Data-driven Methods: Faces

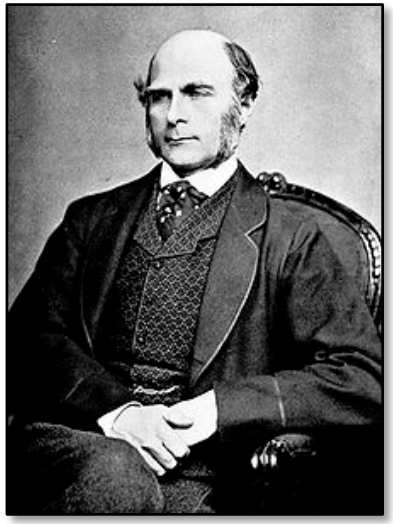
Portrait of Piotr Gibas © Joaquin Rosales Gomez (2003)

CS194: Image Manipulation & Computational Photography
Alexei Efros, UC Berkeley, Fall 2018

The Power of Averaging

8-hour exposure

Image Composites



Sir Francis Galton
1822-1911

Multiple Individuals

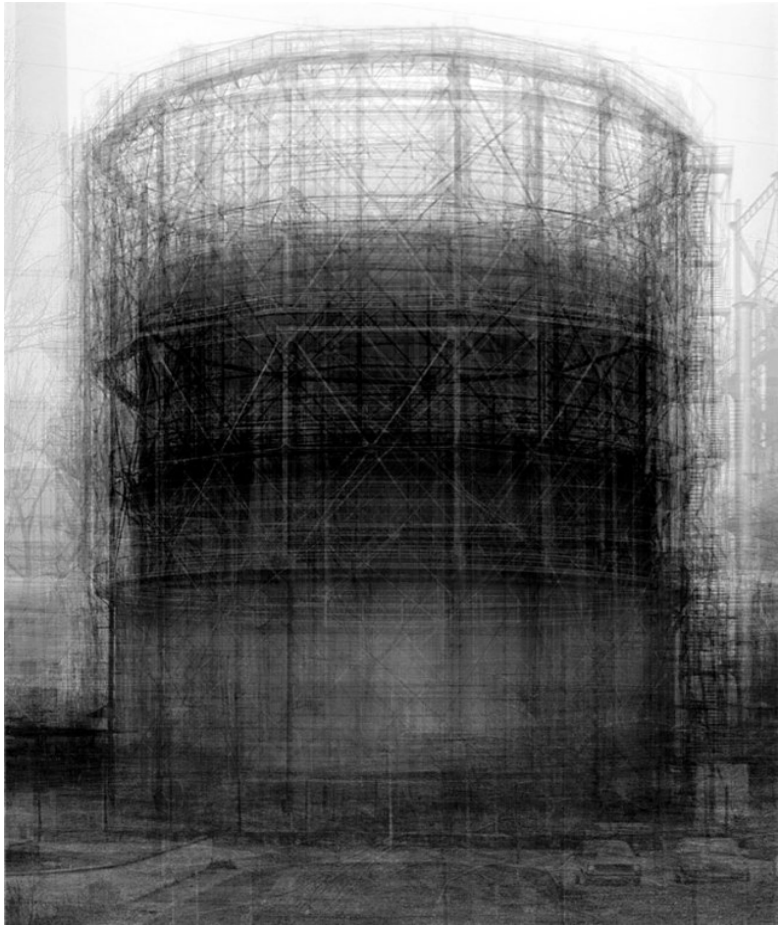
Composite

[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)

