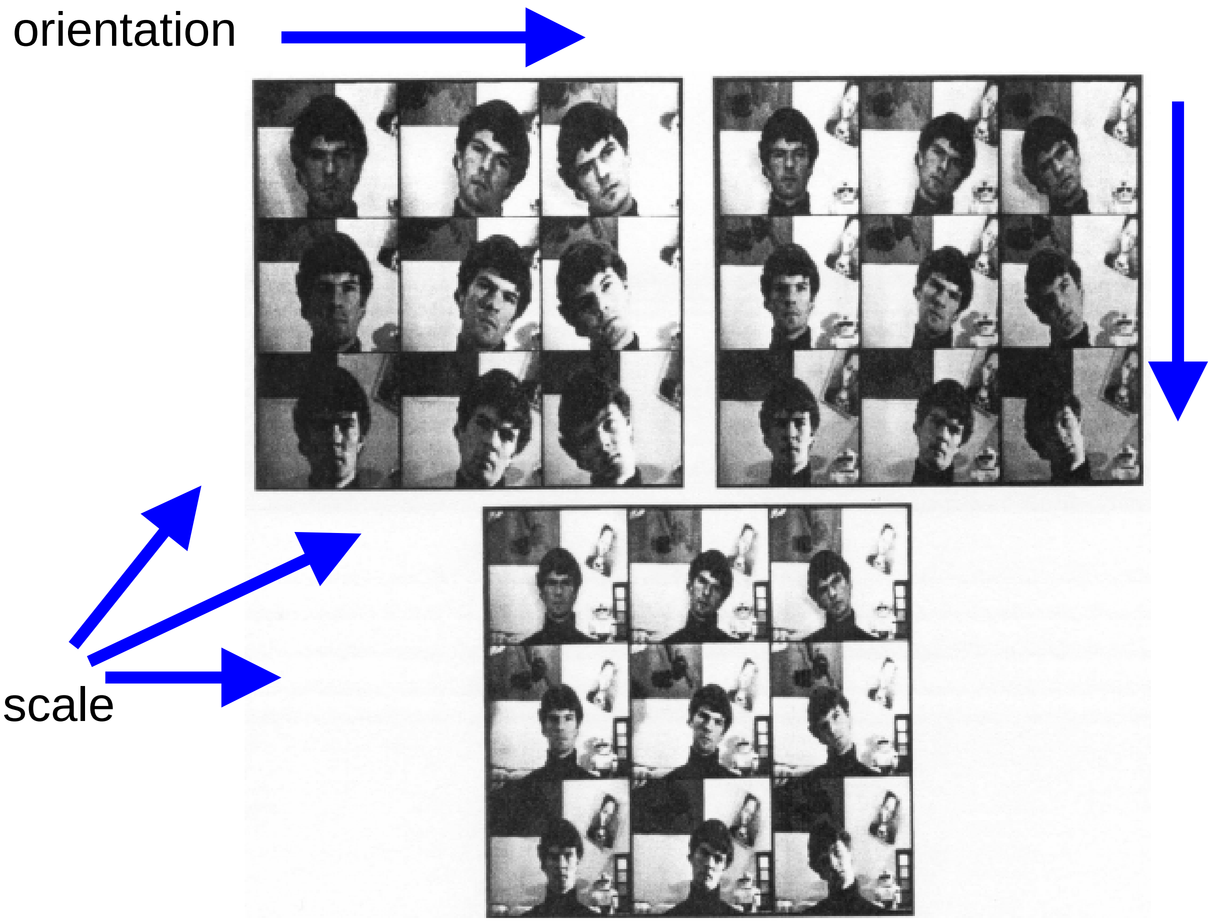




Experiments: 1- robustness

- Testing three independent variables identified as potential issues: lighting, scale, orientation



