Data-driven Methods: Faces

Portrait of
Piotr Gibas
© Joaquin
Rosales
Gomez (2003)

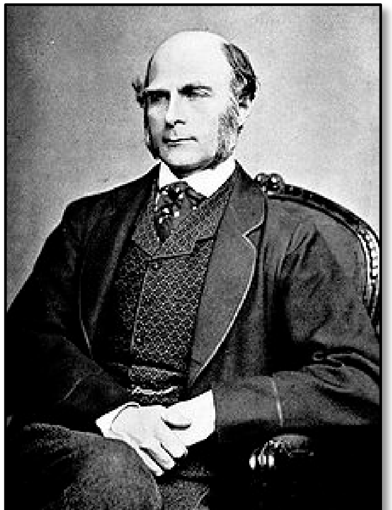
CS194: Image Manipulation & Computational Photography
Alexei Efros, UC Berkeley, Fall 2014

The Power of Averaging

8-hour exposure

© Atta Kim

Image Composites



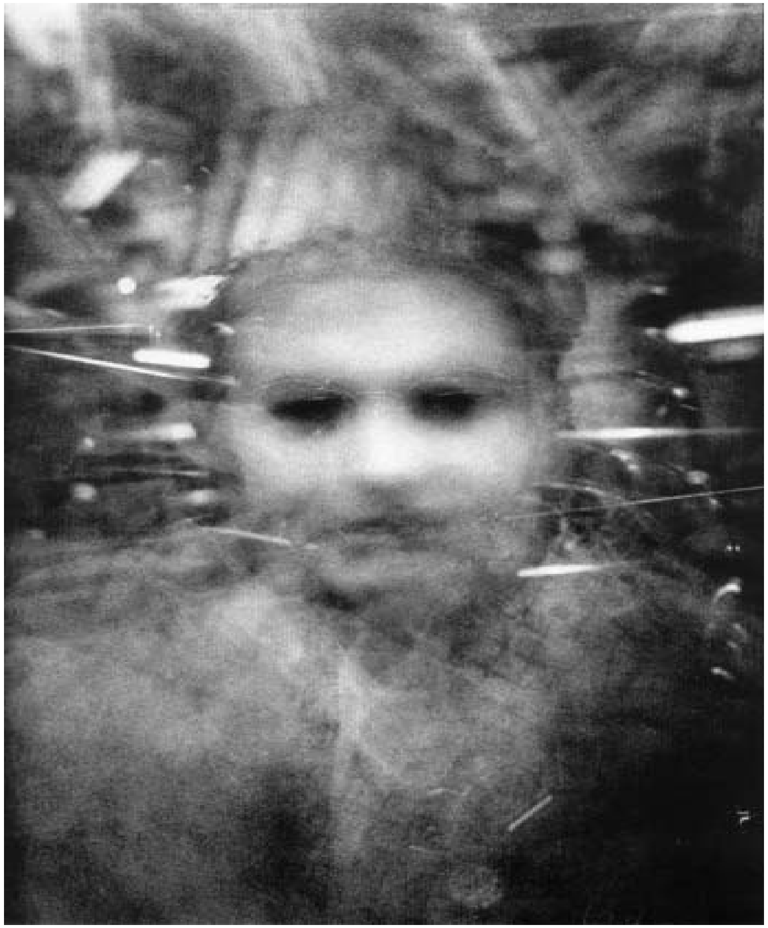
Sir Francis
Galton
1822-1911

Multiple Individuals

Composite

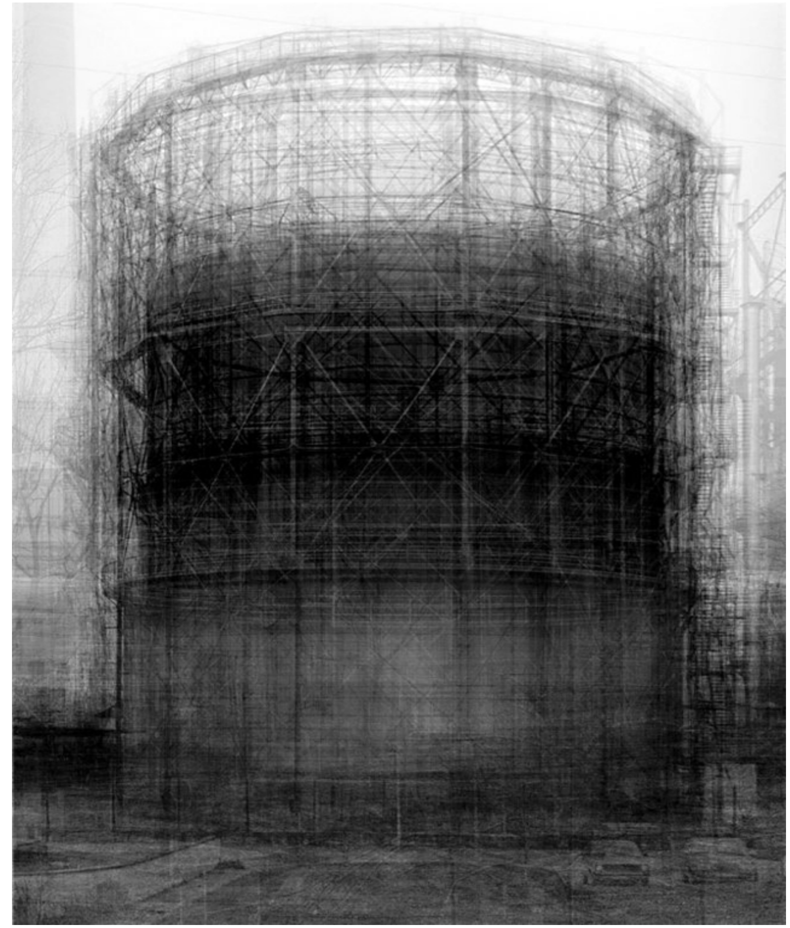
[Galton, “Composite Portraits”, Nature, 1878]

Average Images in Art



“60 passagers de 2e classe du metro, entre 9h et 11h” (1985)

Krzysztof Pruszkowski



“Spherical type gasholders” (2004)

Idris Khan

More by Jason Salavon

More at: http://www.salavon.com/

“100 Special Moments” by Jason Salavon

Little Leaguer

Kids with Santa

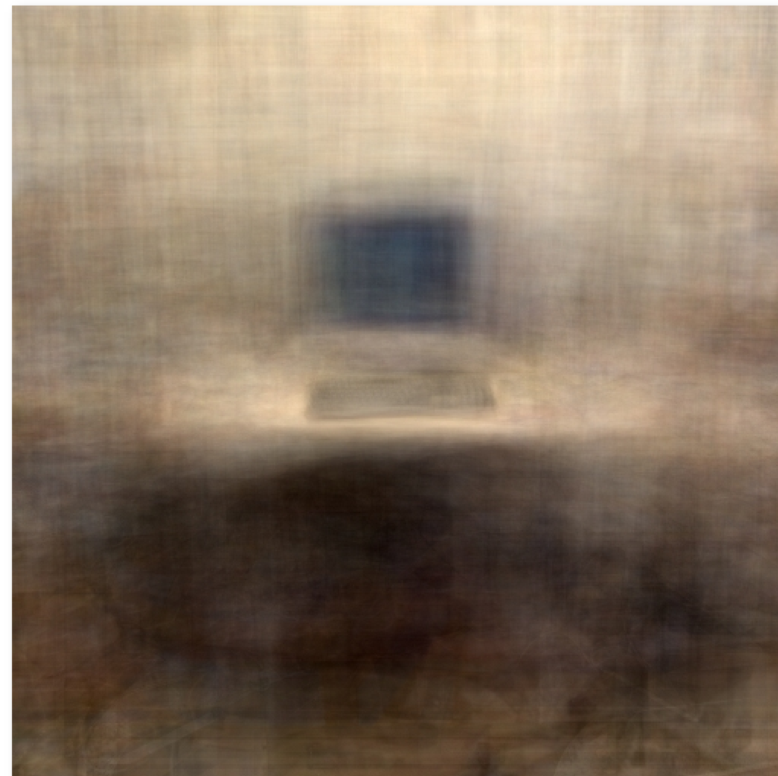
The Graduate

Newlyweds

Why blurry?

Object-Centric Averages by Torralba (2001)

Manual Annotation and Alignment



Average Image

Slide by Jun-Yan Zhu

Computing Means

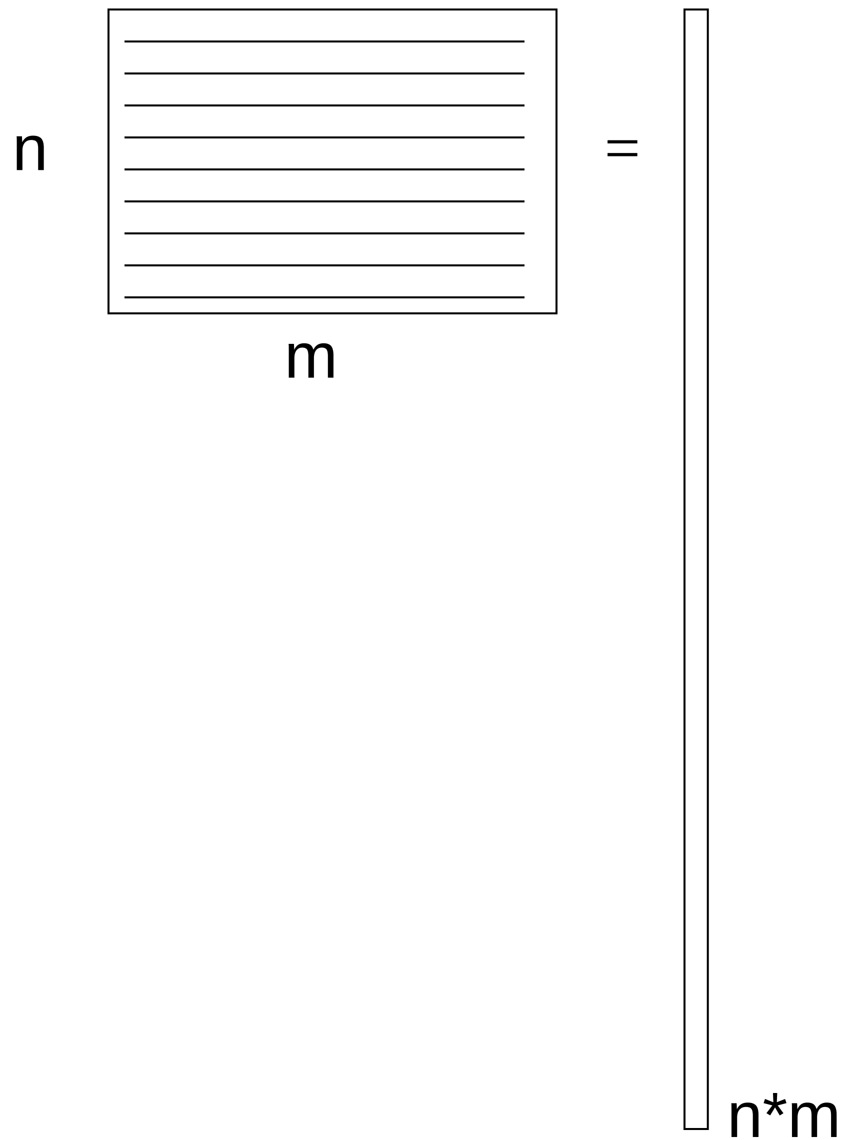
Two Requirements:

- Alignment of objects
- Objects must span a subspace

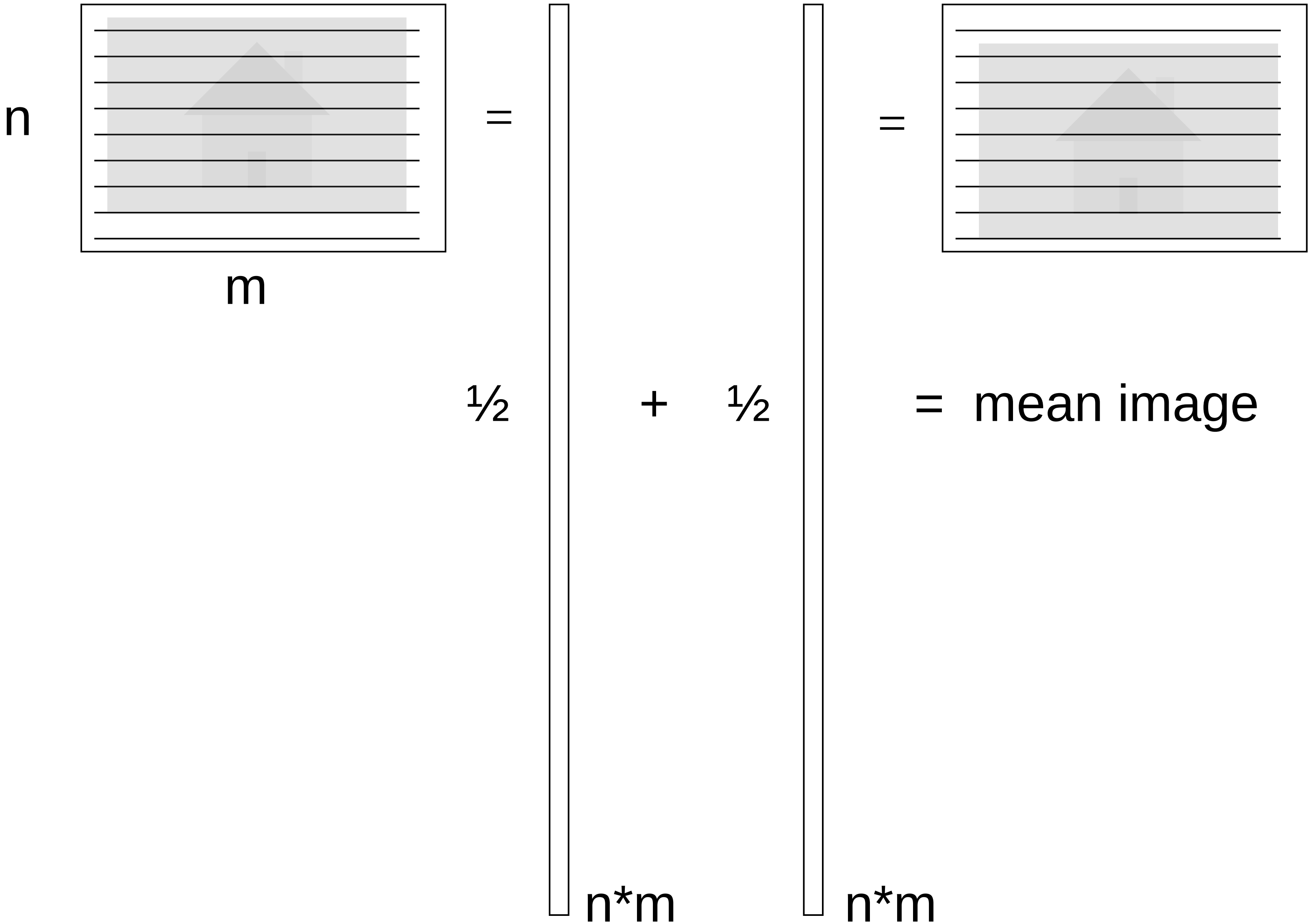
Useful concepts:

- Subpopulation means
- Deviations from the mean

Images as Vectors



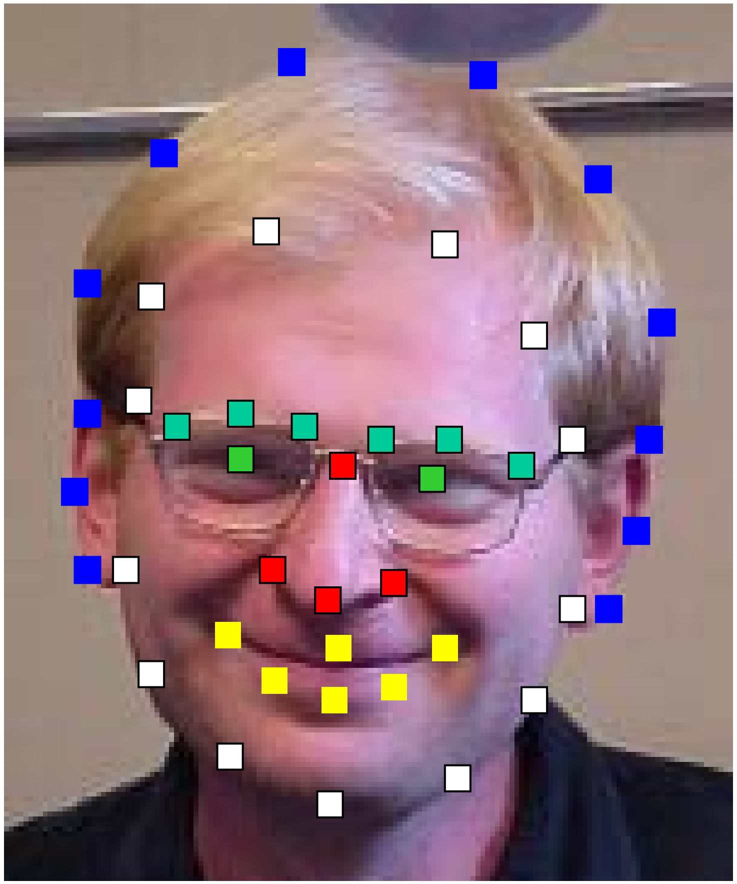
Vector Mean: Importance of Alignment



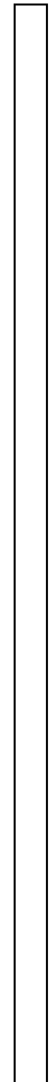
How to align faces?

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

Shape Vector



=



43

Provides alignment!

Average Face

1. Warp to mean shape
2. Average pixels

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

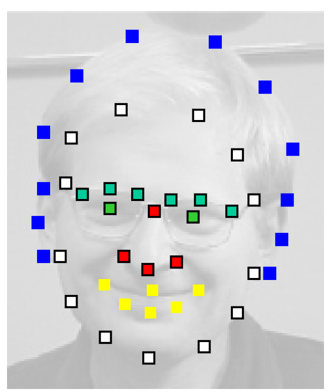
Appearance Vectors vs. Shape Vectors

Appearance Vector

200*150 pixels (RGB)

Vector of 200*150*3 Dimensions

Shape Vector



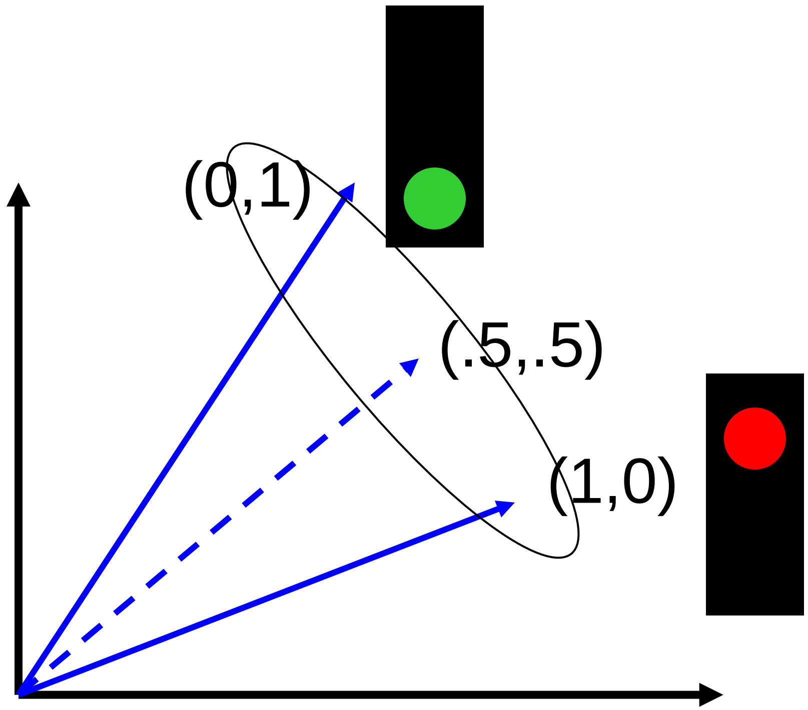
43 coordinates (x,y)

Vector of 43*2 Dimensions

- Requires Annotation
- Provides alignment!

Slide by Kevin Karsch

Objects must span a subspace



Example

mean

Does not span a subspace

Subpopulation means

Examples:

- Male vs. female
- Happy vs. said
- Average Kids
- Happy Males
- Etc.
- http://www.faceresearch.org