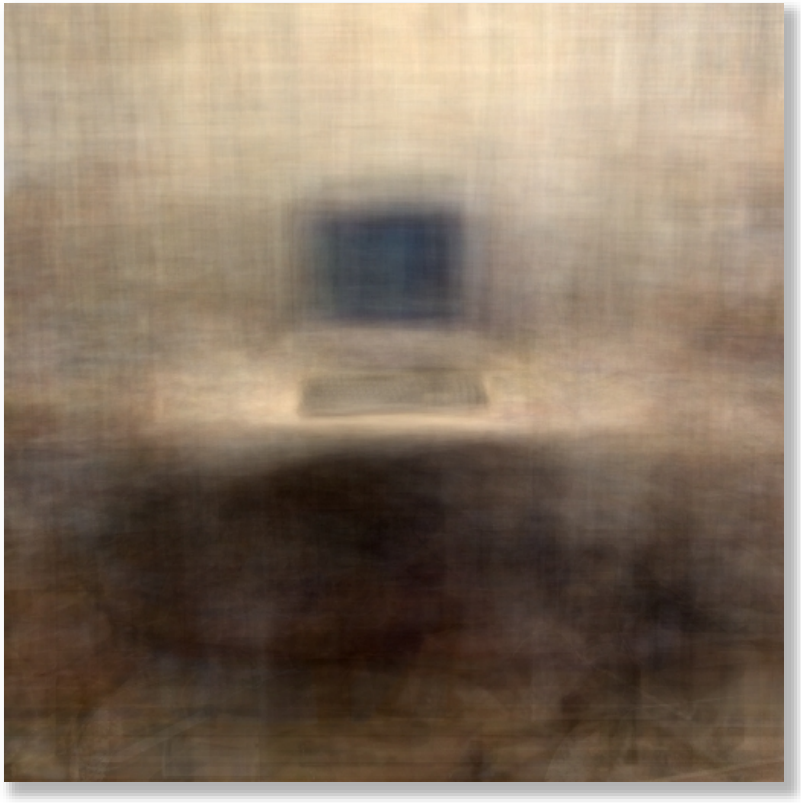
Idris Khan

“100 Special Moments” by Jason Salavon

Why blurry?

Object-Centric Averages by Torralba (2001)

Manual Annotation and Alignment



Average Image

Slide by Jun-Yan Zhu

Computing Means

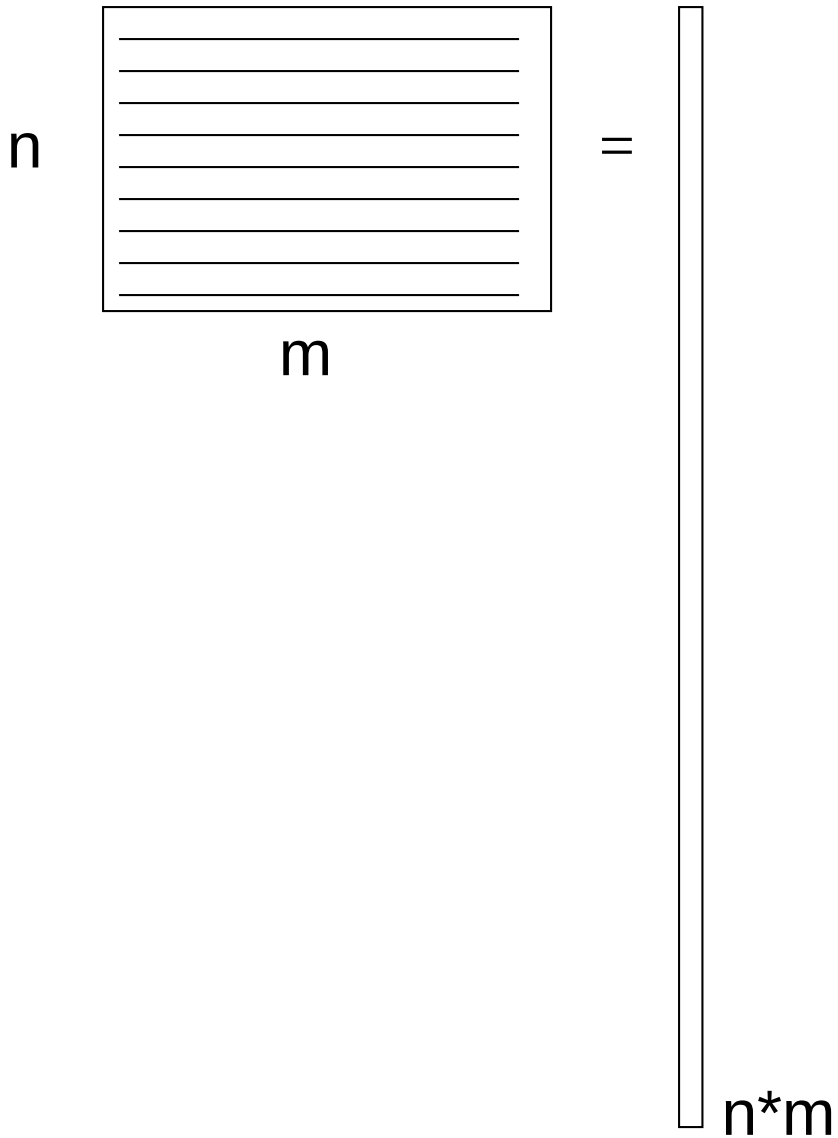
Two Requirements:

