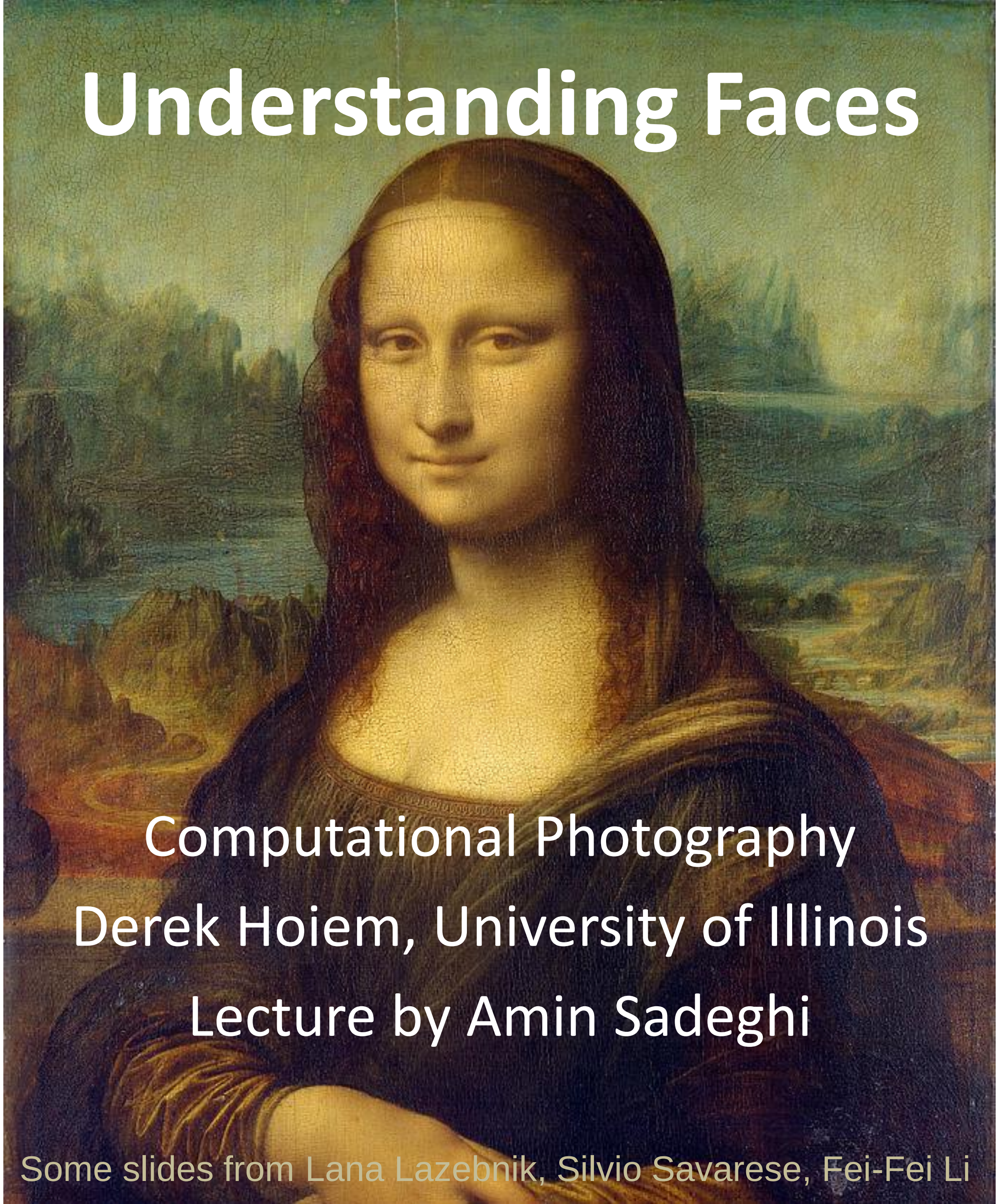


Understanding Faces

Computational Photography

Derek Hoiem, University of Illinois

Lecture by Amin Sadeghi

Some slides from Lana Lazebnik, Silvio Savarese, Fei-Fei Li

Face detection and recognition

Applications of Face Recognition

Album organization

Digital photography

Face Detection

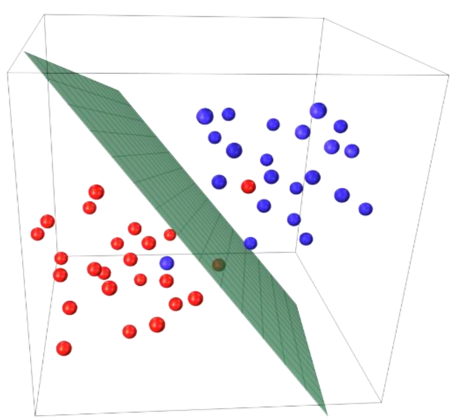
How to find faces anywhere in an image?

- Filter Image with a face?

Train a Filter

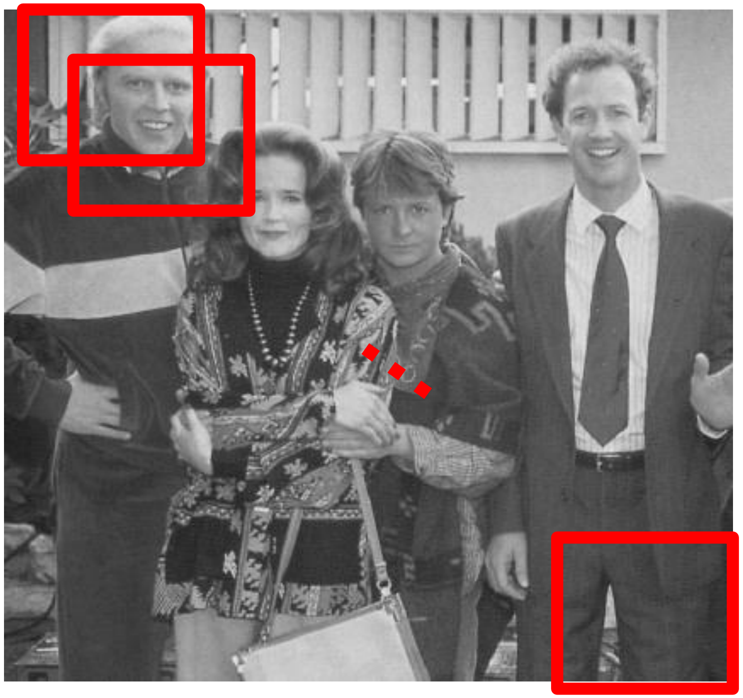
Positive Training Images

Negative Training Images



SVM

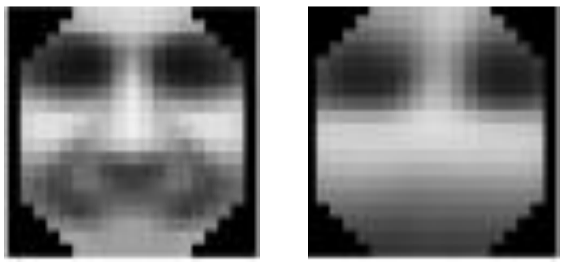
Face detection: sliding windows



Filter/Template

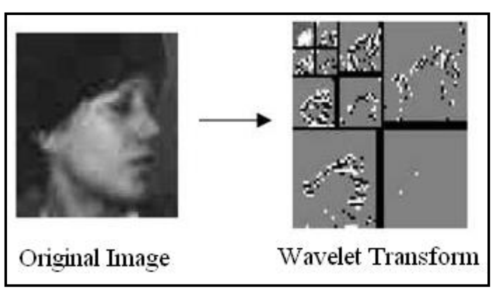
Multiple scales

What features?



Exemplars
(Sung Poggio 1994)

Intensity Patterns (with NNs)
(Rowely Baluja Kanade1996)



Edge (Wavelet) Pyramids
(Schneiderman Kanade 1998)

Haar Filters
(Viola Jones 2000)

How to classify?