Results1: correct

Light:	96%
Orientation:	85%
Scale:	64%

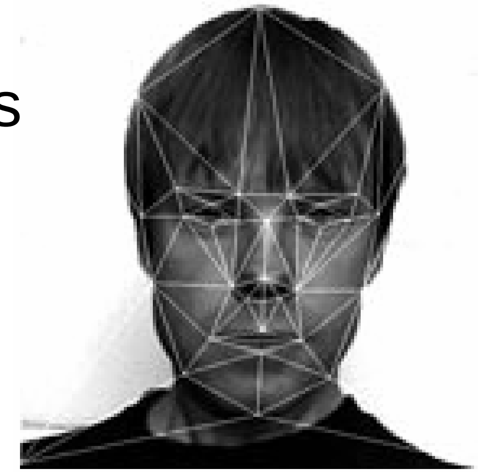
Results2: unknown

Light:	19%
Orientation:	39%
Scale:	60%

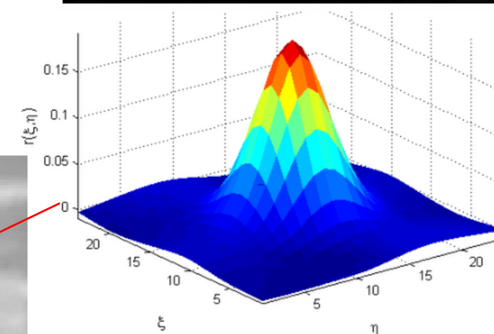
Eigenface Enhancement Extensions

- Shape-free faces potentially addresses issues

  Craw, 1995; Craw & Cameron, 1991; Burton, Bruce, and Hancock, 1999



- Eliminate Background through gaussian



- Rotate tilted face by pre-process

ϕ

- Address scale variance through multiscale training or size estimation through pre-processing

>data_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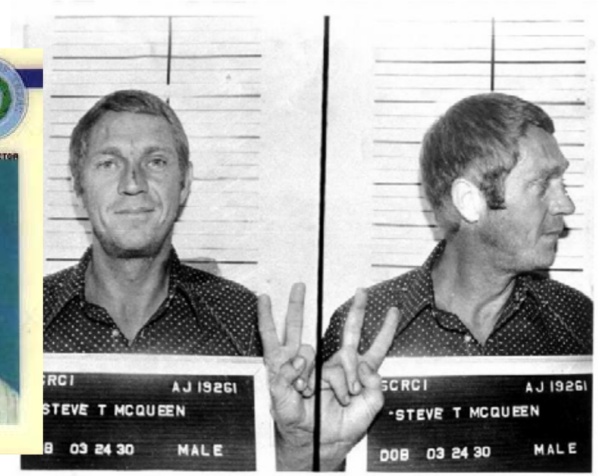
TEXAS
DEPARTMENT OF PUBLIC SAFETY
DRIVER LICENSE
DIRECTOR
CLASS: C
DL: [redacted]
DOB: 11-27-83
HT: 6-01
EXPIRES: 11-27-12
EYES: BRN
REST:
SEX: M
END:
MOSCOVICI,MIHAI
[redacted] GREEK ROW
ARLINGTON TX 76013


AJ 19261
STEVE T MCQUEEN
03 24 30 MALE
SCRCI AJ 19261
STEVE T MCQUEEN
DOB 03 24 30 MALE


SHE MARRIED HIM??!!
AND THEY'VE GOT 7 KIDS??
classmates.com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Looking for old friends?
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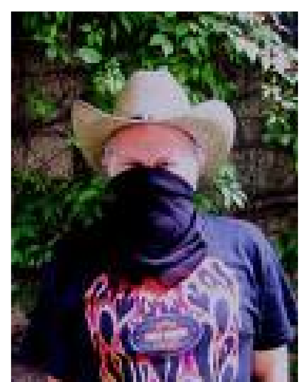
the worlds best place to reunite
- click here -


Find Your Graduating Class
classmates.com
I graduated in:
1995
1985
1975
1965
1955
Click here so we can stop running these.