- Alignment of objects
- Objects must span a subspace

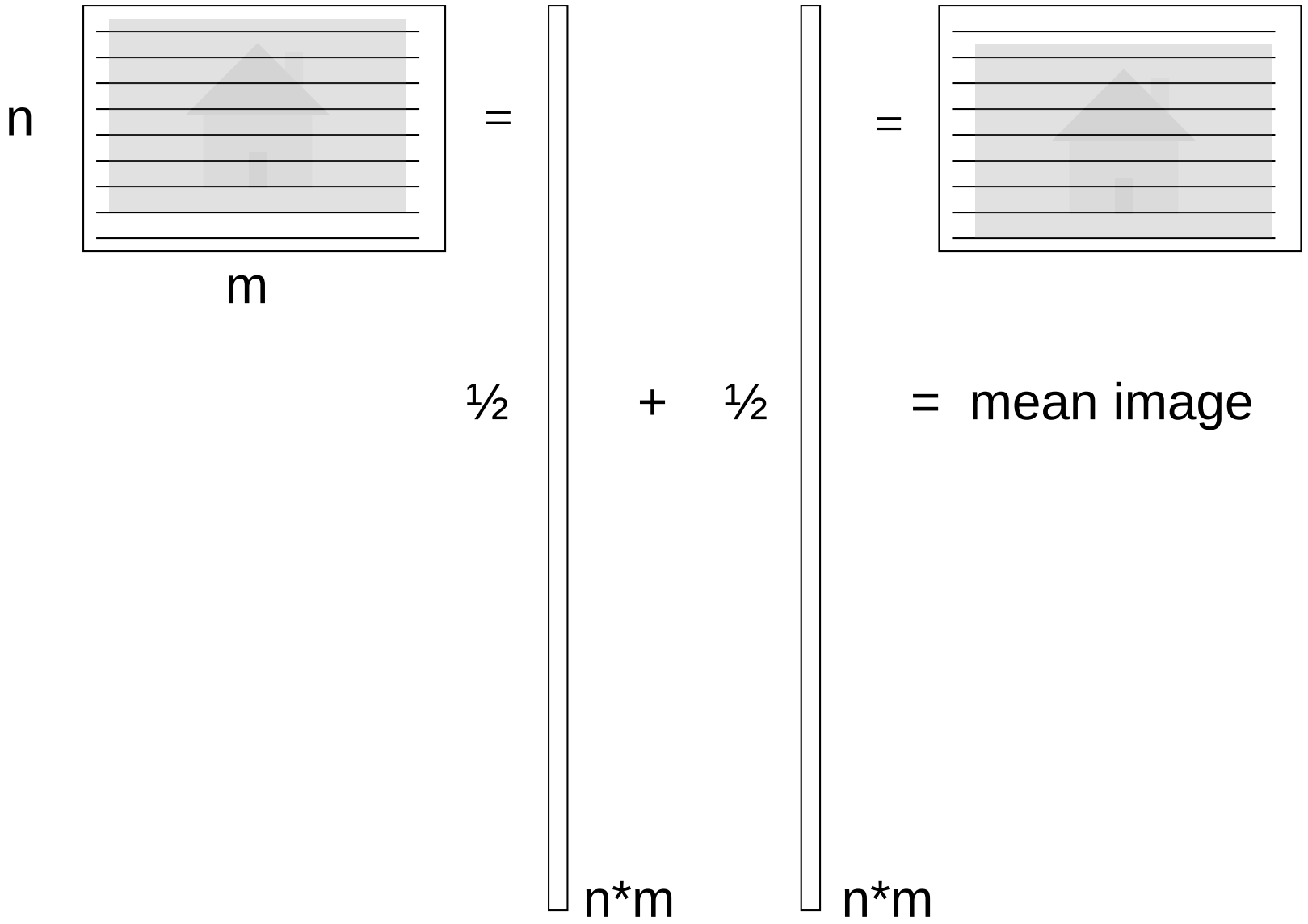
Useful concepts:

- Subpopulation means
- Deviations from the mean

Images as Vectors



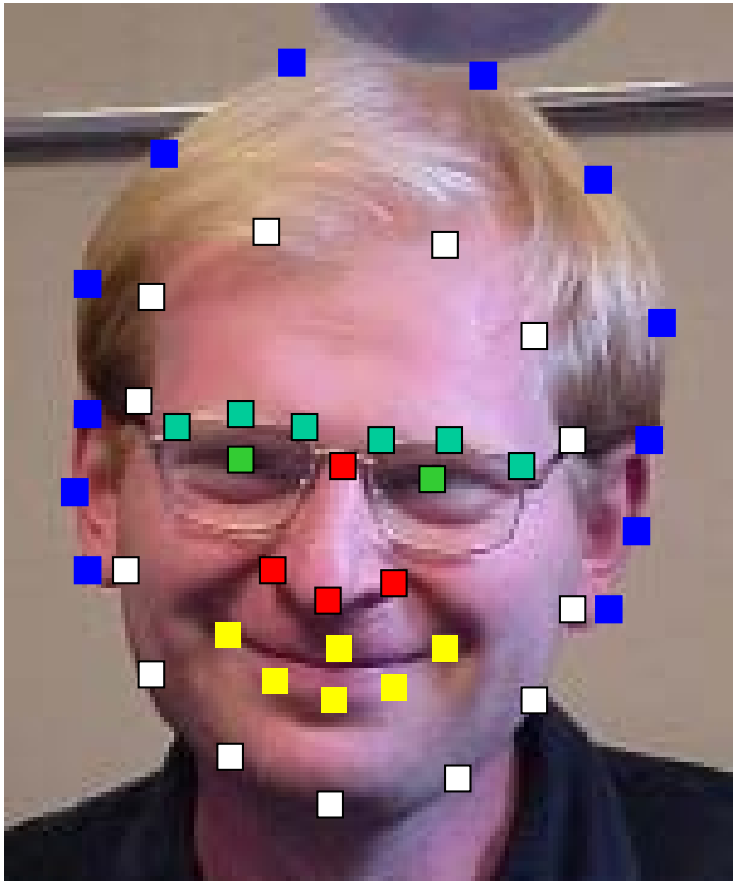
Vector Mean: Importance of Alignment



How to align faces?

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

Shape Vector



=

43

Provides alignment!

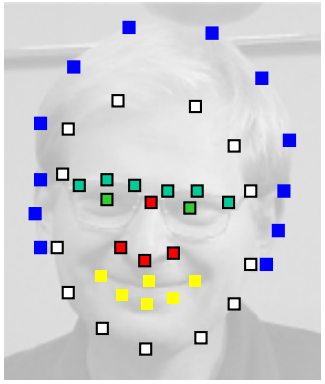
Appearance Vectors vs. Shape Vectors

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!