- Many ways
  - Neural networks
  - Adaboost
  - SVMs
  - Nearest neighbor

What makes face detection hard?

Expression

What makes face detection hard?

Viewpoint

What makes face detection hard?

Occlusion

Consumer application: iPhoto 2009

http://www.apple.com/ilife/iphoto/

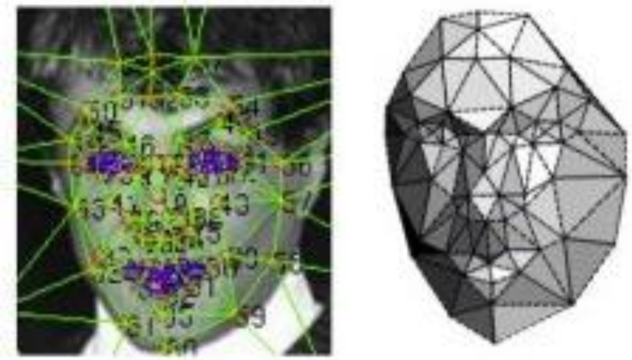
Consumer application: iPhoto 2009

- Things iPhoto thinks are faces

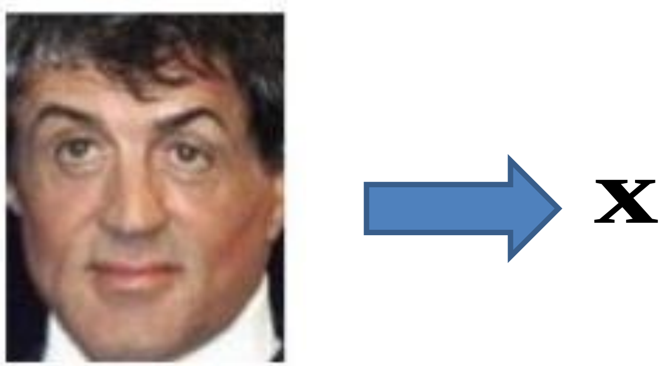
Face Recognition

Face recognition

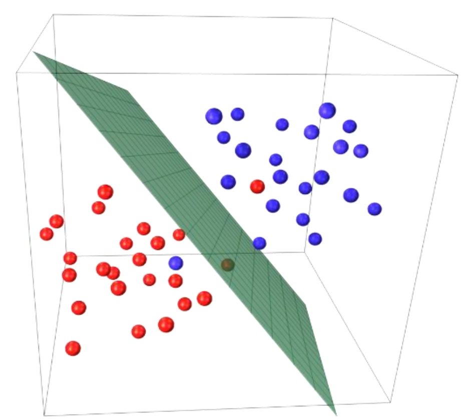
1. Detect



2. Align



3. Represent



4. Classify

Simple technique

1. Treat pixels as a vector

$$\rightarrow \mathbf{x}$$

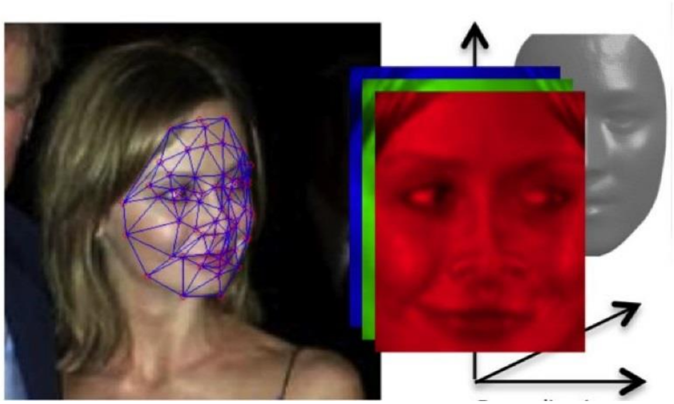
2. Recognize face by nearest neighbor

$$\rightarrow \mathbf{y}_1 \ldots \mathbf{y}_n$$

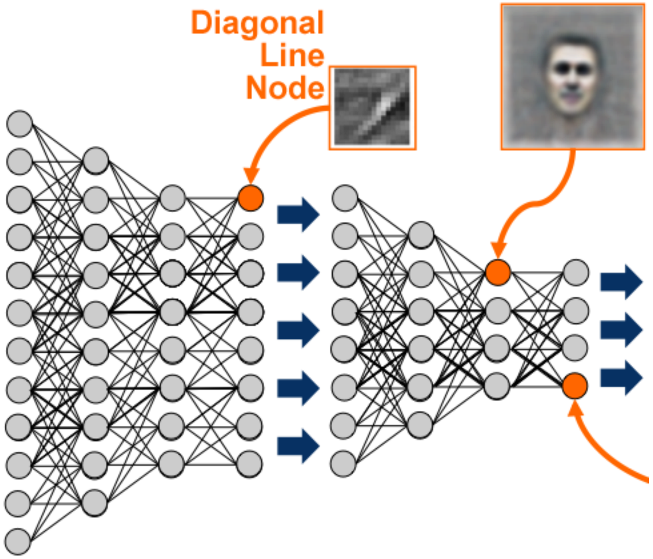
$$k = \underset{k}{\operatorname{argmin}} \left\| \mathbf{y}_k^T - \mathbf{x} \right\|$$

DeepFace

- 3D Alignment



- Deep Learning



Morphing and Alignment

Figure-centric averages

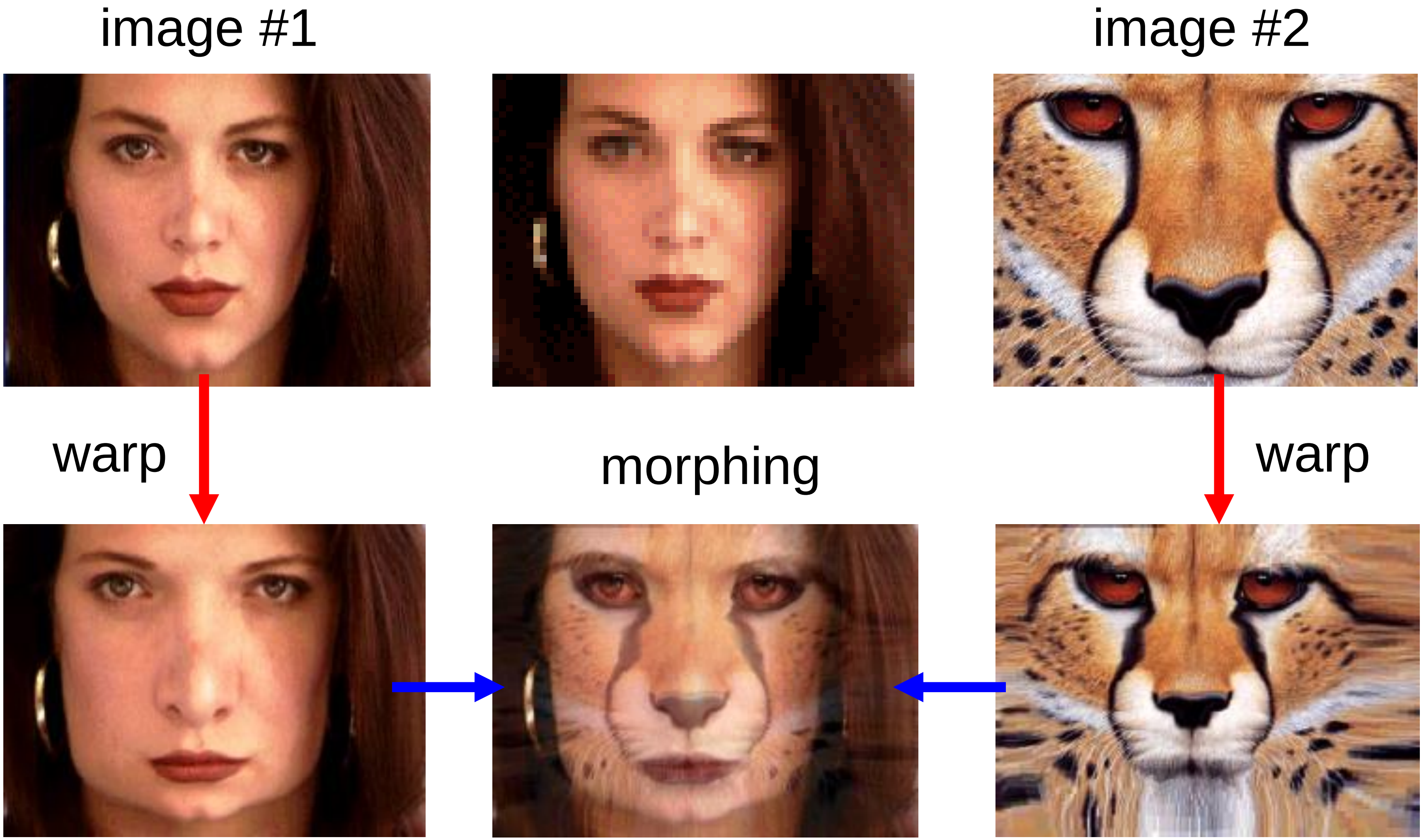
- Need to Align
  - Position
  - Scale
  - Orientation