YOU ARE
WATCHING ME

Camera 2
12/12/2006 21:16:56



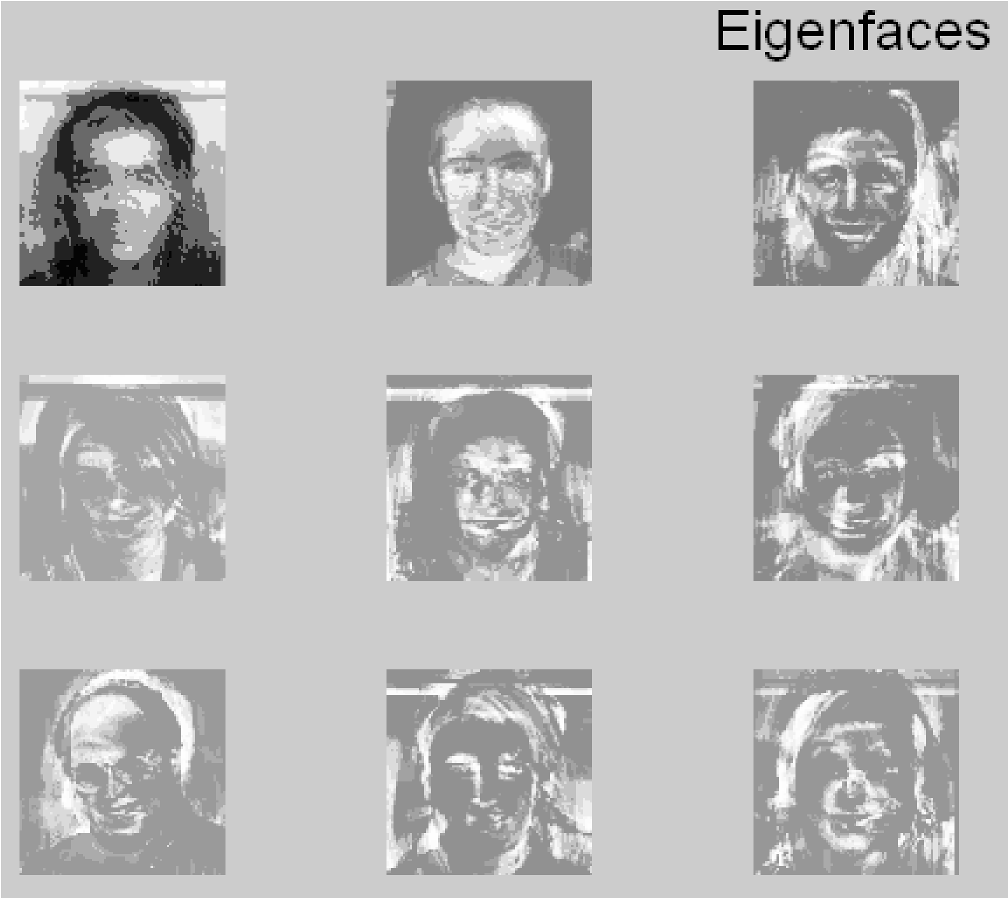

Concourse A
Pasillo A
Hall A
コンコース A
Restrooms
Baños
Toilettes
お手洗い


WELCOME TO AGGIELAND
HOME OF THE 12TH MAN

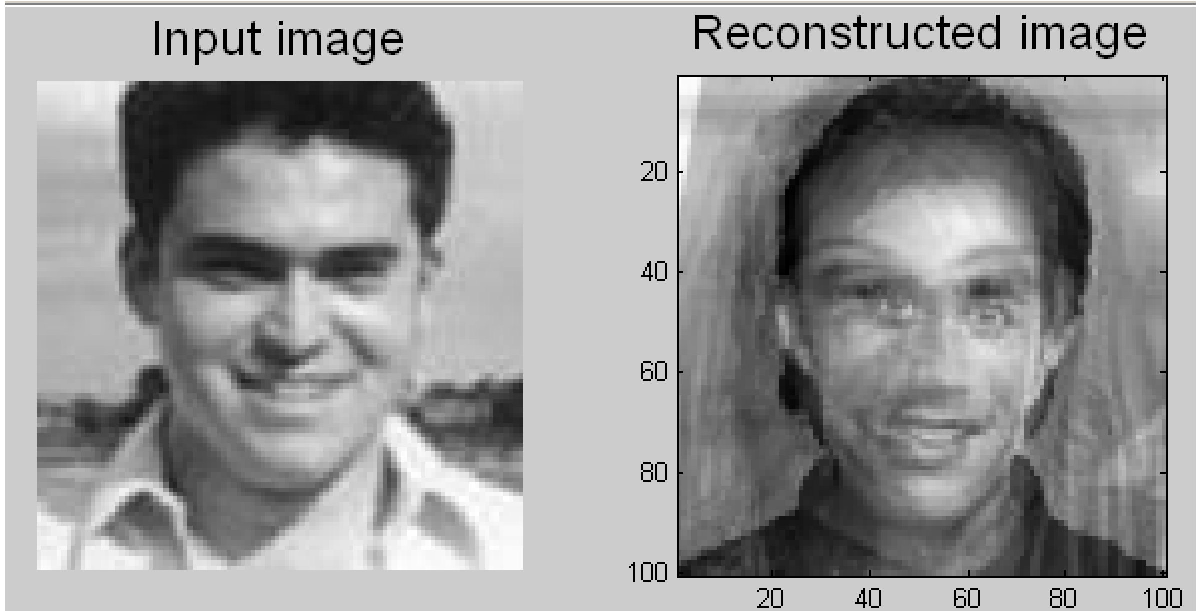
Demo (1/4)