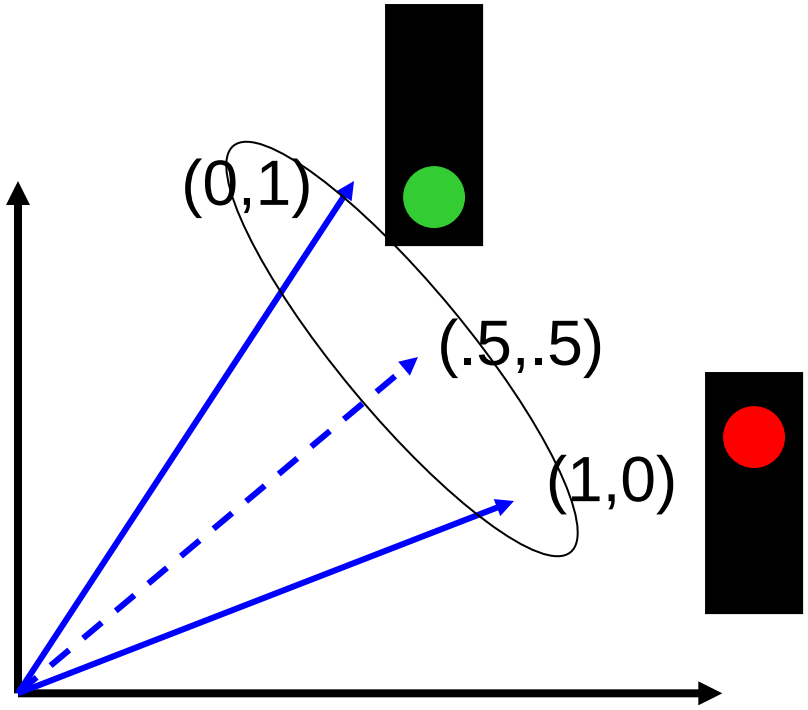
Slide by Kevin Karsch

Average Face

1. Warp to mean shape
2. Average pixels

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

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