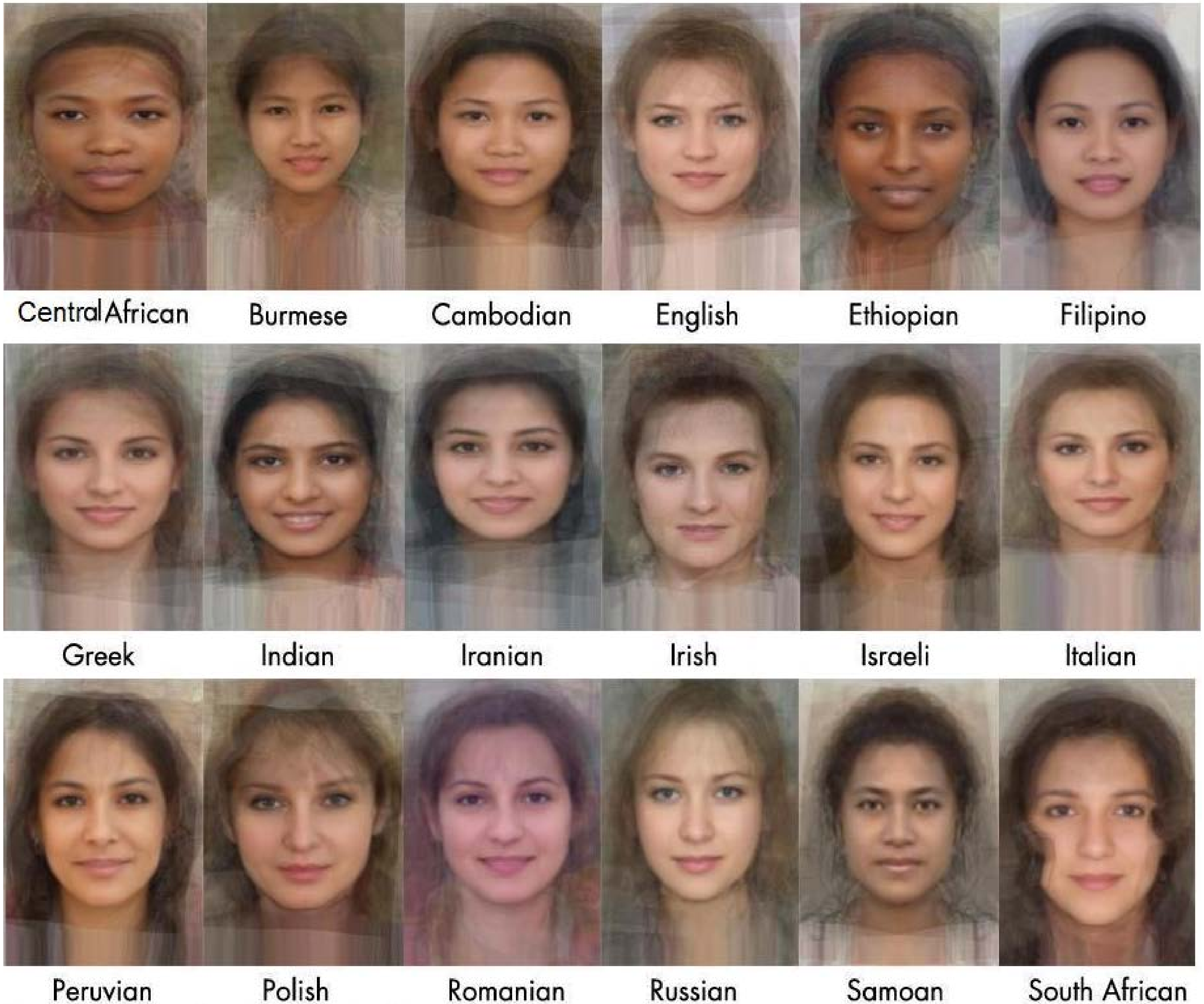
Average female

Average kid

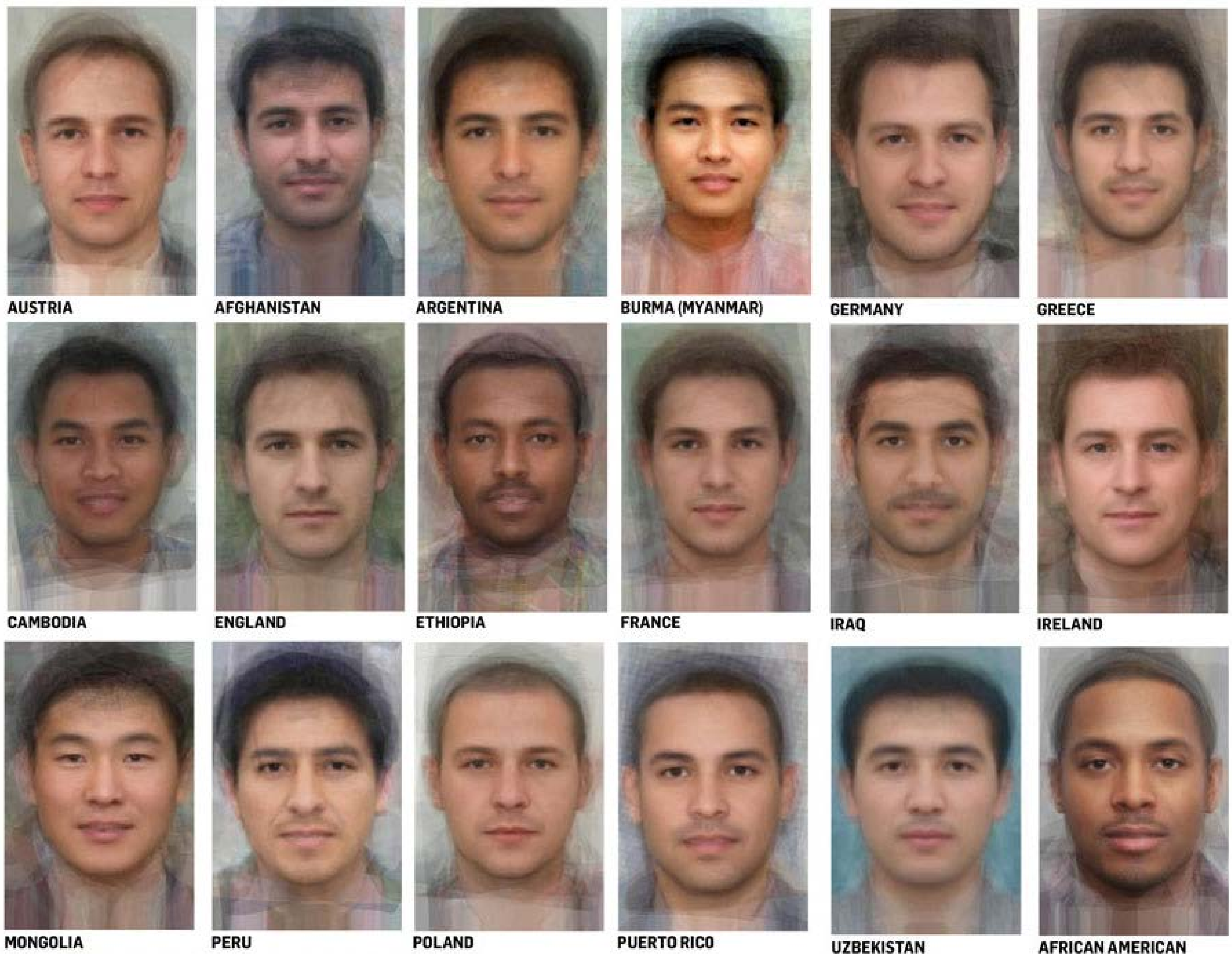
Average happy male

Average male

Average Women of the world



Average Men of the world



Deviations from the mean

Image X

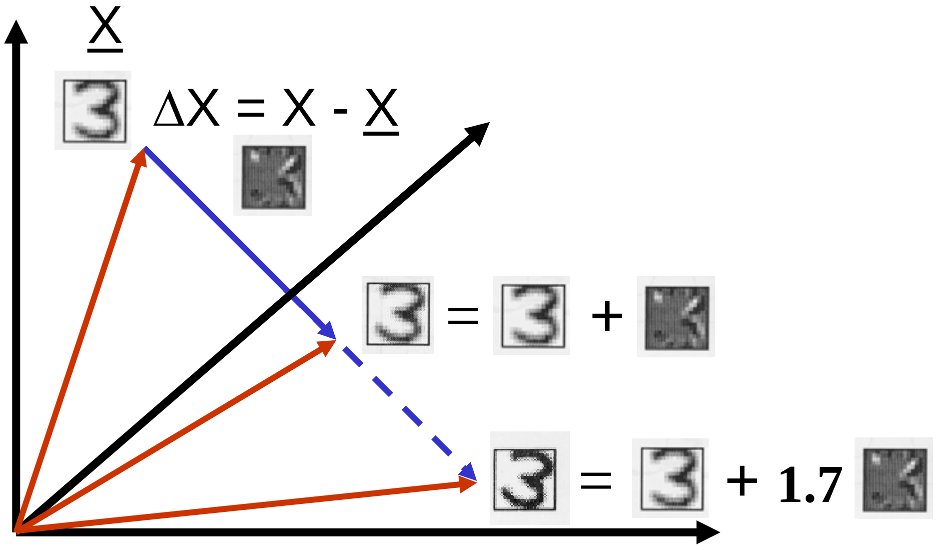
-

Mean $\underline{X}$

=

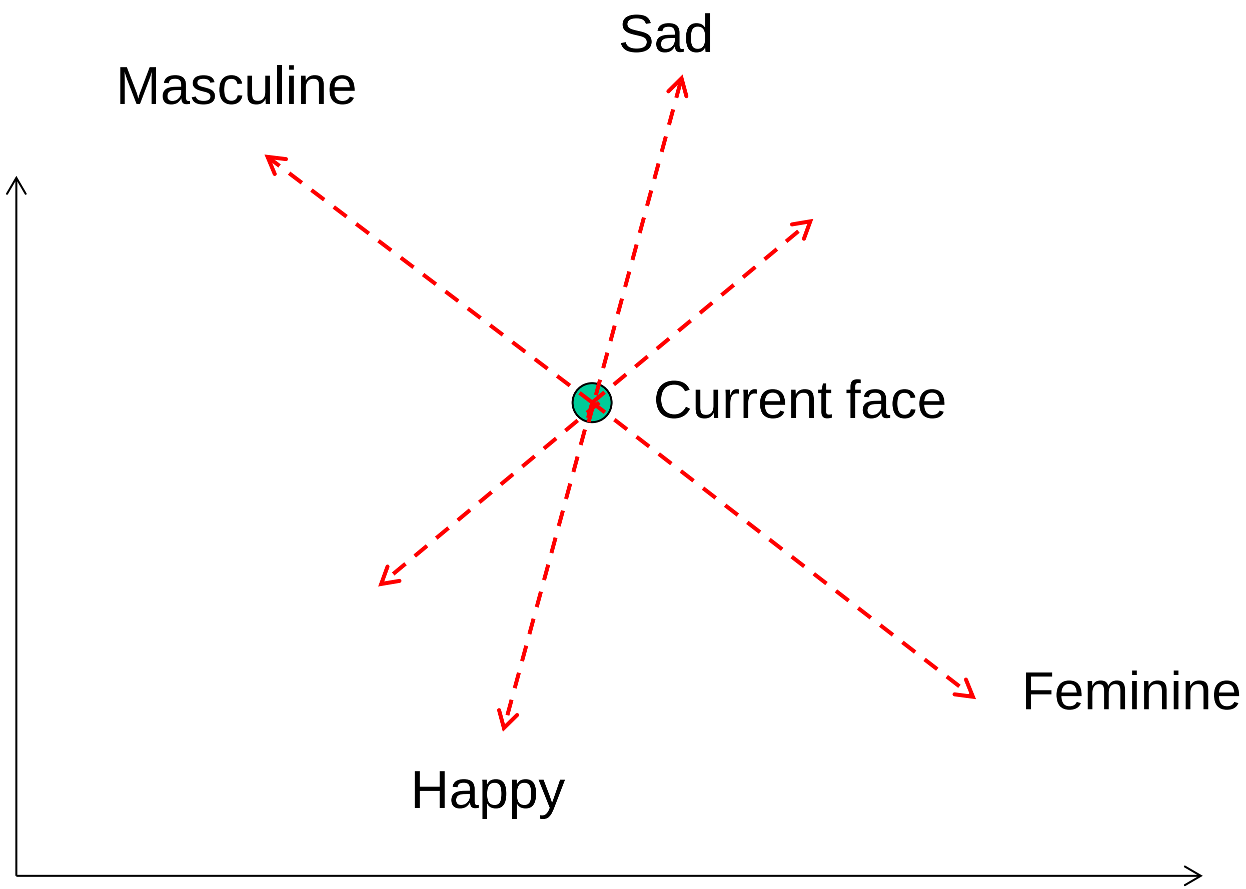
$\Delta X = X - \underline{X}$

Deviations from the mean



Extrapolating faces

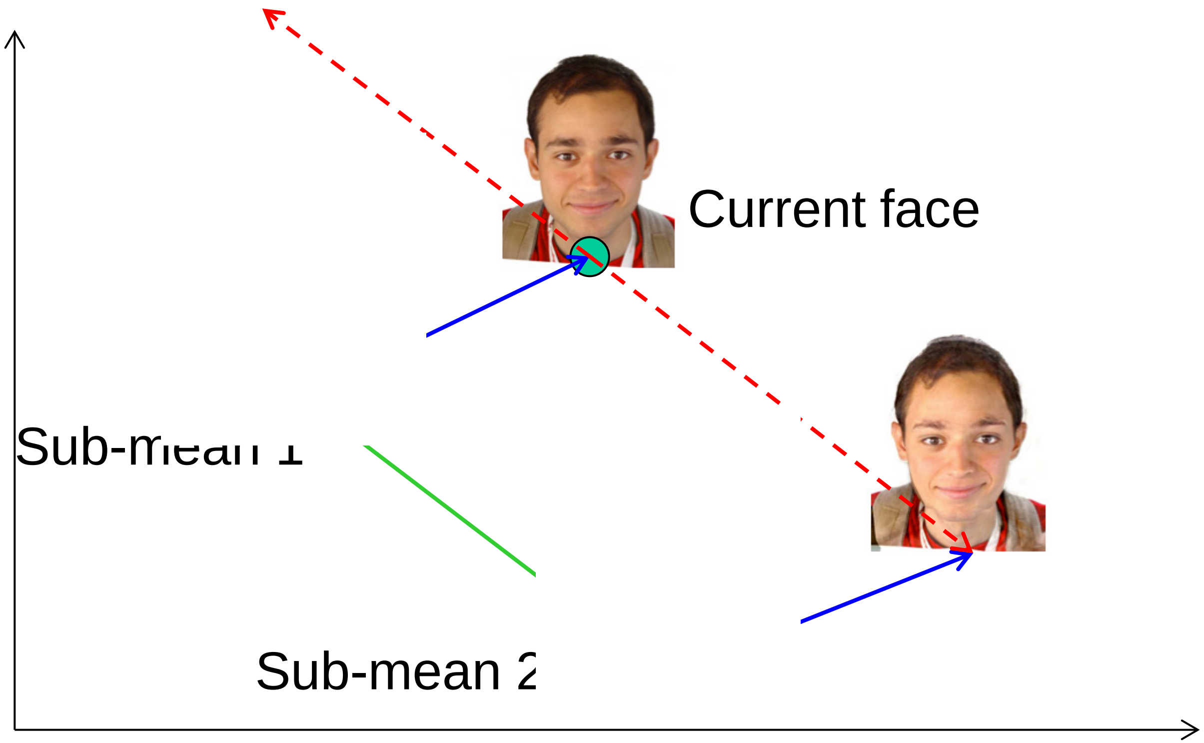
- We can imagine various meaningful <u>directions</u>.