Antonio Torralba & Aude Oliva (2002)
Averages: Hundreds of images containing a person are averaged to reveal regularities in the intensity patterns across all the images.

How do we average faces?

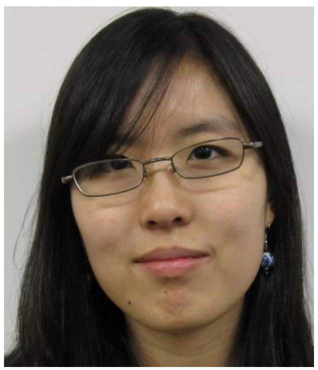
http://www2.imm.dtu.dk/~aam/datasets/datasets.html

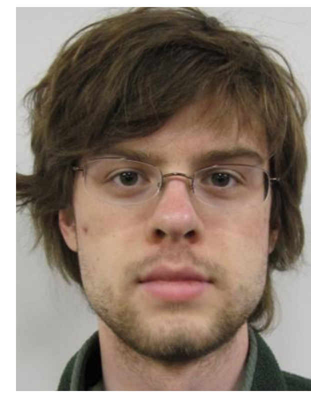
Morphing



Cross-Dissolve vs. Morphing

Average of
Appearance Vectors





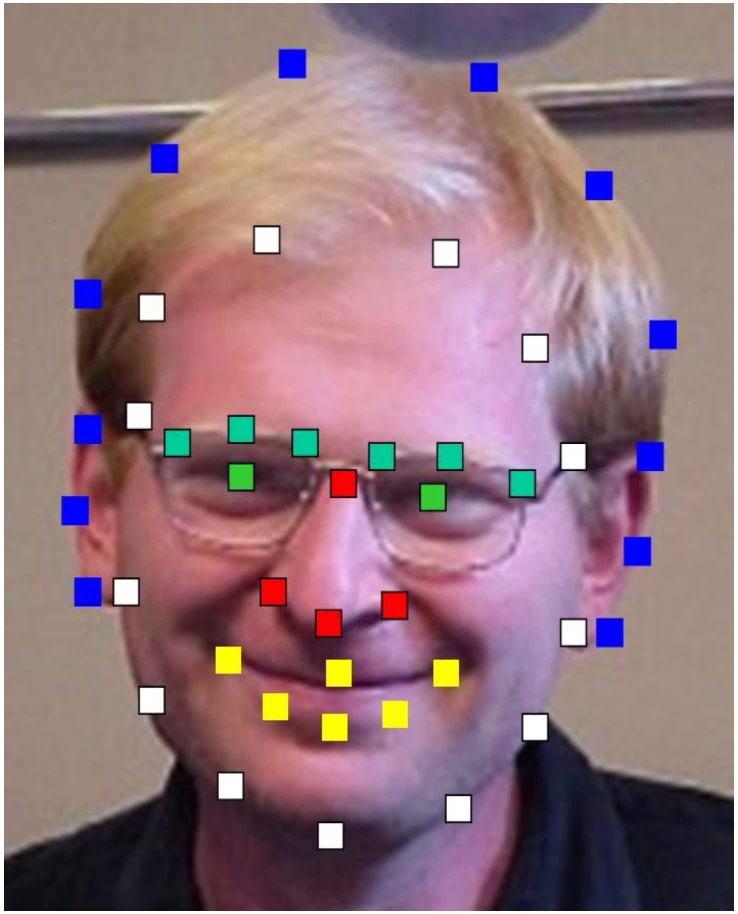
Average of
Shape Vectors

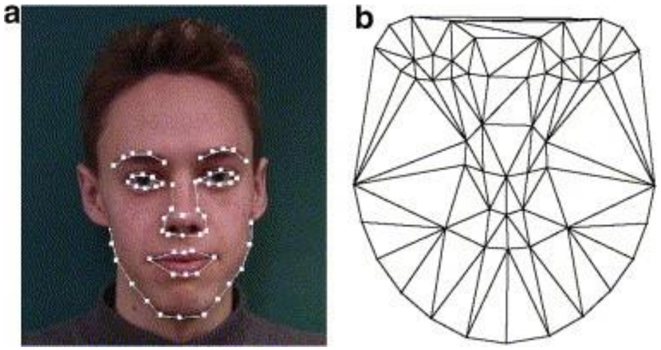
http://www.faceresearch.org/demos/vector

Images from James Hays

Aligning Faces

- Need to Align
  - Position
  - Scale
  - Orientation
  - Key-points
- The more key-points the finer alignment

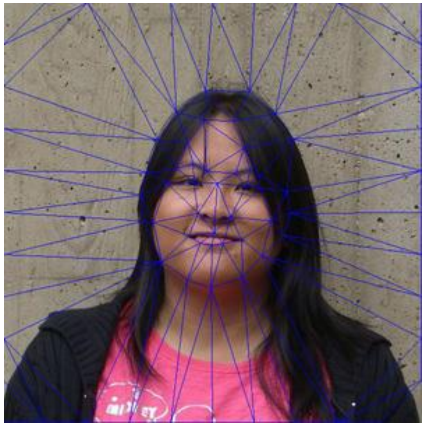




Images from Alyosha Efros

Average of two Faces

1. Input face key-points
2. Pairwise Average key-point co-ordinates
3. Triangulate the faces
4. Warp: Transform every face triangle
5. Average The pixels



Average of multiple Face

1. Warp to mean shape
2. Average pixels

http://www.faceresearch.org/demos/average

http://graphics.cs.cmu.edu/courses/15-463/2004_fall/www/handins/brh/final/

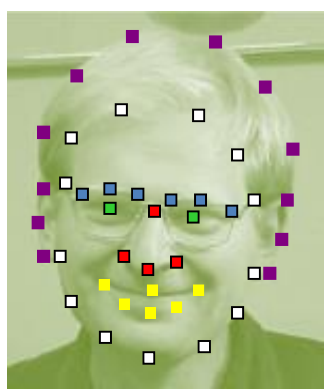
Appearance Vectors vs. Shape Vectors

Appearance Vector

200*150 pixels (RGB)