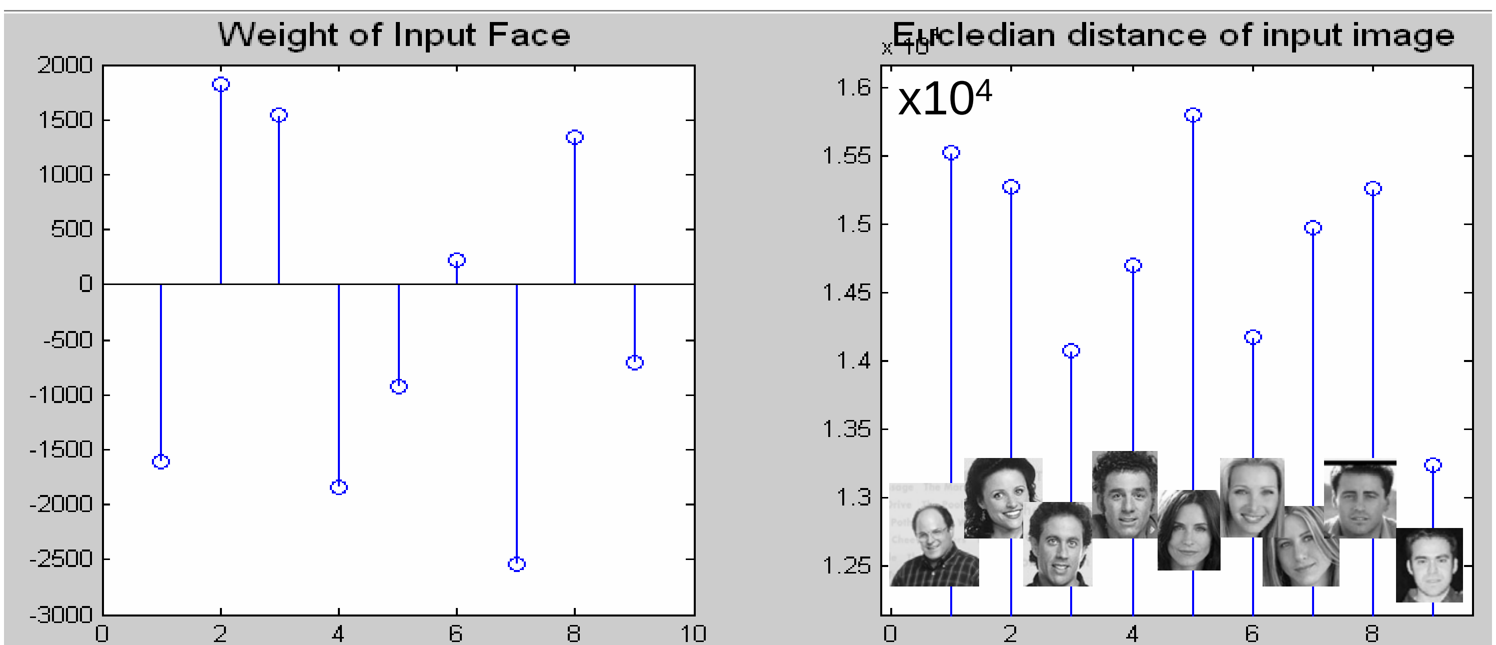
http://www.pages.drexel.edu/~sis26/Eigenface%20Tutorial.htm

Demo (2/4)