Slide by Kevin Karsch

Manipulating faces

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



Slide by Kevin Karsch

Manipulating Facial Appearance through Shape and Color

Duncan A. Rowland and David I. Perrett

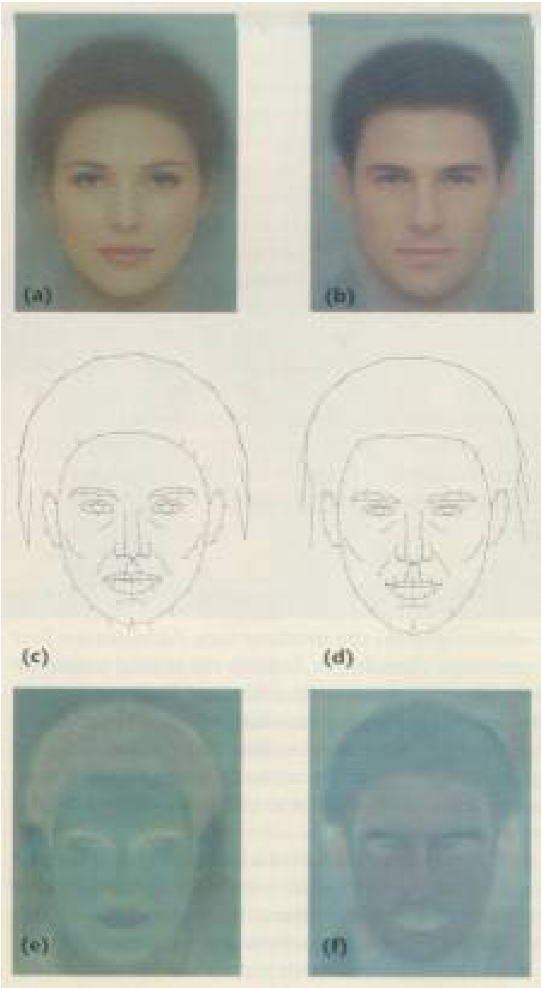
St Andrews University

IEEE CG&A, September 1995

Face Modeling

Compute *average* faces (color and shape)

Compute *deviations* between male and female (vector and color differences)

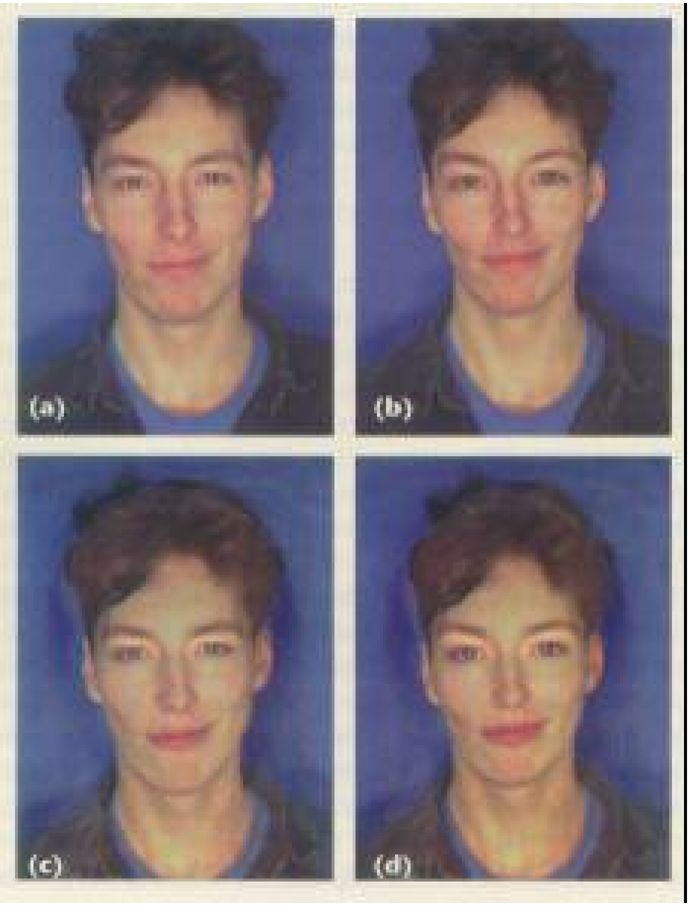


Changing gender

Deform shape and/or color of an input face in the direction of “more female”

original

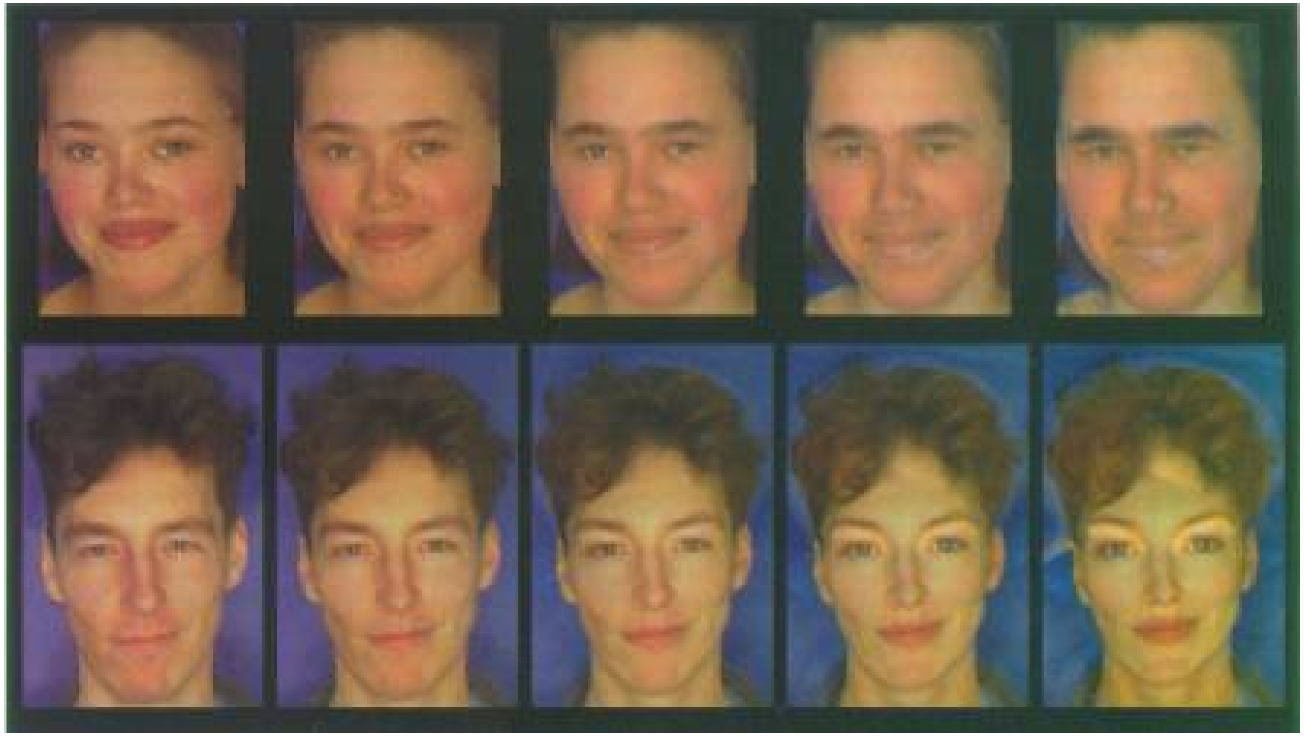
shape



color

both

Enhancing gender



more same **original** androgynous more opposite

Changing age

Face becomes “rounder” and “more textured” and “grayer”

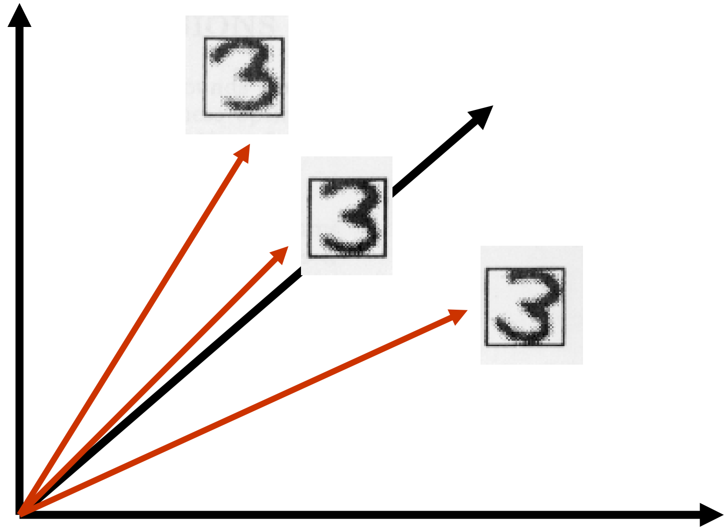
original

shape

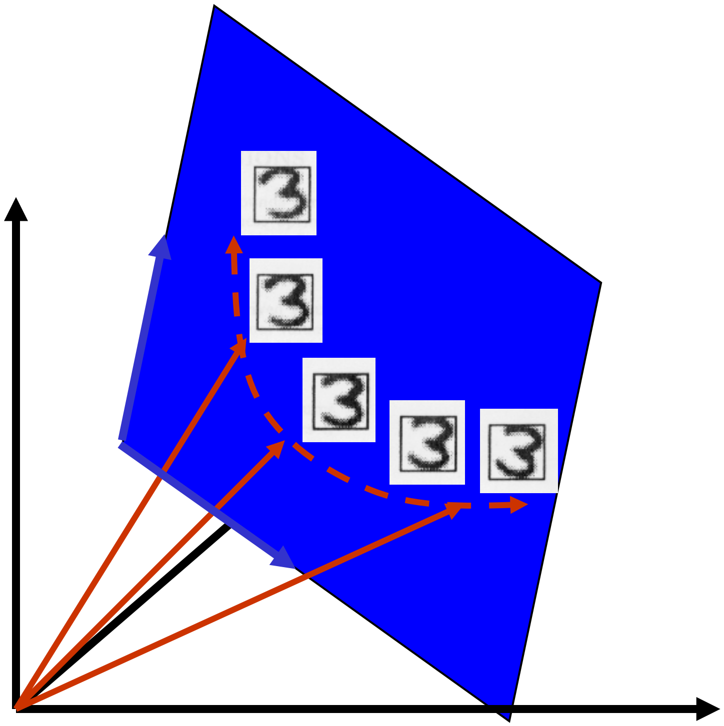
color

both

Back to the Subspace



Linear Subspace: convex combinations



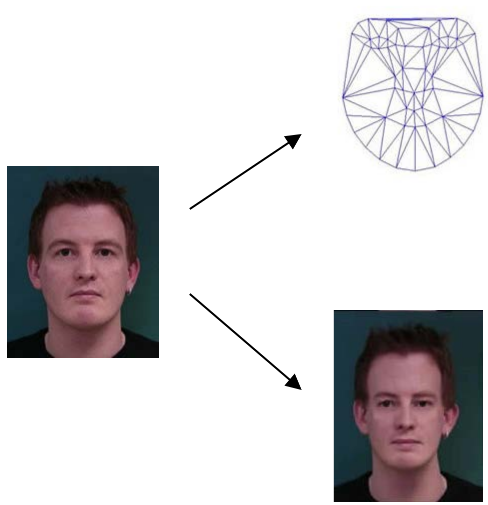
Any new image X can be obtained as weighted sum of stored "basis" images.

$$X = \sum_{i=1}^{m} a_i X_i$$

Our old friend, change of basis! What are the new coordinates of X?

The Morphable Face Model

The actual structure of a face is captured in the shape vector **S** = $(x_1, y_1, x_2, \ldots, y_n)^T$, containing the (x, y) coordinates of the n vertices of a face, and the appearance (texture) vector **T** = $(R_1, G_1, B_1, R_2, \ldots, G_n, B_n)^T$, containing the color values of the mean-warped face image.



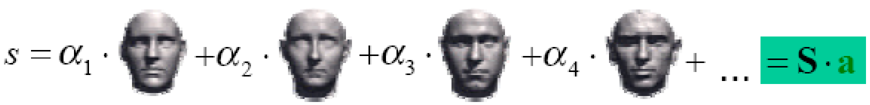
Shape S

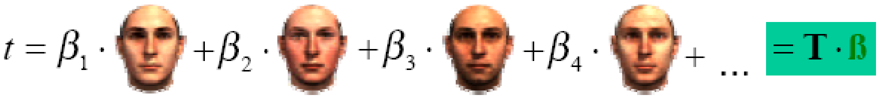
Appearance T

The Morphable face model

Again, assuming that we have ***m*** such vector pairs in full correspondence, we can form new shapes $\mathbf{S}_{model}$ and new appearances $\mathbf{T}_{model}$ as:

$$\mathbf{S}_{model} = \sum_{i=1}^{m} a_i \mathbf{S}_i \qquad \mathbf{T}_{model} = \sum_{i=1}^{m} b_i \mathbf{T}_i$$





If number of basis faces ***m*** is large enough to span the face subspace then:

<u>Any new</u> face can be represented as a pair of vectors

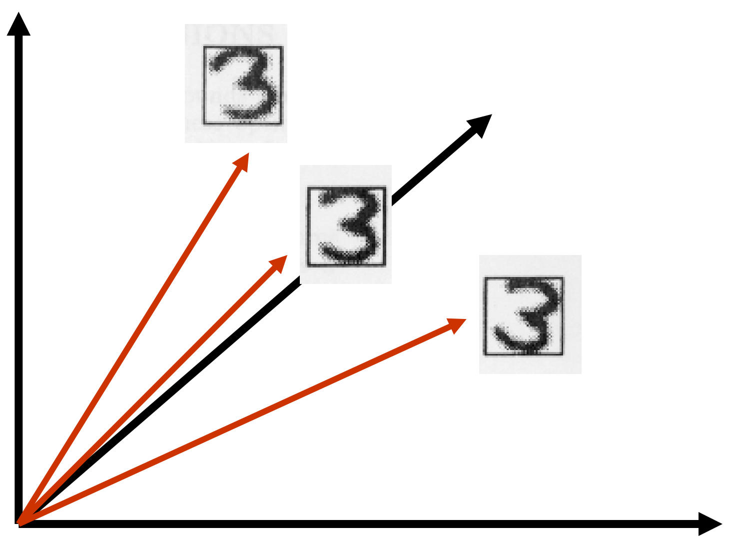
$(\alpha_1, \alpha_2, \ldots, \alpha_m)^T$ and $(\beta_1, \beta_2, \ldots, \beta_m)^T$!