Vector of 200*150*3 Dimensions

Shape Vector



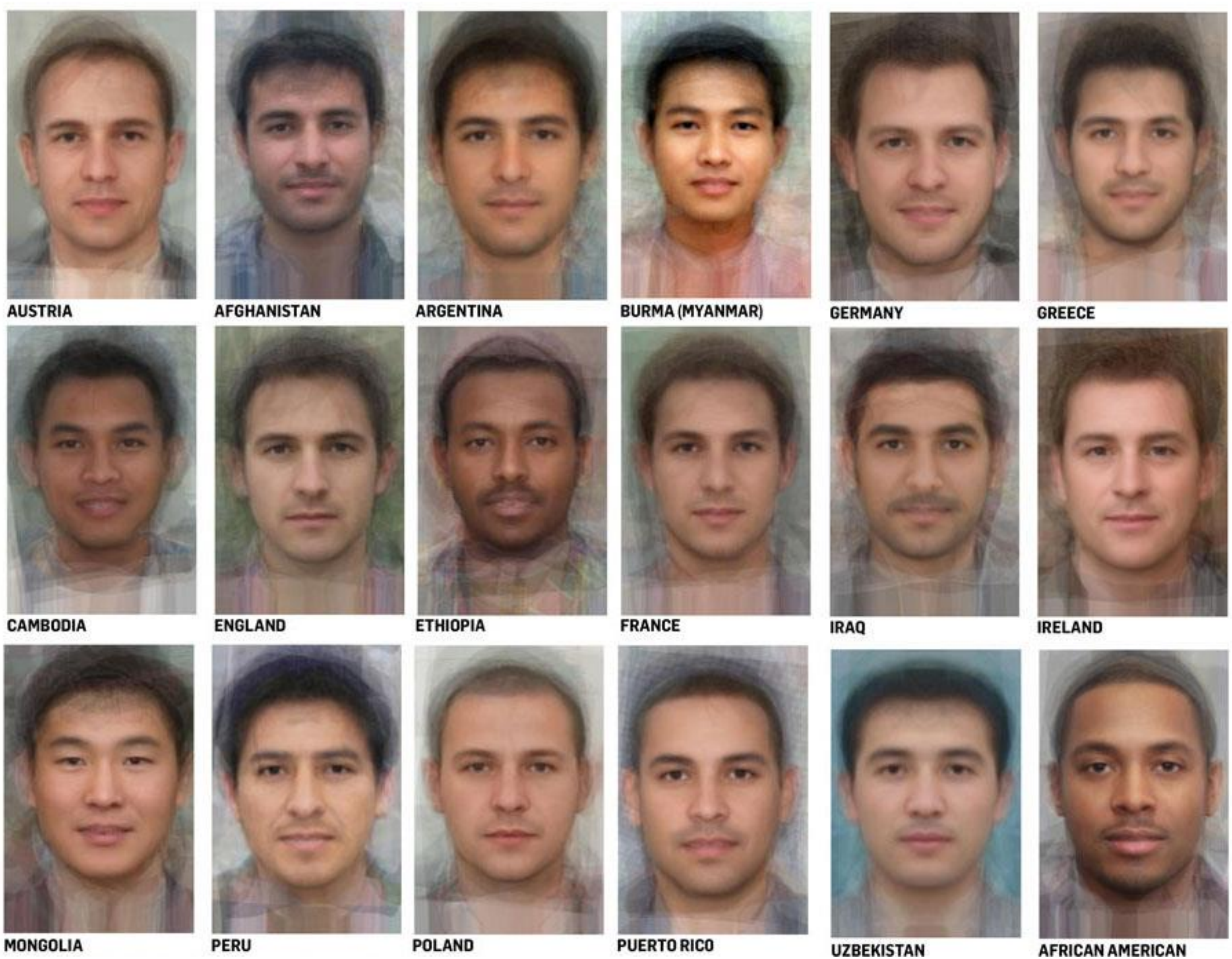
43 coordinates (x,y)

Vector of 43*2 Dimensions

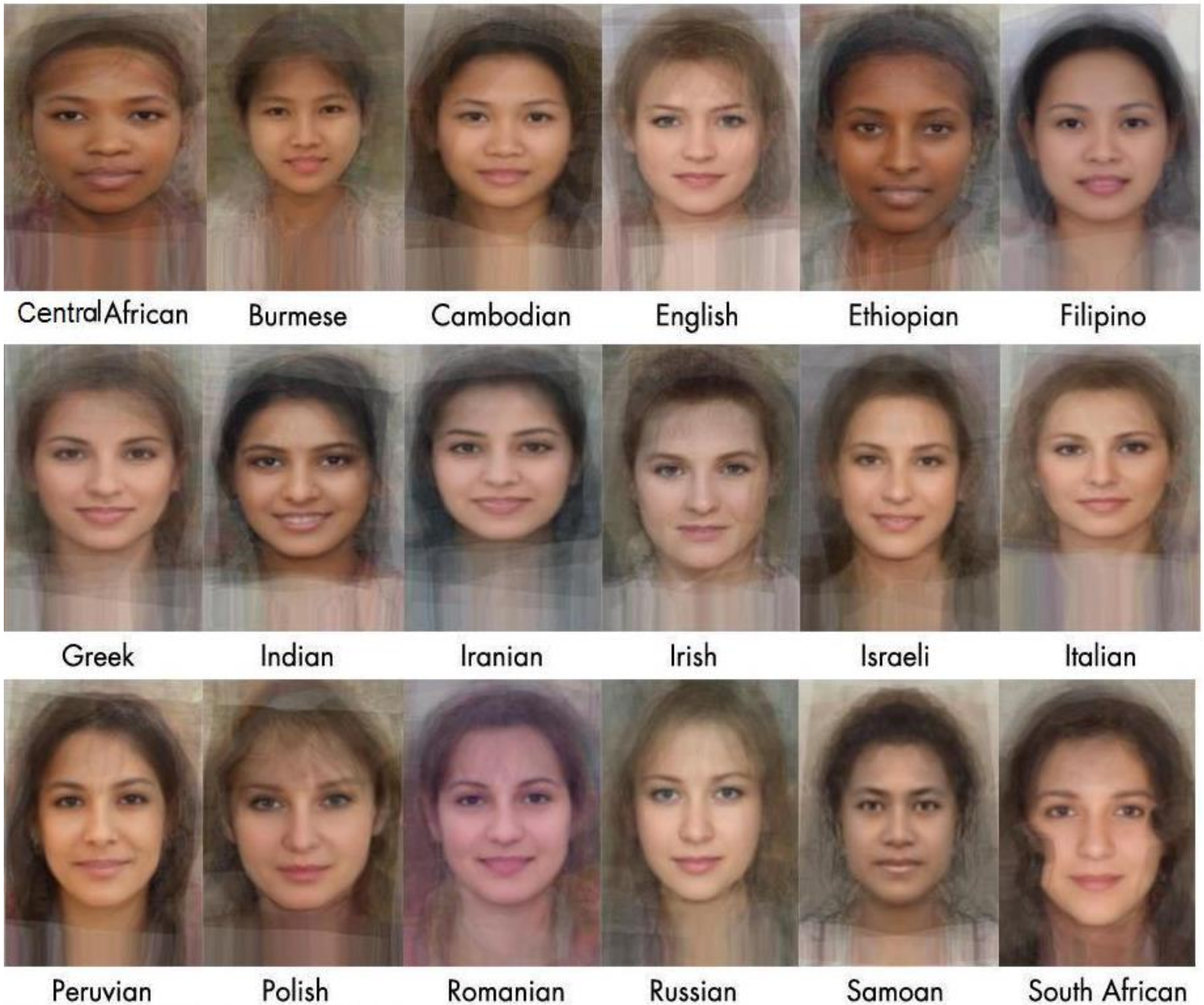
- Requires Annotation
- Provides alignment!