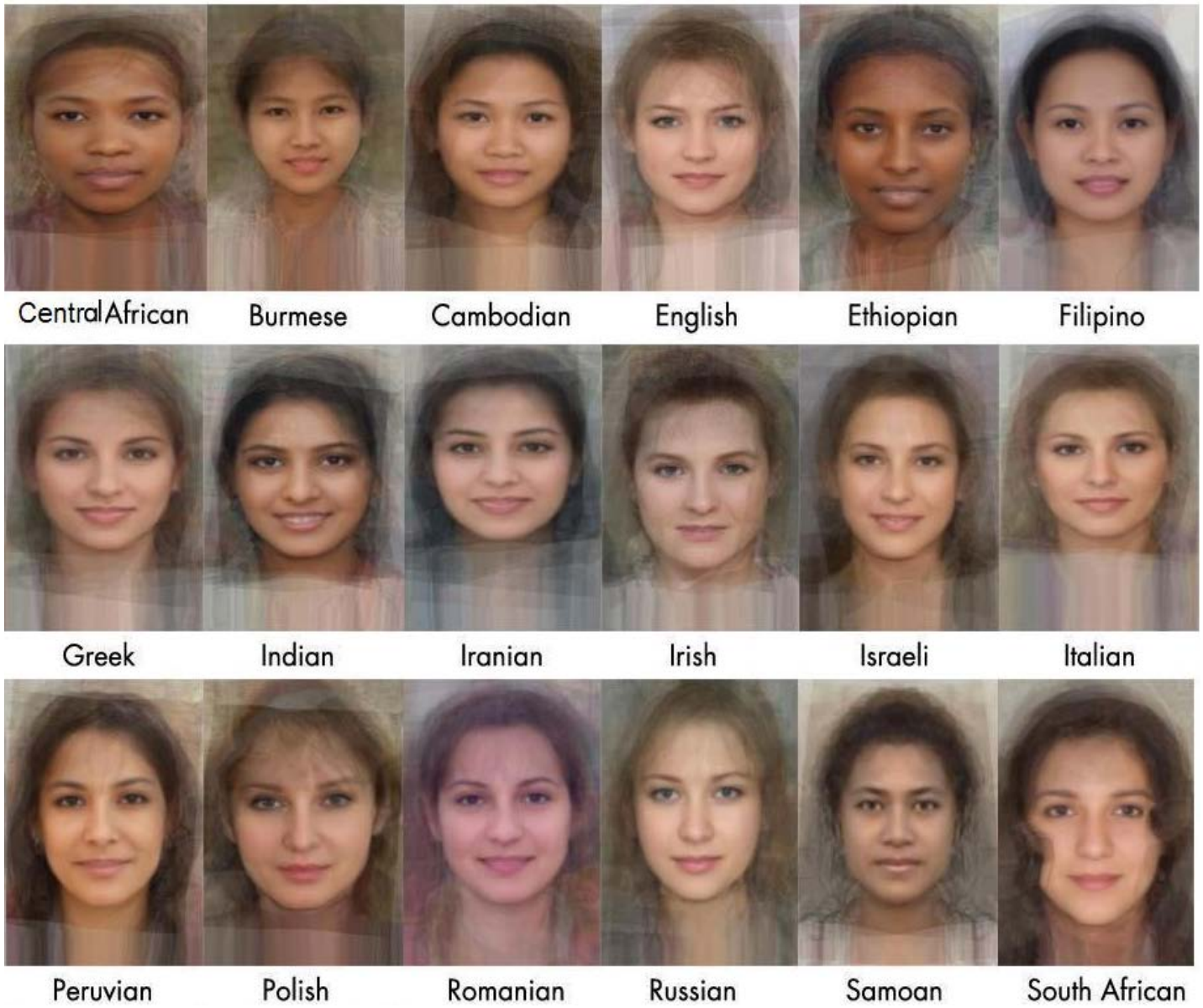
Average female

Average kid

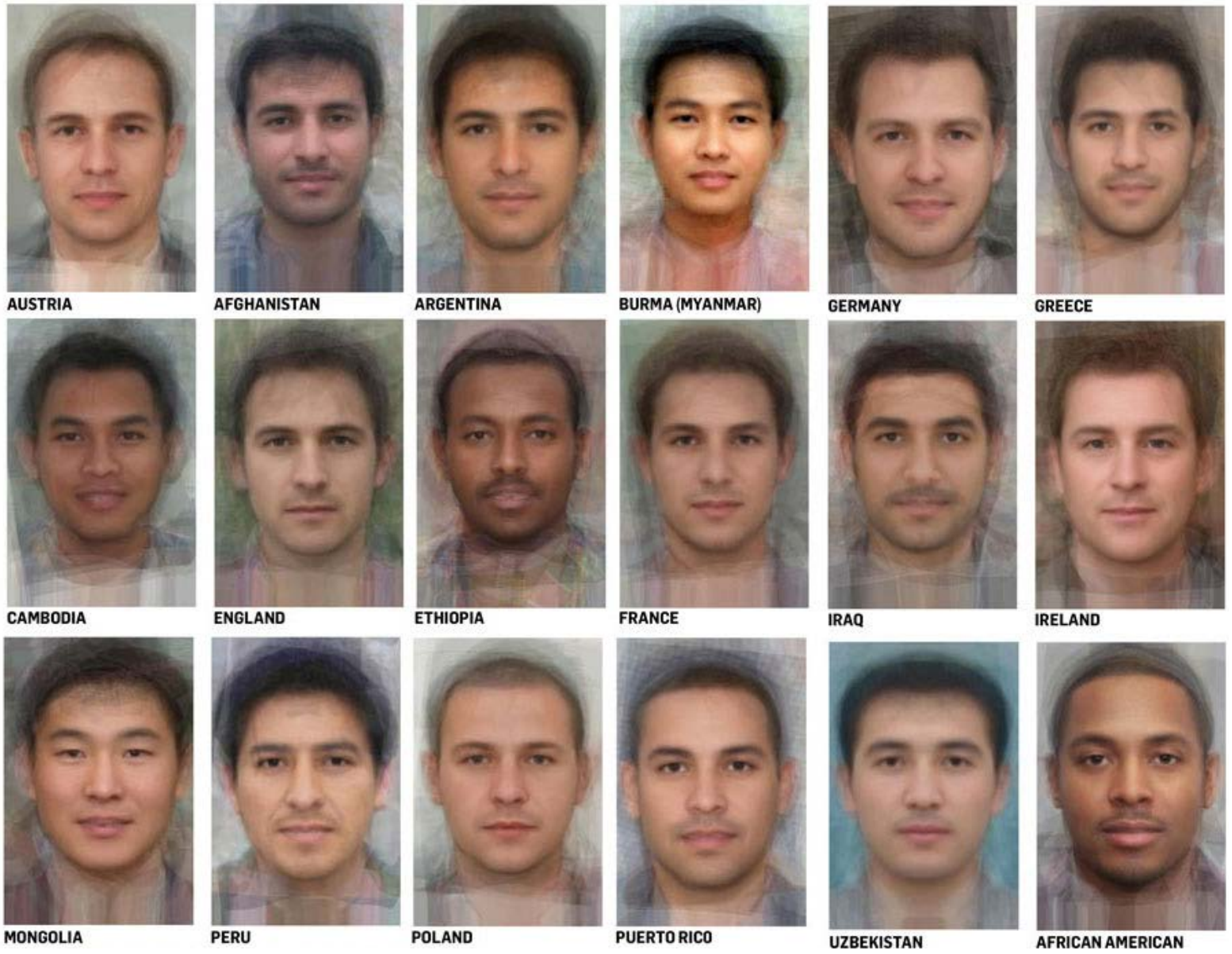
Average happy male

Average male

Average Women of the world



Average Men of the world



Deviations from the mean