Issues:

1. How many basis images is enough?
2. Which ones should they be?
3. What if some variations are more important than others?
   - E.g. corners of mouth carry much more information than haircut

Need a way to obtain basis images automatically, in order of importance!

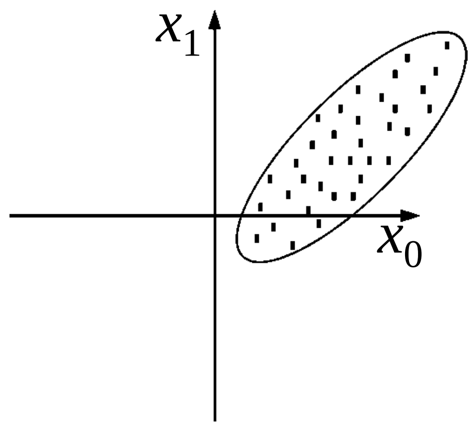
But what's important?

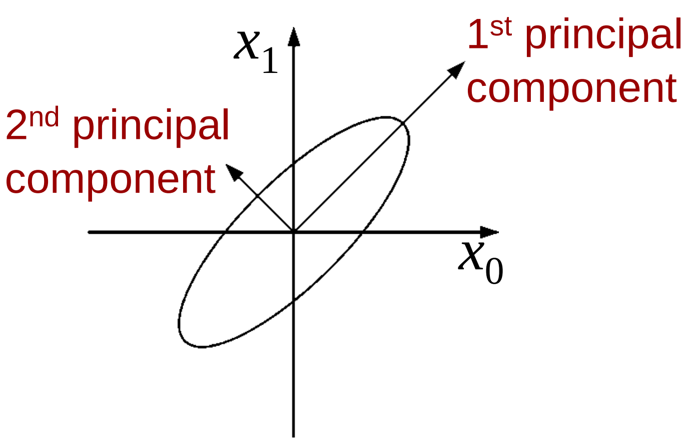


Principal Component Analysis

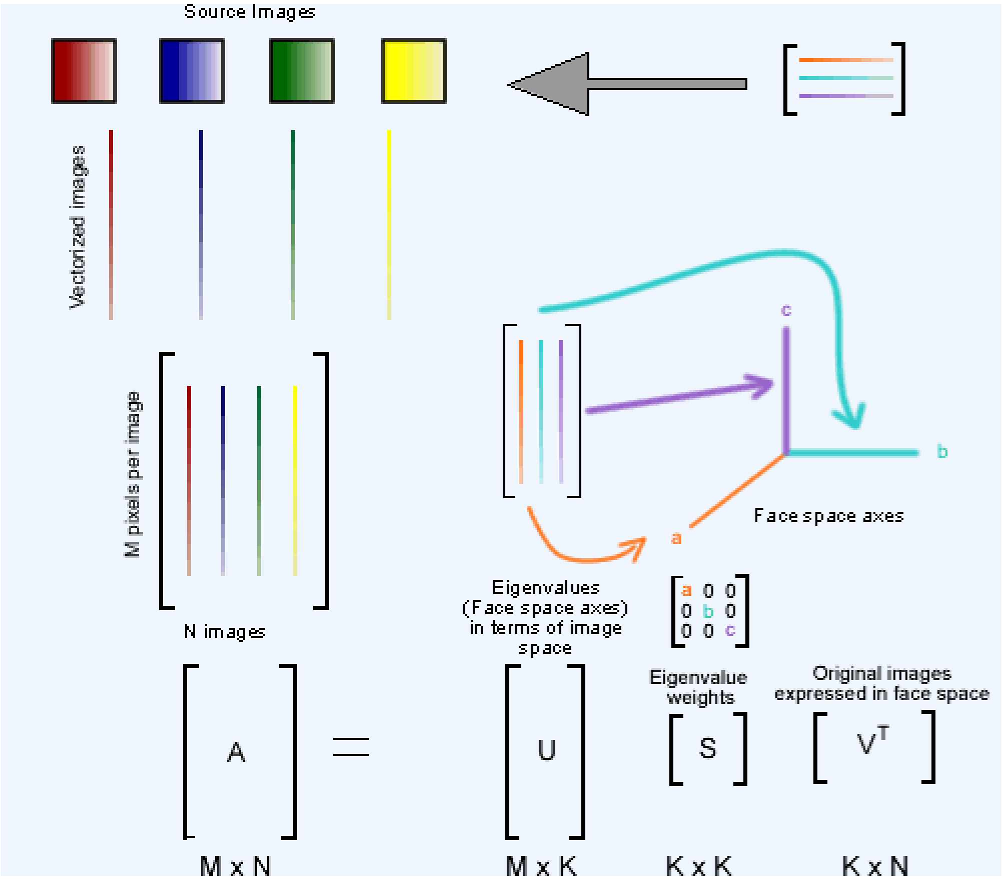
Given a point set $\{\vec{\mathrm{p}}_j\}_{j=1...P}$, in an M-dim space, PCA finds a basis such that

- coefficients of the point set in that basis are uncorrelated
- 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)





PCA via Singular Value Decomposition



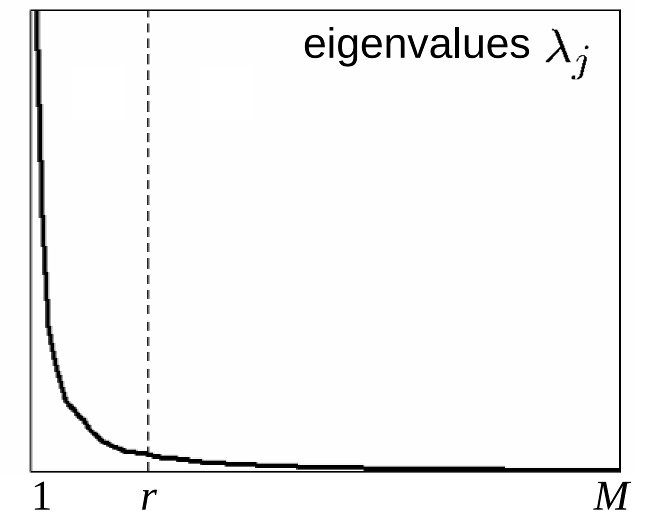
[u,s,v] = svd(A);

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

Principal Component Analysis

Choosing subspace dimension r:

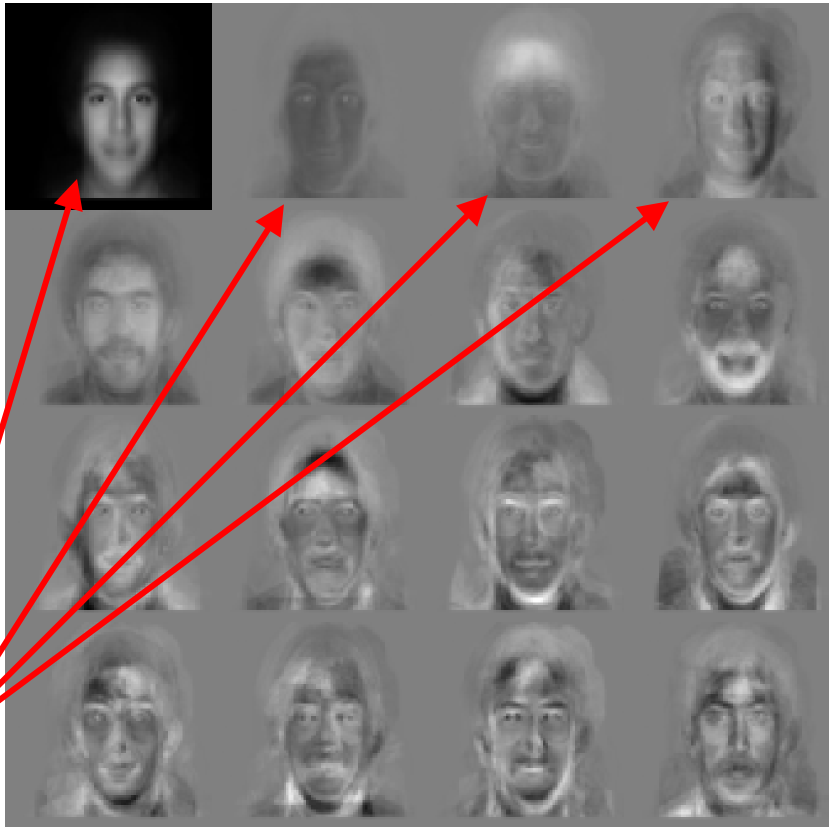
- look at decay of the eigenvalues as a function of r
- Larger r means lower expected error in the subspace data approximation



EigenFaces

First popular use of PCA on images was for modeling and recognition of faces *[Kirby and Sirovich, 1990, Turk and Pentland, 1991]*

- Collect a face ensemble
- Normalize for contrast, scale, & orientation.
- Remove backgrounds
- Apply PCA & choose the first N eigen-images that account for most of the variance of the data.