Complements

Average Men of the world



Average Women of the world



Subpopulation means

- Other Examples:
  - Average Kids
  - Happy Males
  - Etc.
  - http://www.faceresearch.org

Average female

Average kid

Average happy male

Average male

Eigen-face

Eigenfaces example

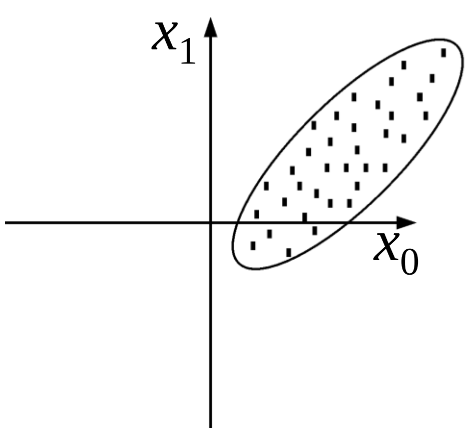
- Training images
- $\mathbf{x}_1, \ldots, \mathbf{x}_N$

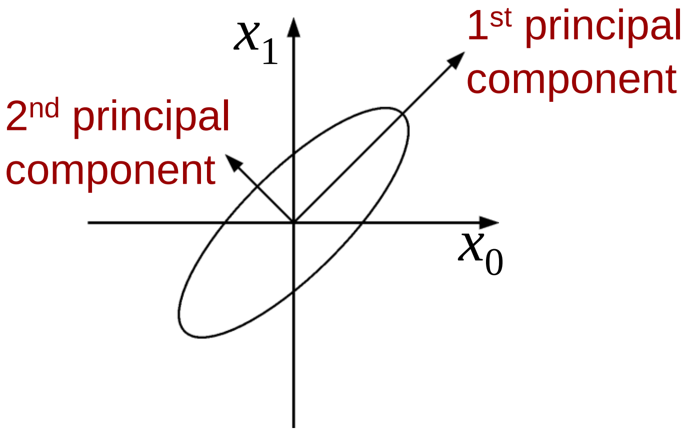
PCA

- General dimensionality reduction technique
- Preserves most of variance with a much more compact representation
  - Lower storage requirements (eigenvectors + a few numbers per face)
  - Faster matching
- What are the problems for face recognition?

Principal Component Analysis

- Given a point set $\{\vec{\mathrm{p}}_j\}_{j=1\ldots P}$, in an M-dim space, PCA finds a basis such that
  - coefficients of the point set in that basis are uncorrelated
  - The most variation is in the first basis vector, then second, …





PCA in MATLAB

- `x=rand(3,10);%10 3D examples`
-
- `M=mean(x,2);`
- `x2=x-repmat(M,[1 n]);`
- `covariance=x2*x2';`
- `[U E] = eig(covariance)`

```
U =
     0.74  0.07  -0.66
     0.65  0.10   0.74
    -0.12  0.99  -0.02
```

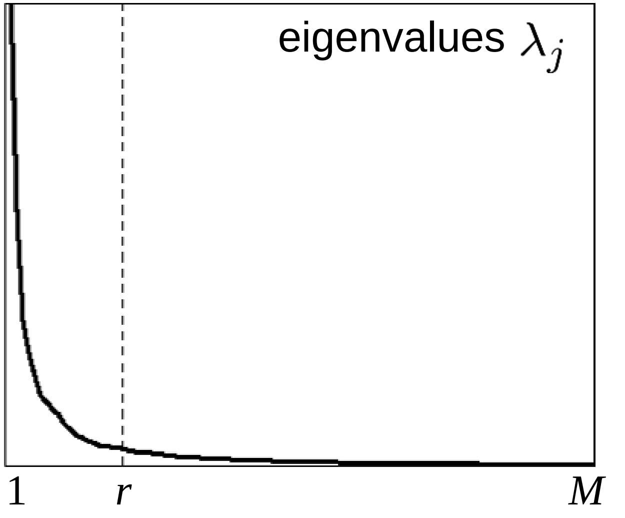
```
E =
     0.27     0       0
     0     0.63       0
     0        0    0.94
```

Principal Component Analysis

- Continued…
  – first $r < M$ basis vectors provide an approximate basis that minimizes the mean-squared-error (MSE) in the approximation (over all bases with dimension r)

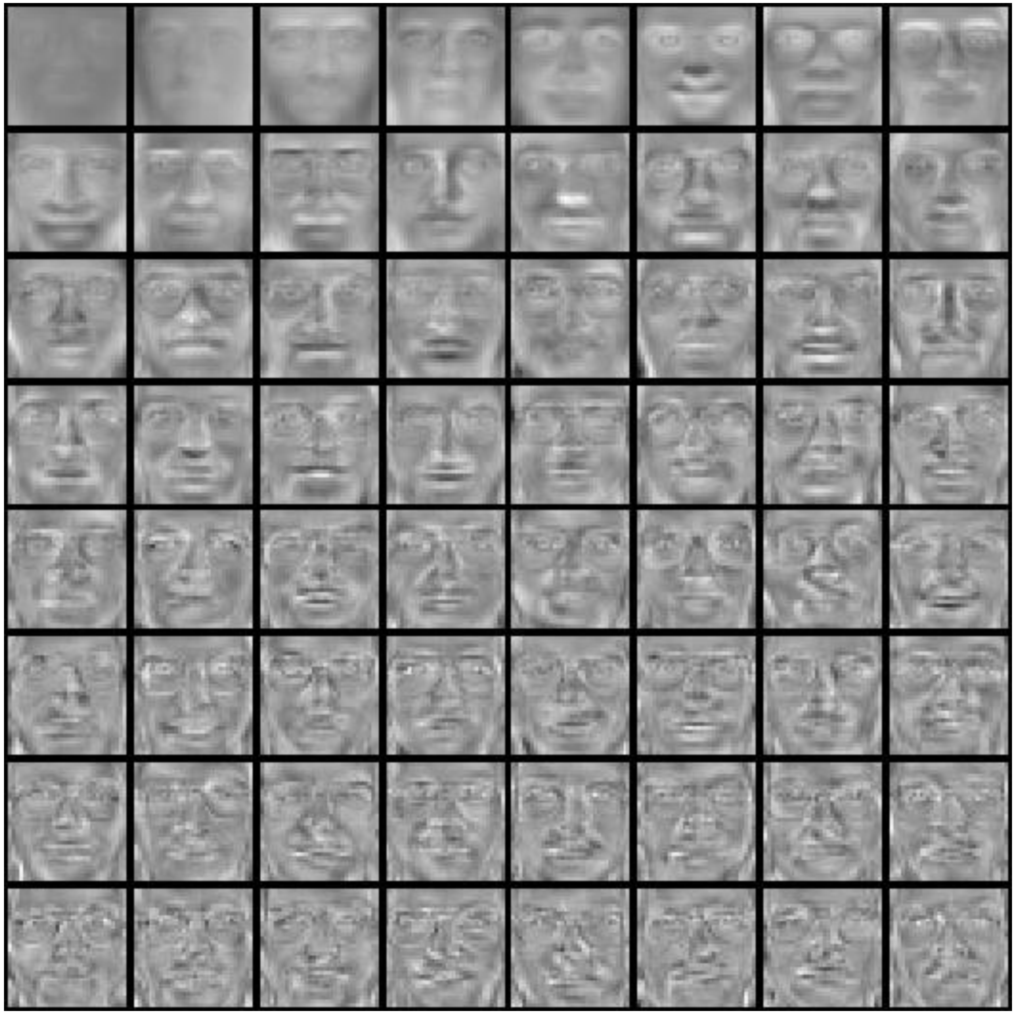
Choosing subspace dimension r:

- look at decay of the eigenvalues as a function of r
- Larger r means lower expected error in the subspace data approximation



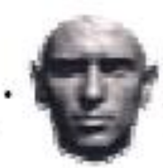
Eigenfaces example

Top eigenvectors: $u_1, \ldots u_k$



Face Space

- How to find a set of directions to cover all space?
- We call these directions **Basis**
- If number of basis faces is large enough to span the face subspace:
- Any new face can be represented as a linear combination of basis vectors.