Image X

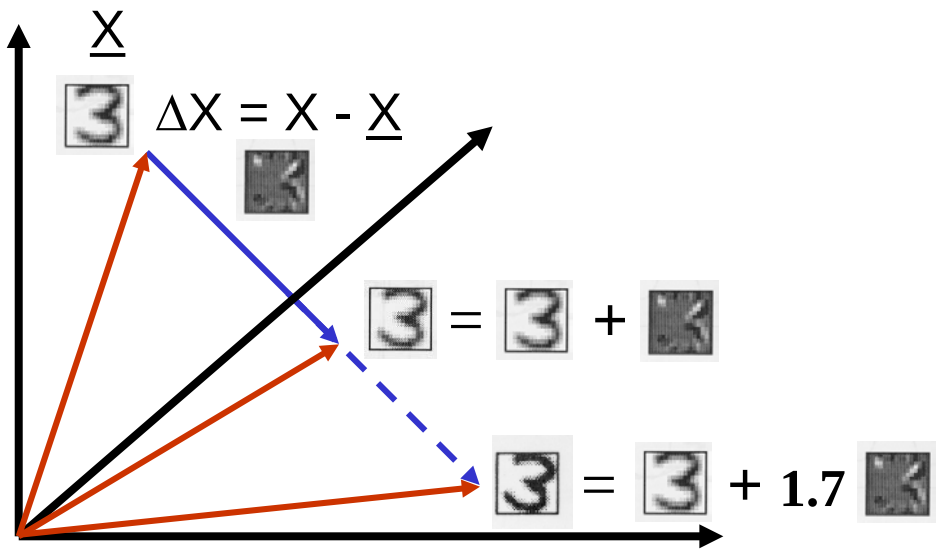
-

Mean $\underline{X}$

=

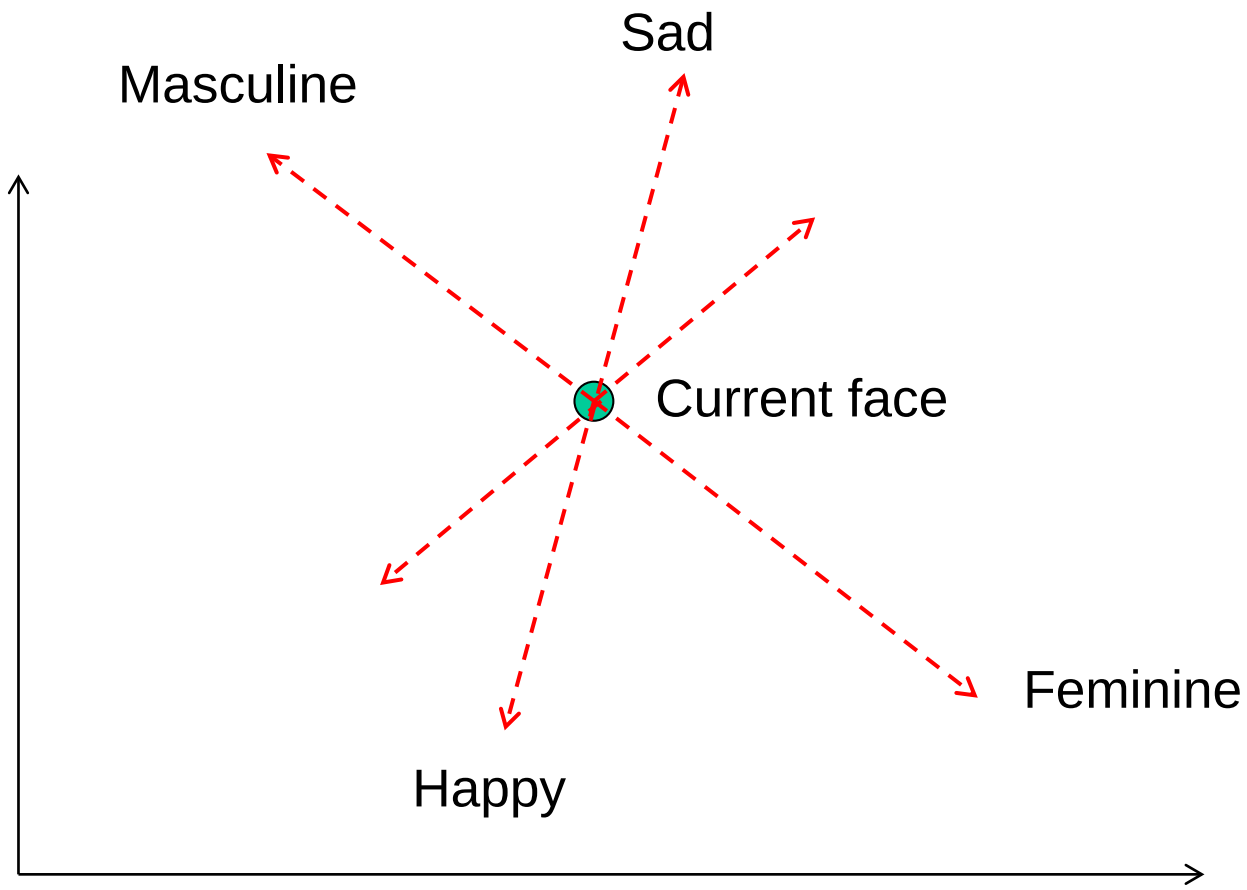
$\Delta X = X - \underline{X}$

Deviations from the mean



Extrapolating faces

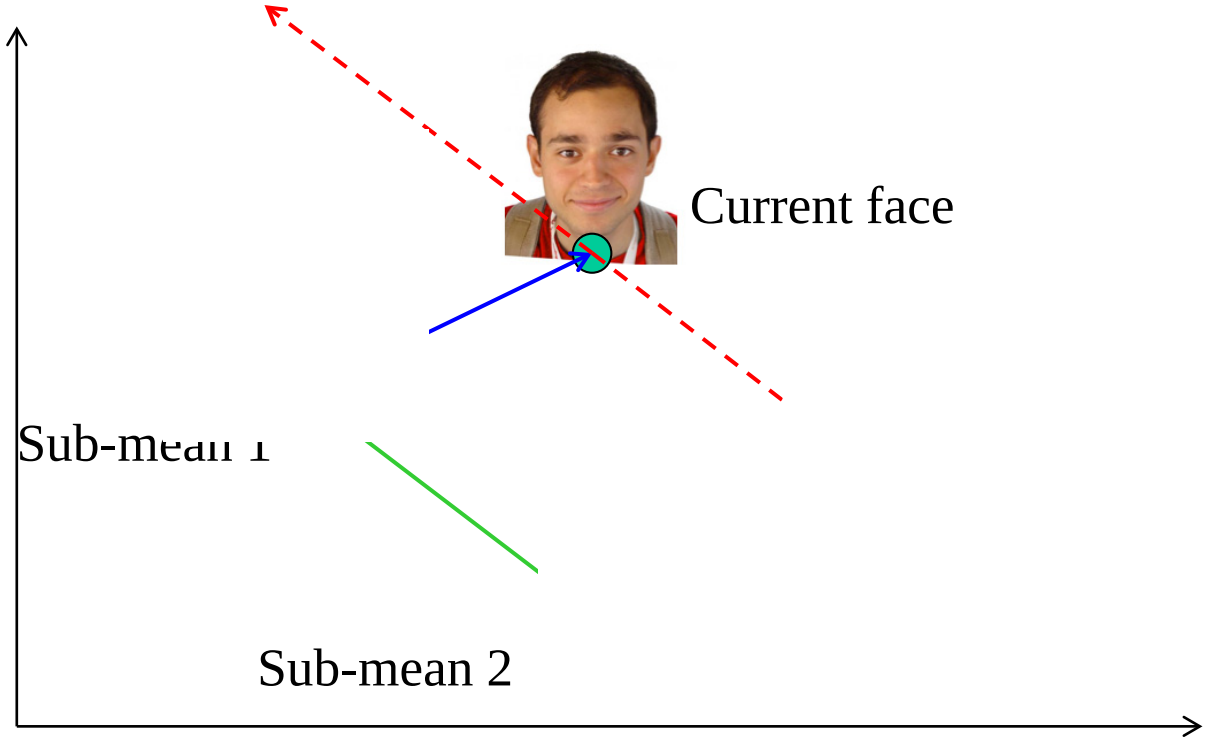