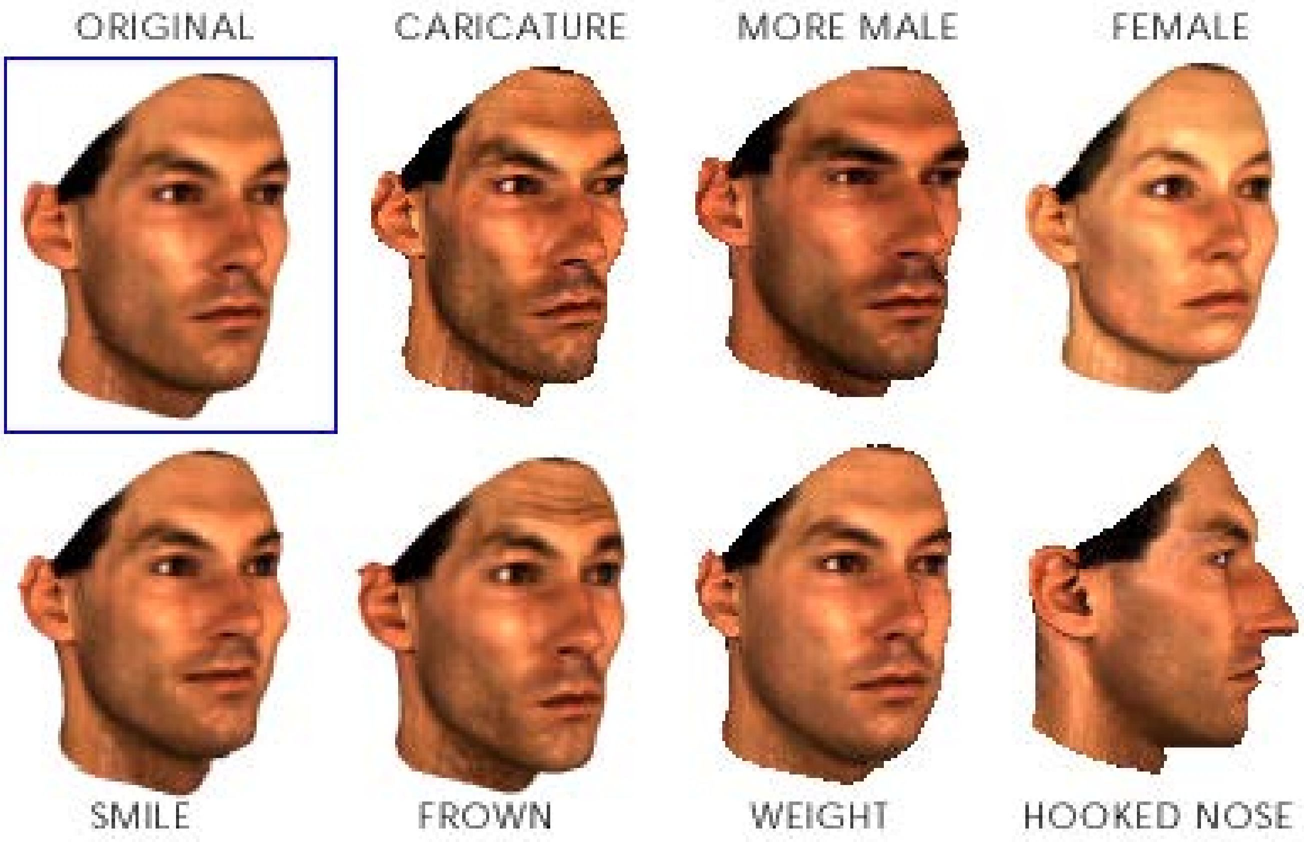


First 3 Shape Basis

Mean appearance

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

Using 3D Geometry: Blinz & Vetter, 1999



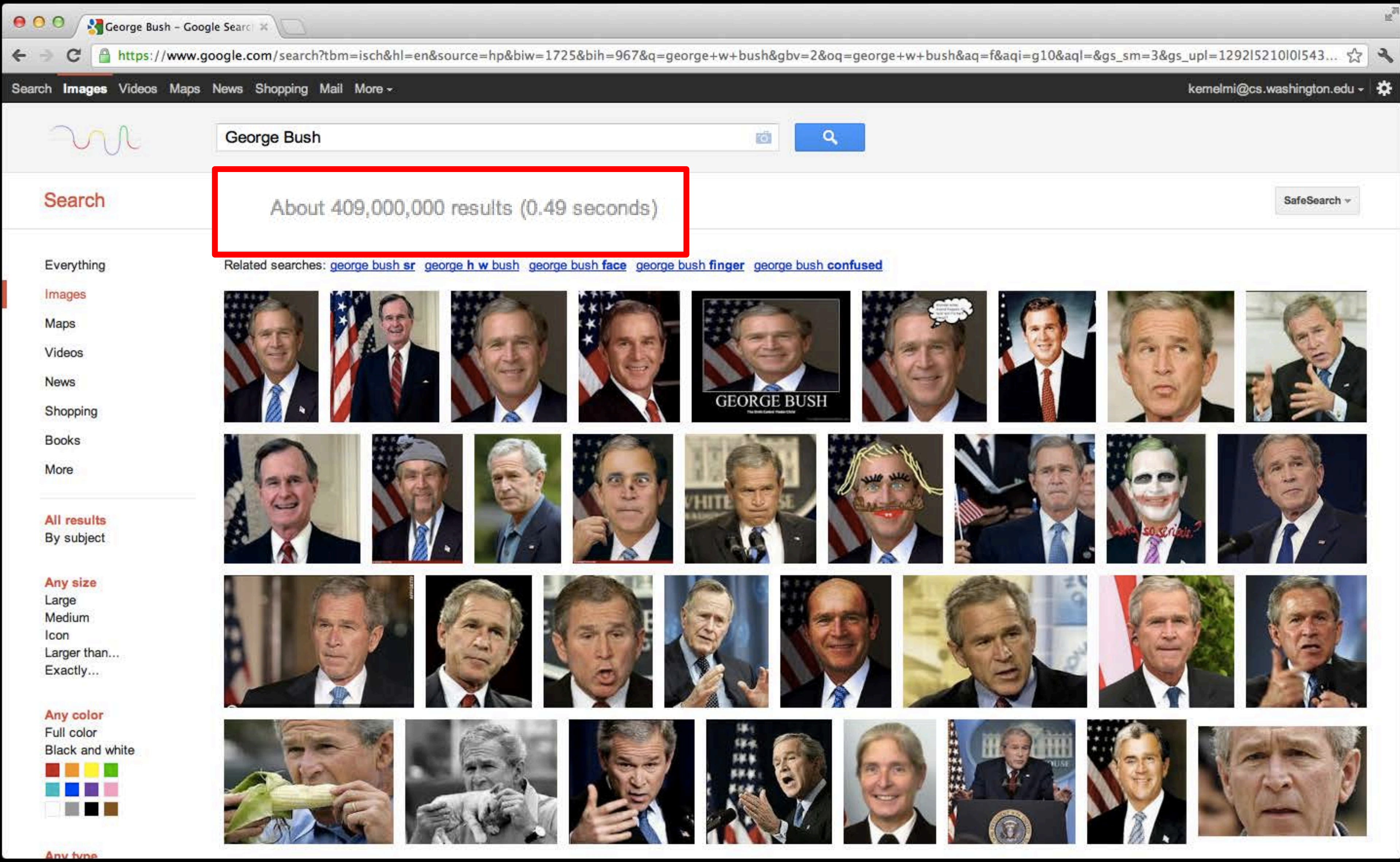
http://www.youtube.com/watch?v=jrutZaYoQJo

Walking in the Face-graph!

Ira Kemelmacher-Shlizerman, Eli Shechtman, Rahul Garg, Steven M. Seitz. "Exploring Photobios." ACM Transactions on Graphics 30(4) (SIGGRAPH), Aug 2011.

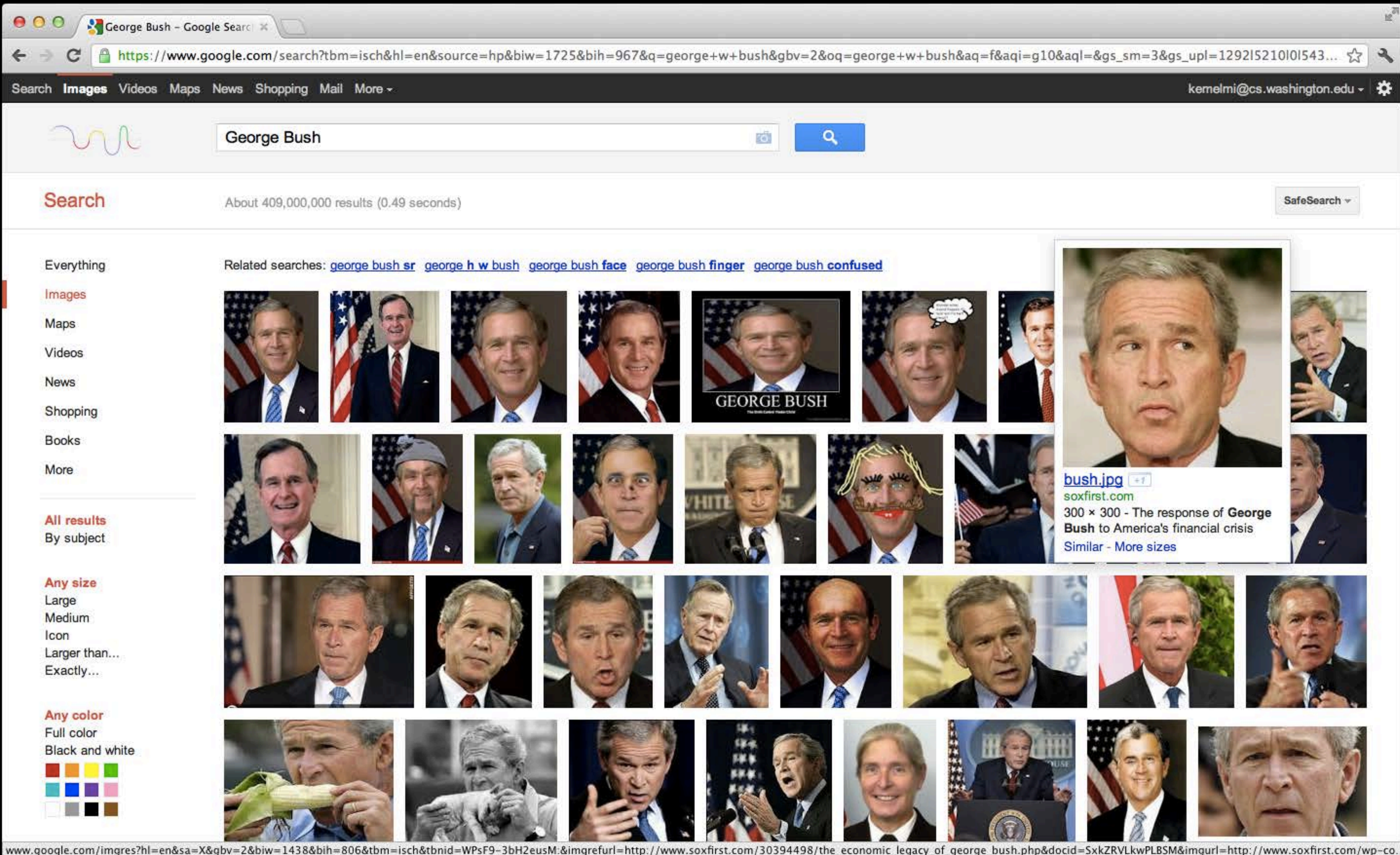
http://vimeo.com/23561002

Photobio



George Bush - Google Searc
https://www.google.com/search?tbm=isch&hl=en&source=hp&biw=1725&bih=967&q=george+w+bush&gbv=2&oq=george+w+bush&aq=f&aqi=g10&aql=&gs_sm=3&gs_upl=1292l5210l0l543...
Search Images Videos Maps News Shopping Mail More
kemelmi@cs.washington.edu
George Bush
Search
About 409,000,000 results (0.49 seconds)
SafeSearch
Everything
Images
Maps
Videos
News
Shopping
Books
More
All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
Full color
Black and white
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
GEORGE BUSH

Photobio



George Bush - Google Searc
https://www.google.com/search?tbm=isch&hl=en&source=hp&biw=1725&bih=967&q=george+w+bush&gbv=2&oq=george+w+bush&aq=f&aqi=g10&aql=&gs_sm=3&gs_upl=1292l5210l0l543...
Search Images Videos Maps News Shopping Mail More
kemelmi@cs.washington.edu
George Bush
Search
About 409,000,000 results (0.49 seconds)
SafeSearch
Everything
Images
Maps
Videos
News
Shopping
Books
More
All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
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GEORGE BUSH
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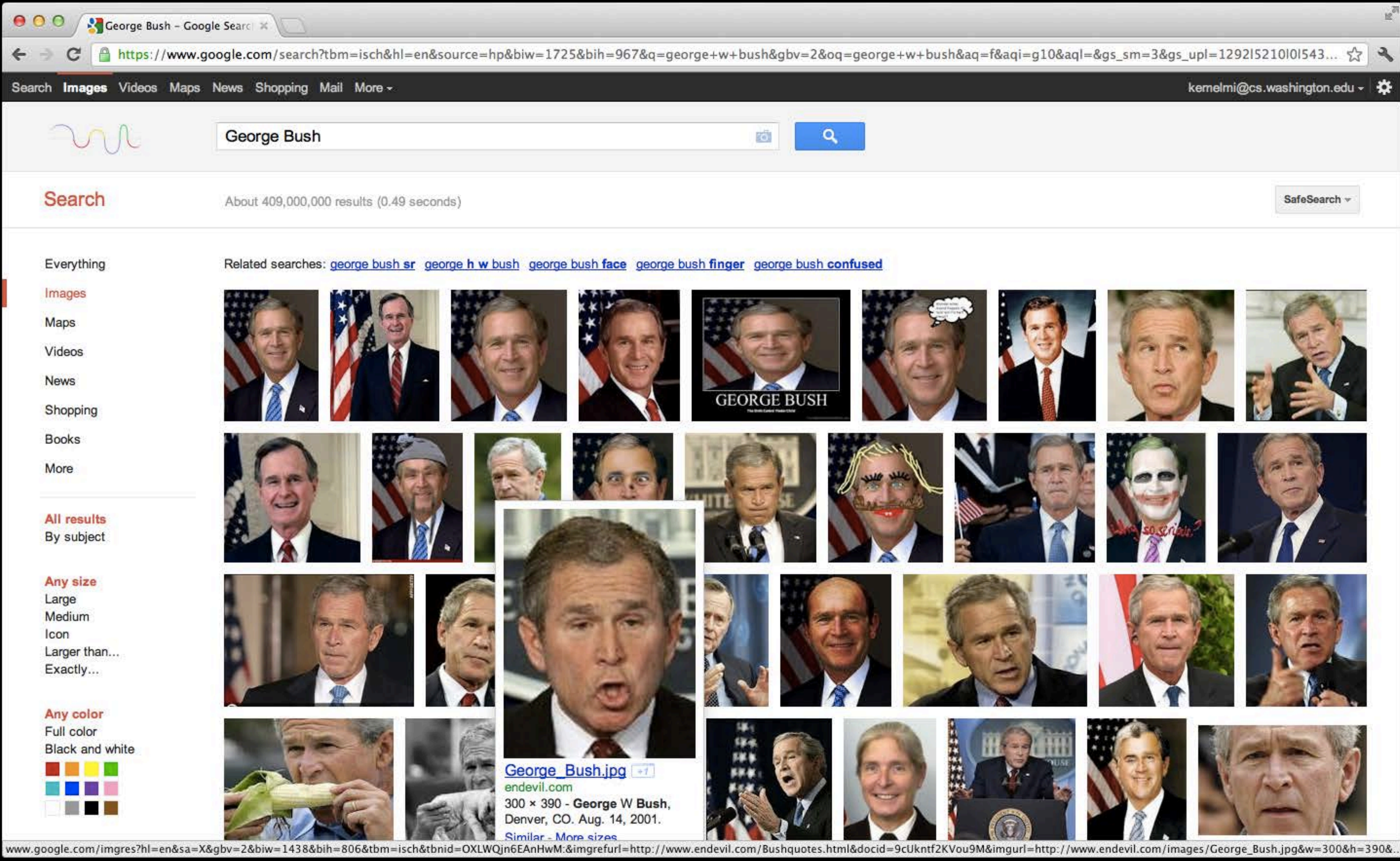
Photobio