$s = \alpha_1 \cdot$  $+ \alpha_2 \cdot$  $+ \alpha_3 \cdot$  $+ \alpha_4 \cdot$  $+ \ \ldots \ = \mathbf{S} \cdot \mathbf{a}$

Limitations

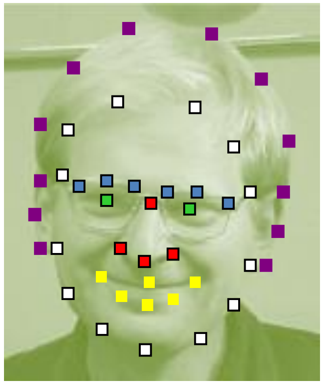
Global appearance method: not robust to misalignment, background variation

Use Shape information

Appearance
Vector

200*150 pixels (RGB)

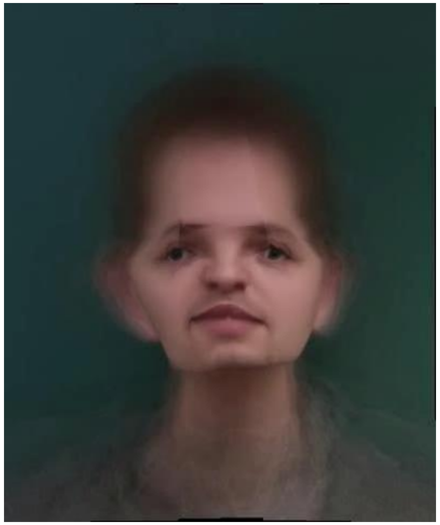
Shape
Vector

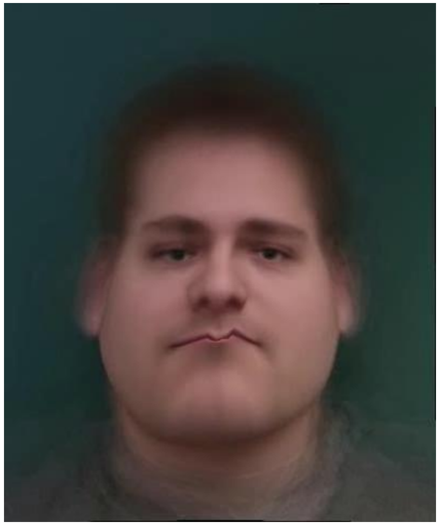


43 coordinates (x,y)

First 3 Shape Basis

Mean appearance

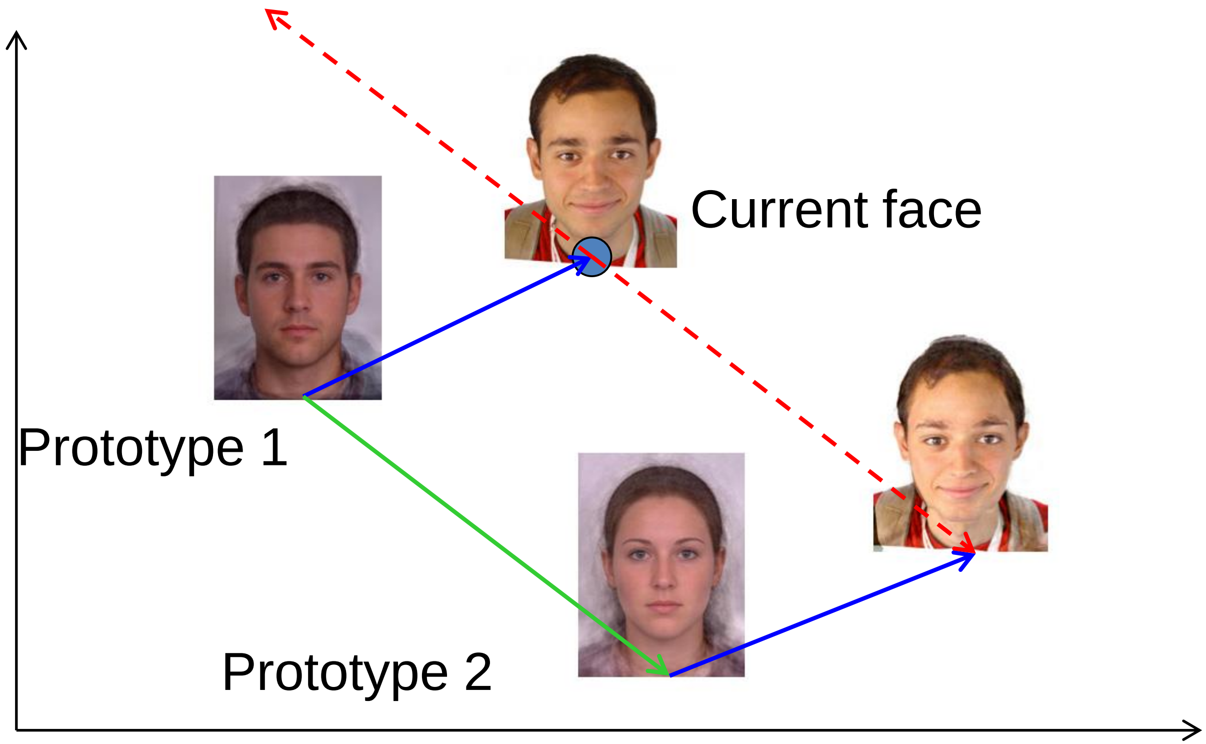




http://graphics.cs.cmu.edu/courses/15-463/2004_fall/www/handins/brh/final/

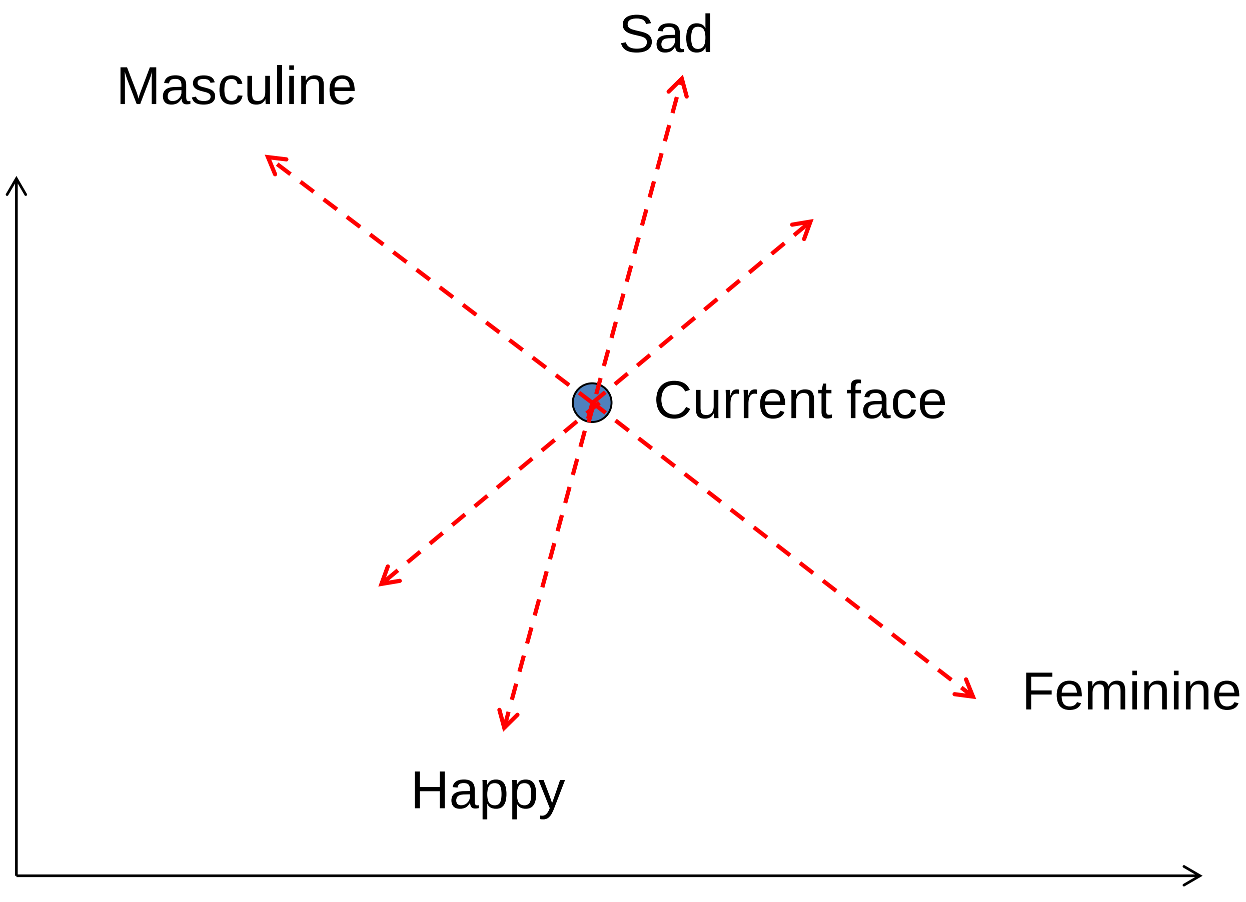
Manipulating faces

- How can we make a face look more female/male, young/old, happy/sad, etc.?
- http://www.faceresearch.org/demos/transform