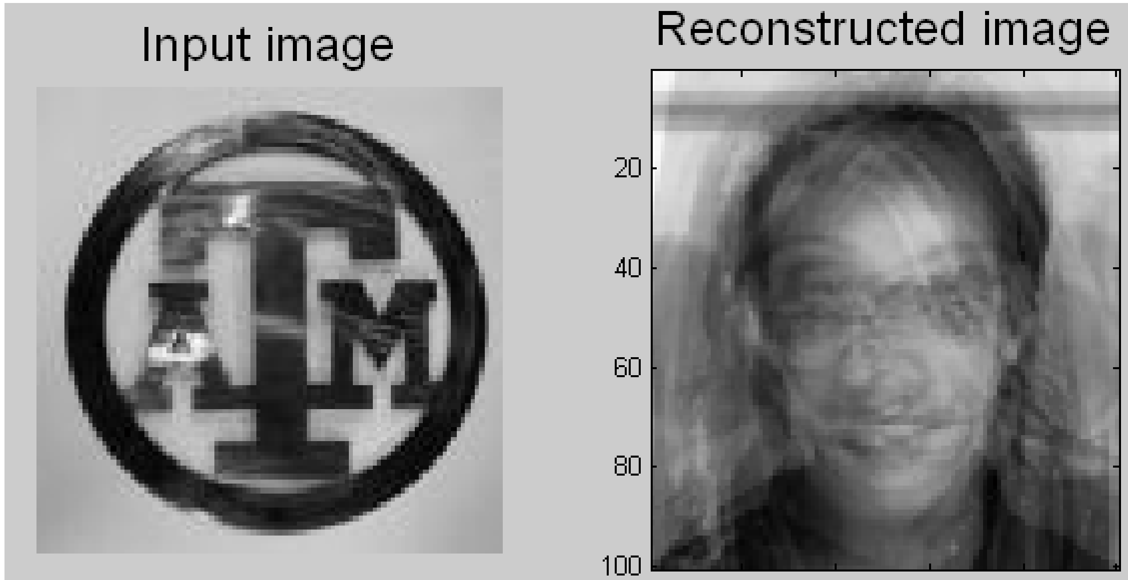


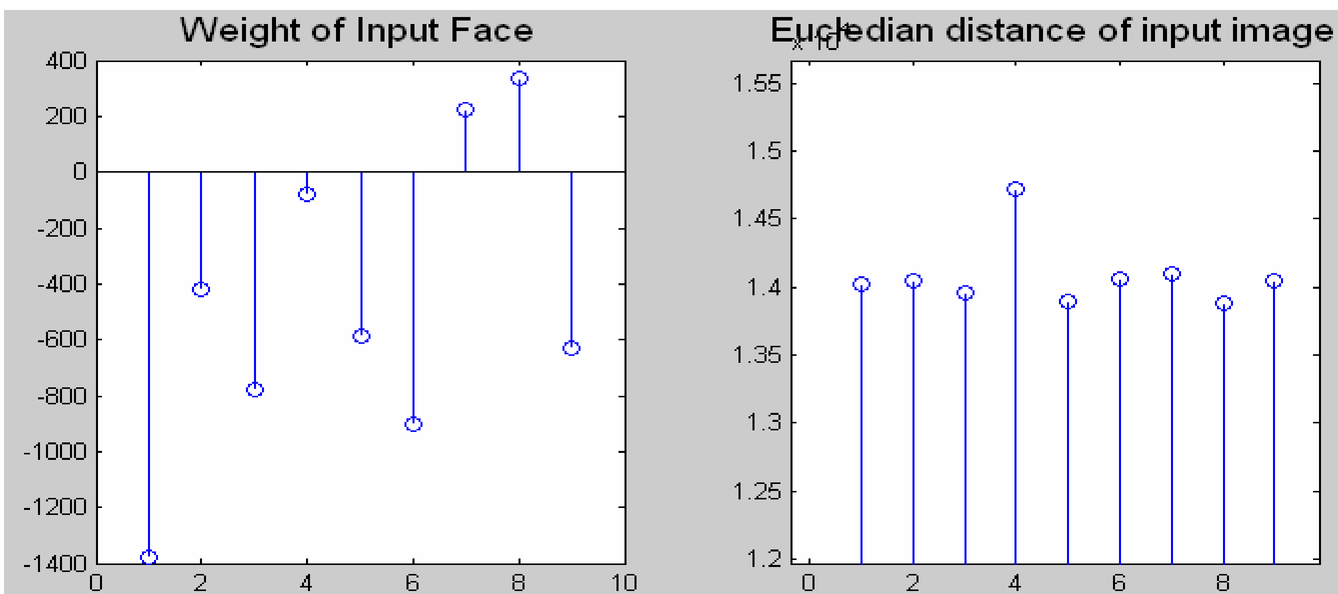
Demo (3/4)


Input image
Reconstructed image
20
40
60
80
100
20
40
60
80
100


Weight of Input Face
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
0
2
4
6
8
10
Eucledian distance of input image
x10^4
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
0
2
4
6
8

Demo (4/4)


Input image
Reconstructed image
20
40
60
80
100


Weight of Input Face
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
0
2
4
6
8
10
Eucledian distance of input image
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
0
2
4
6
8

Eigenfaces Applications

- Recognition/Authentication
- Face Detection/Location
- Compression/Storage
- Reconstruct Occlusions
- Actor segmentation for video
- Facial expression detector

Conclusions

- Implementation of a computational model for recognition
- Dimensionality Reduction
- Holistic approach
- PCA can be used to recognize other objects
- Thresholds have a significant effect