George Bush - Google Search
https://www.google.com/search?tbm=isch&hl=en&source=hp&biw=1725&bih=967&q=george+w+bush&gbv=2&oq=george+w+bush&aq=f&aqi=g10&aql=&gs_sm=3&gs_upl=1292l5210l0l543...
Search Images Videos Maps News Shopping Mail More
kemelmi@cs.washington.edu
George Bush
Search
About 409,000,000 results (0.49 seconds)
SafeSearch
Everything
Images
Maps
Videos
News
Shopping
Books
More
All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
Full color
Black and white
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
GEORGE BUSH
George_Bush.jpg
endevil.com
300 × 390 - George W Bush, Denver, CO. Aug. 14, 2001.
www.google.com/imgres?hl=en&sa=X&gbv=2&biw=1438&bih=806&tbm=isch&tbnid=OXLWQjn6EAnHwM:&imgrefurl=http://www.endevil.com/Bushquotes.html&docid=9cUkntf2KVou9M&imgurl=http://www.endevil.com/images/George_Bush.jpg&w=300&h=390&...

Challenges

Non-rigid (facial expressions, age…)

Occlusions (hair, glasses …)

Arbitrary lighting, pose

Different cameras, exposure, focus …

But: there are many photos!

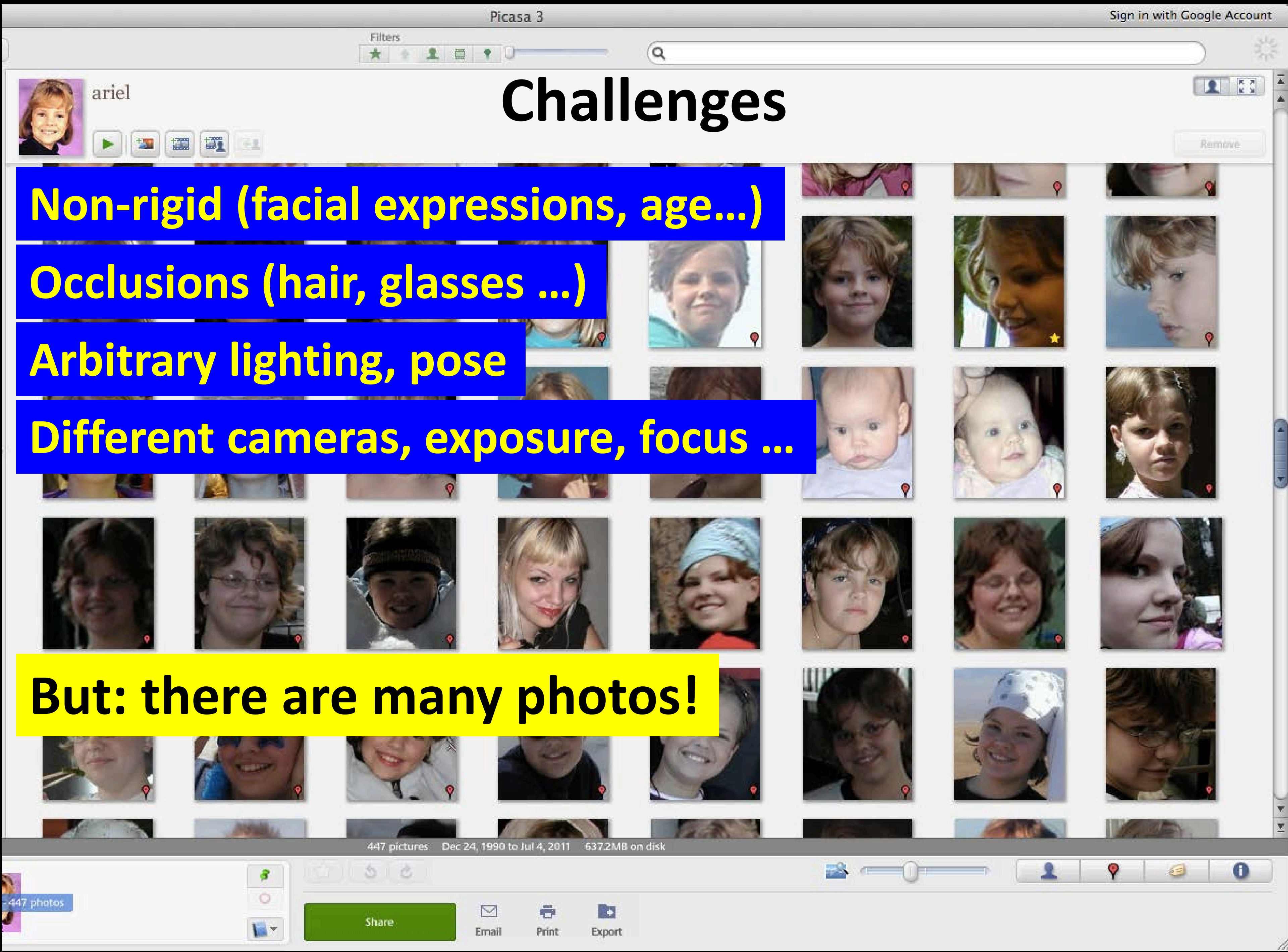


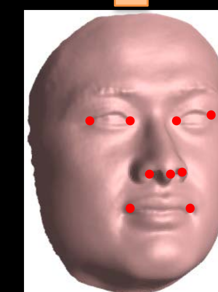
Image registration

Face detection
Bourdev and Brandt '05

Fiducial points detection
Everingham et al. '06

2D registration

Estimate 3D pose



Template 3D model

Kemelmacher, Shechtman, Garg, Seitz, *Exploring Photobios*, SIGGRAPH'11

Image registration

Face detection

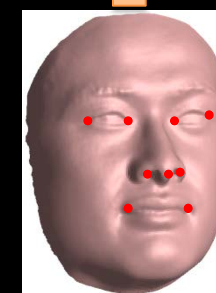
Bourdev and Brandt '05

Fiducial points detection

Everingham et al. '06

3D registration

Estimate 3D pose



Template 3D model

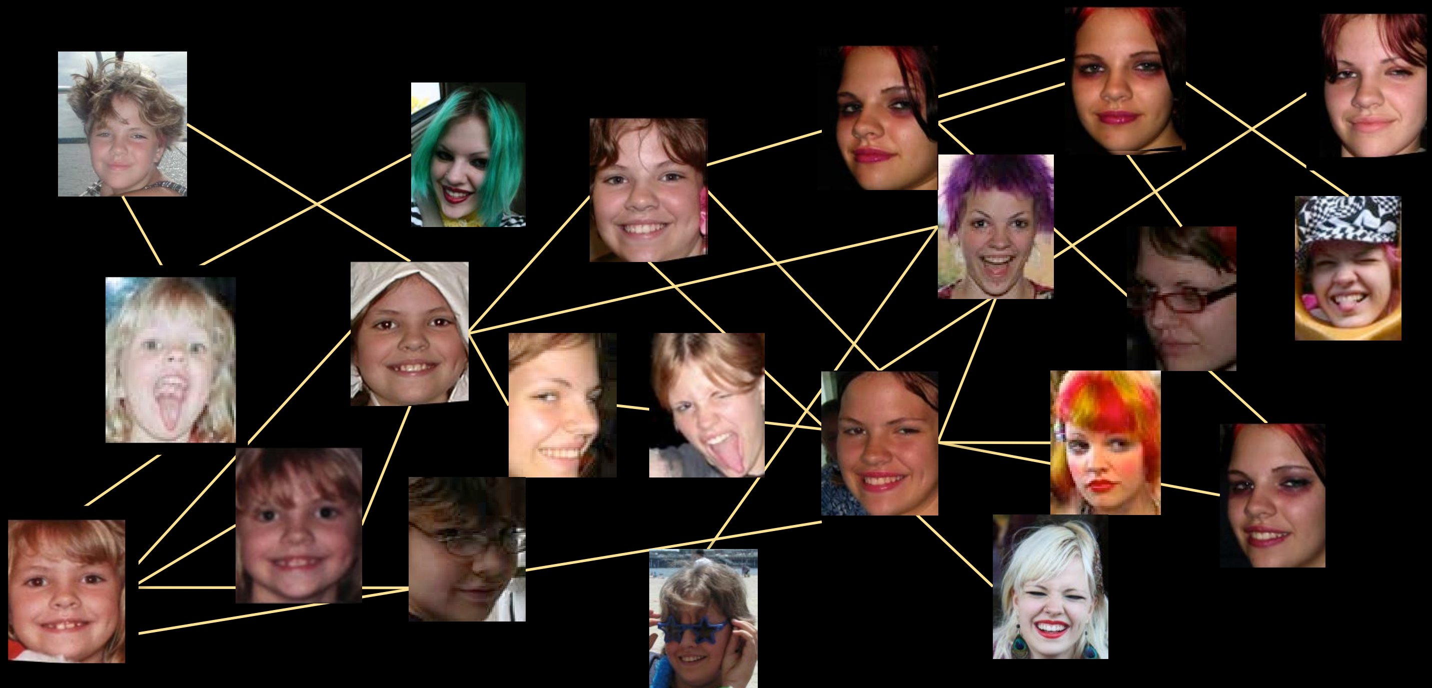
Kemelmacher, Shechtman, Garg, Seitz, *Exploring Photobios*, SIGGRAPH'11

3D transformed photos

before …

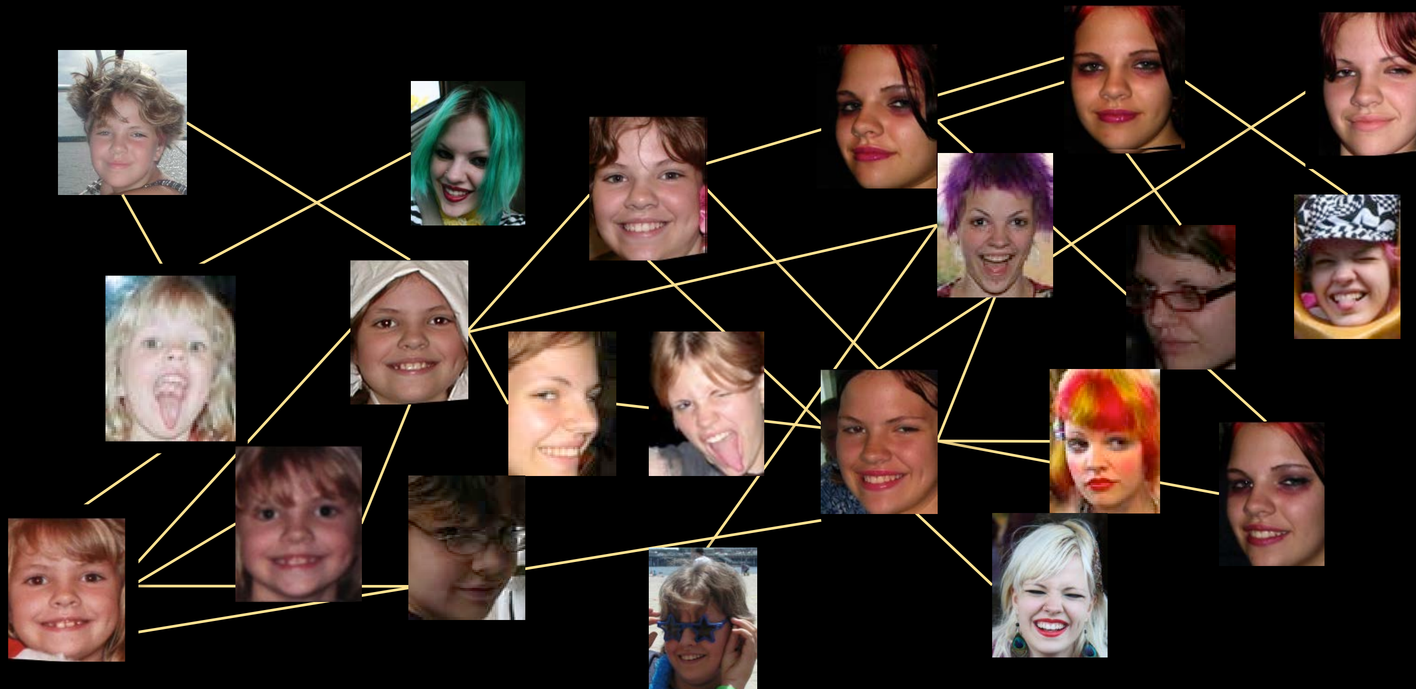
after …

Represent the photo collection as a graph



Similarity between 2 photos = **3D Head Pose similarity** • **Facial Expression similarity** • **Time similarity**