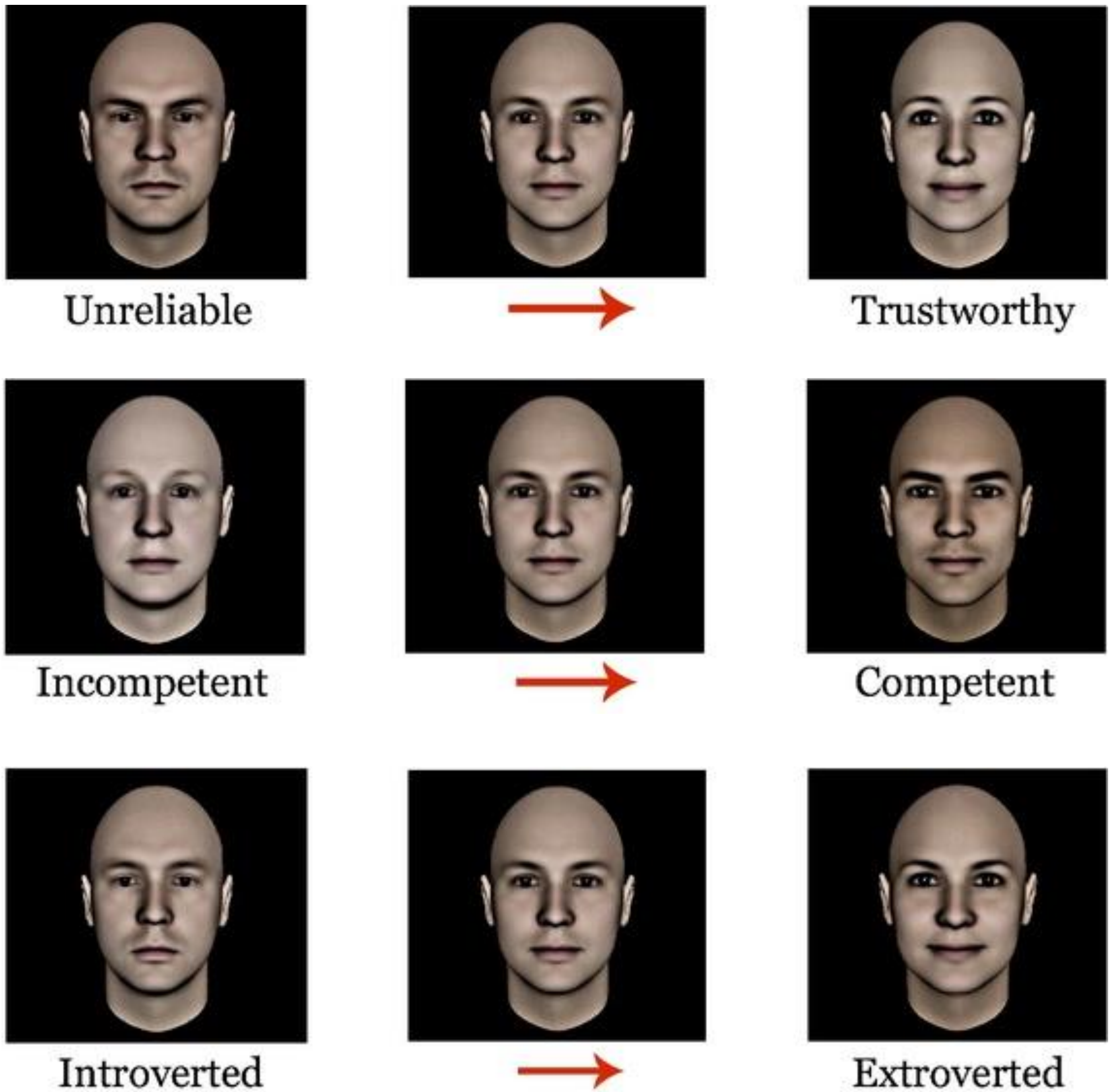


Manipulating faces

- We can imagine various meaningful directions.



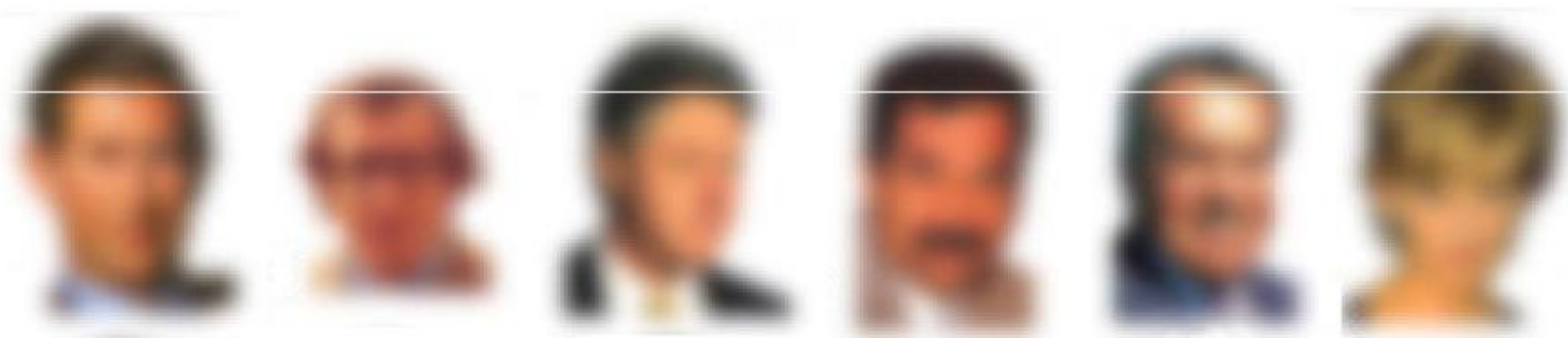
Psychological Attributes



Human Perception

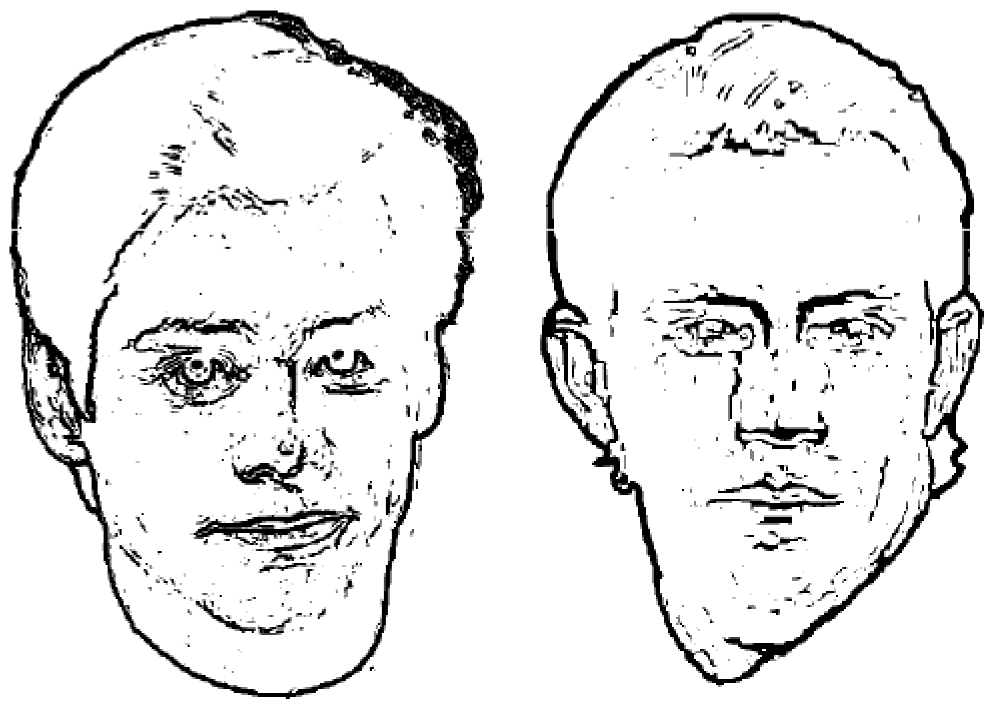
Result 1

- Humans can recognize faces in extremely low resolution images.



Result 3

- High-frequency information by itself does not lead to good face recognition performance



Result 5

- Eyebrows are among the most important for recognition

Result 8

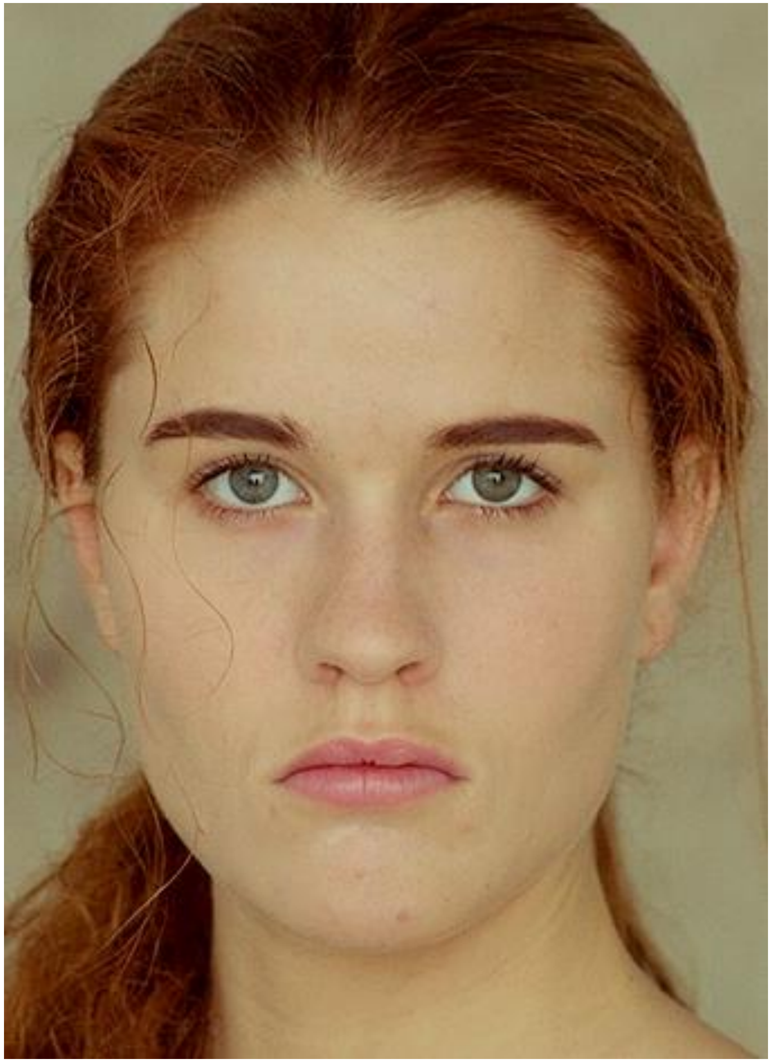
- Vertical inversion dramatically reduces recognition performance

Result 20

- Human memory for briefly seen faces is rather poor

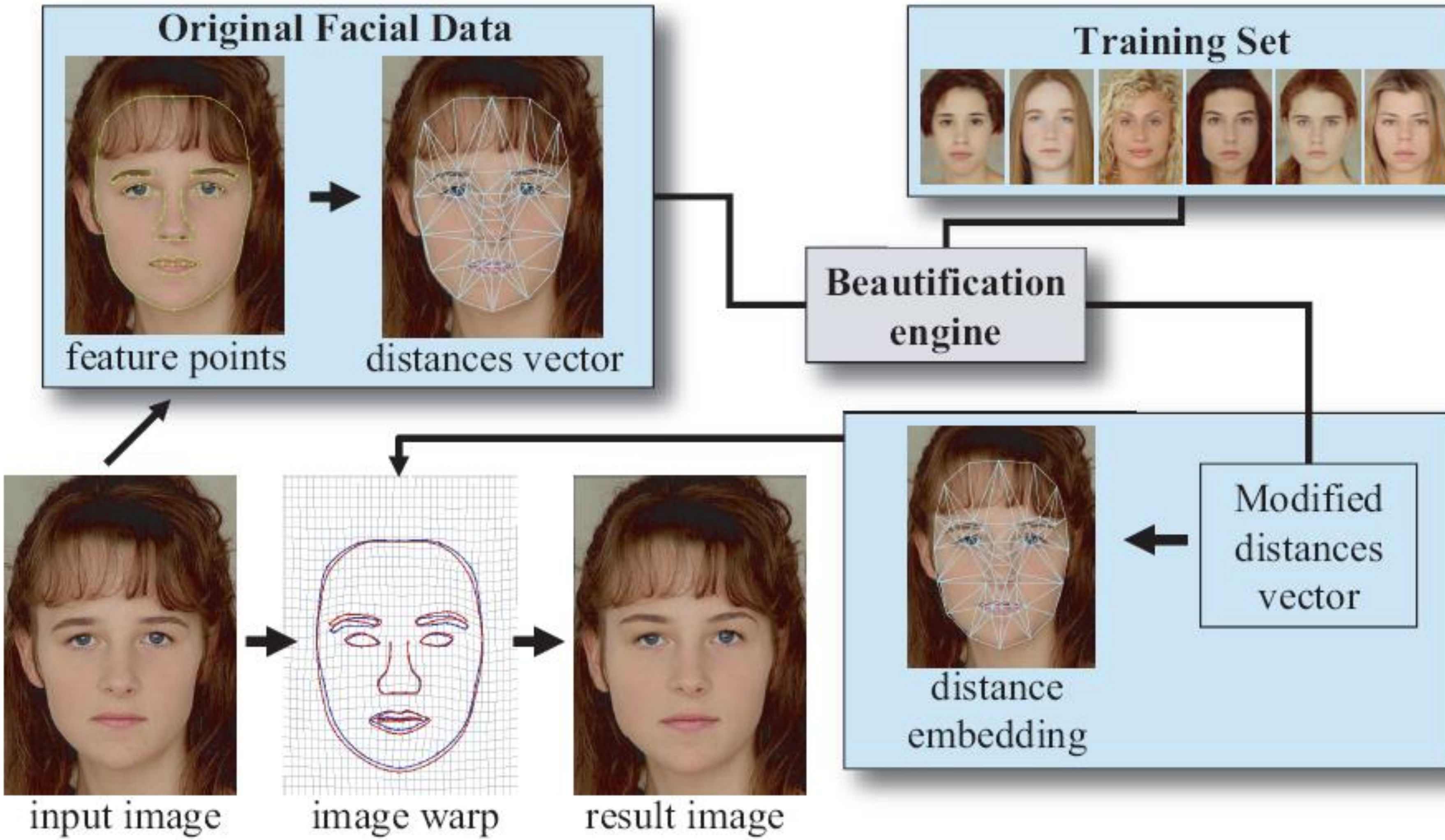
Which face is more attractive?

beautified



original

System Overview



Things to remember

- Face Detection
- Face Recognition
- Appearance Vector
- Shape Vector
- Face Transformation
- Principal Component Analysis