Represent the photo collection as a graph



Similarity between 2 photos = 3D Head Pose similarity • Facial Expression similarity • Time similarity

Represent the photo collection as a graph

Similarity between 2 photos = 3D Head Pose similarity • Facial Expression similarity • Time similarity

Illumination-Aware Age Progression

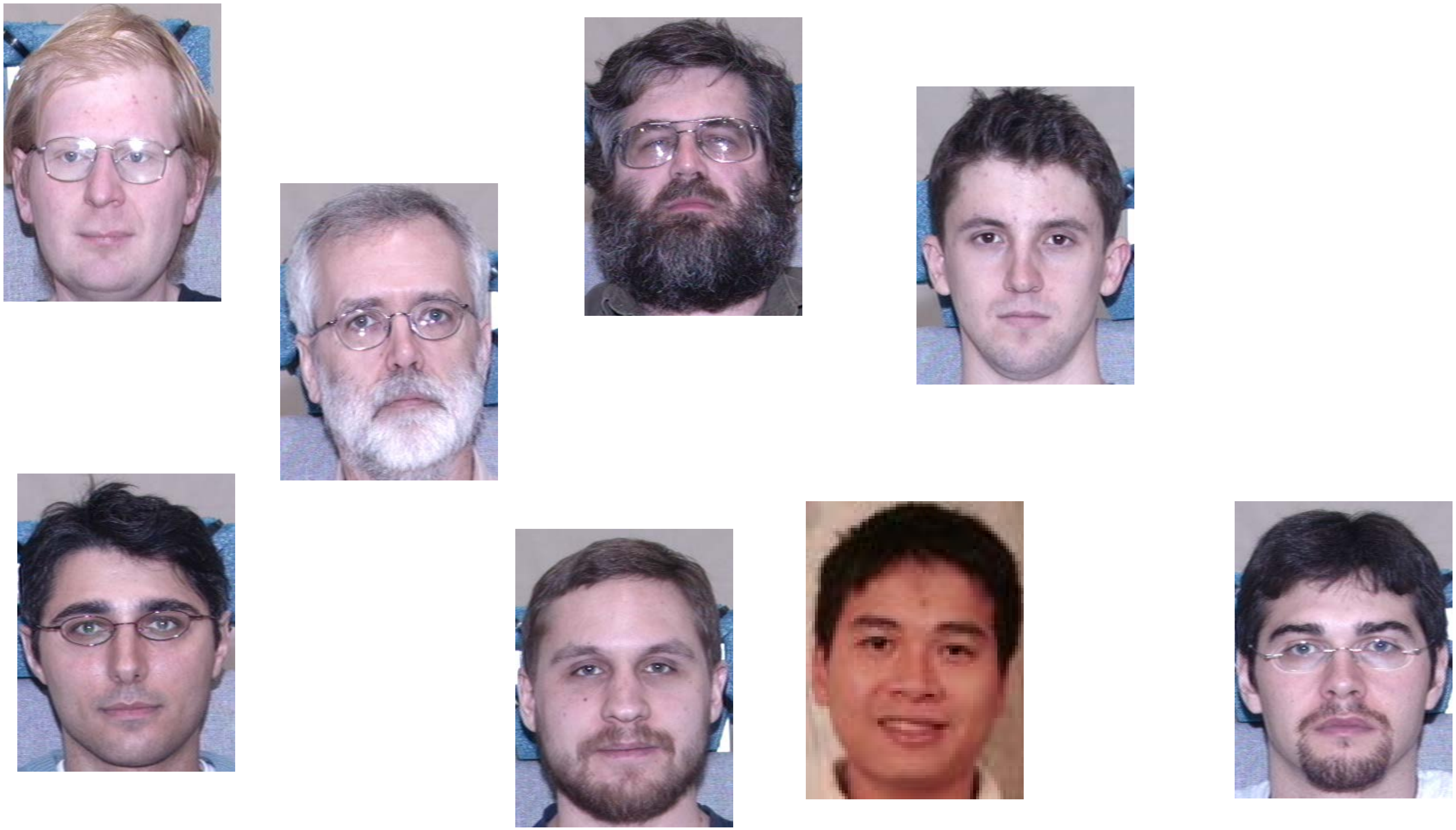
CVPR 2014

Ira Kemelmacher-Shlizerman, Supasorn Suwajanakorn, Steven M. Seitz

3 years old 5-7 14-16 26-35 46-57 58-68 81-100

http://www.youtube.com/watch?v=QuKluy7NAvE

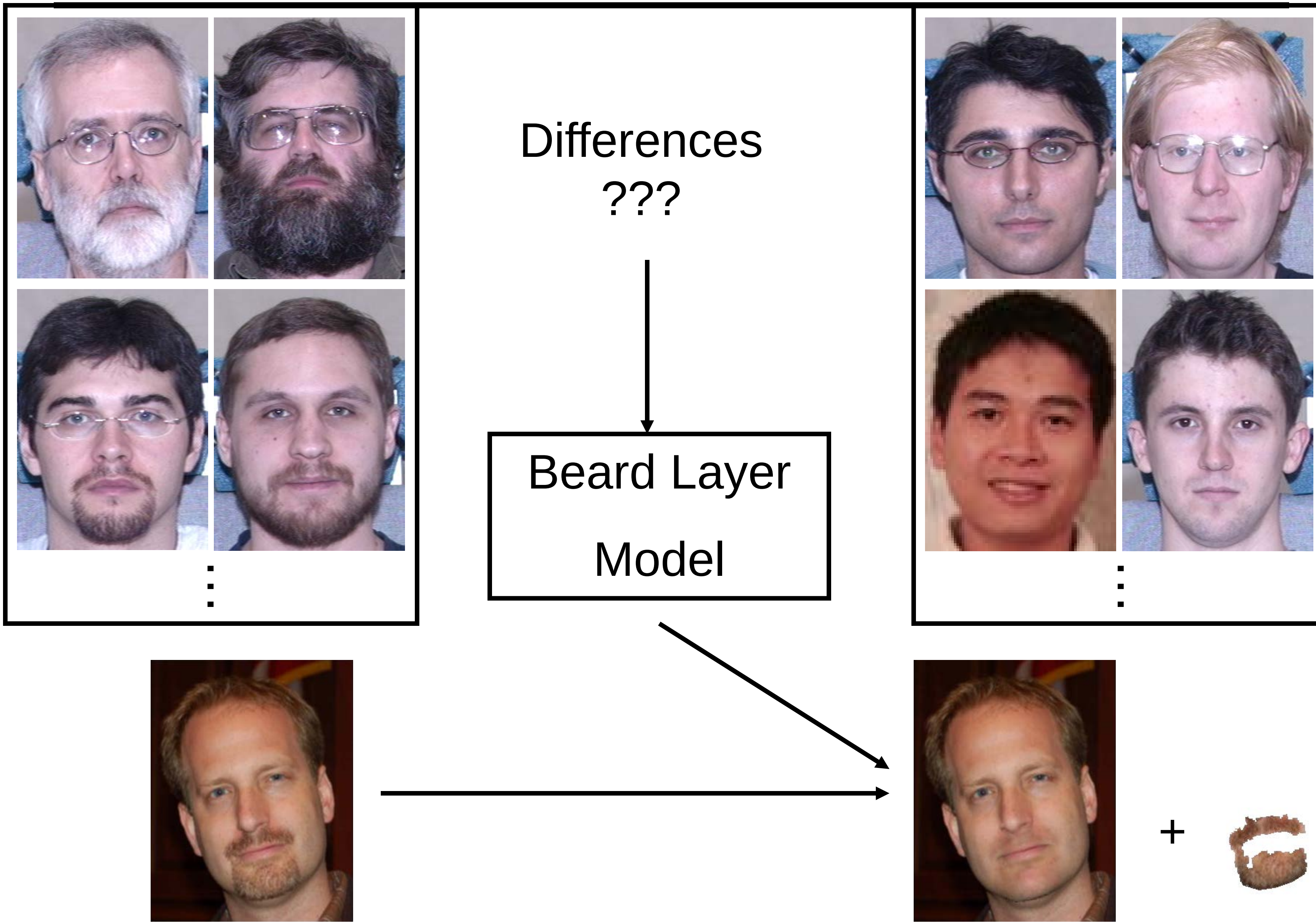
Image-Based Shaving



http://graphics.cs.cmu.edu/projects/imageshaving/

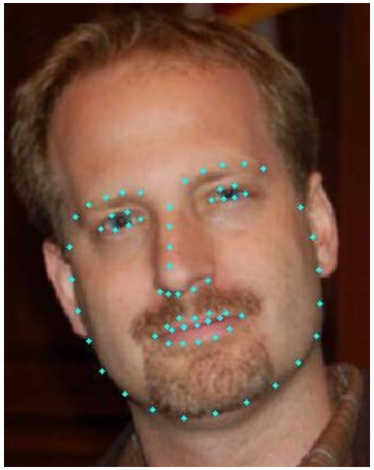
Nguyen et al., 2008

The idea

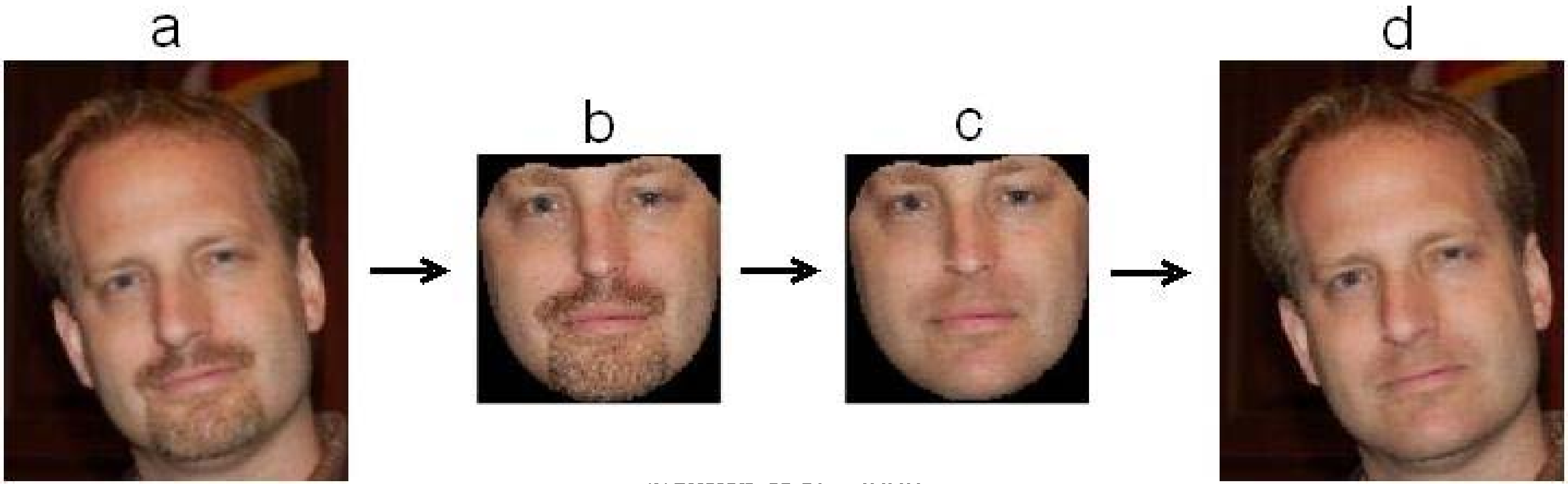


Nguyen et al., 2008

Processing steps



68 landmarks



Nguyen et al., 2008

Some results