- We can imagine various meaningful directions.



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

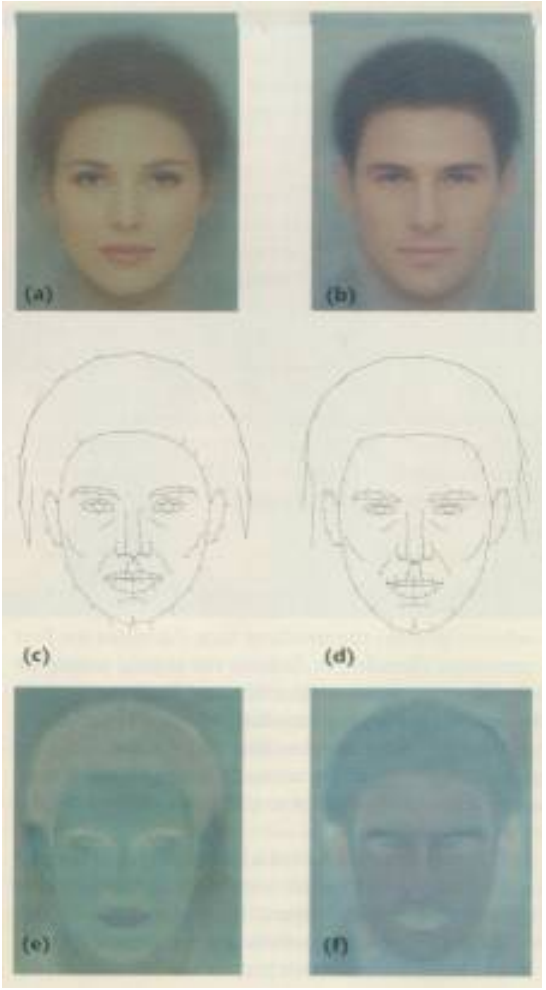
St Andrews University

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

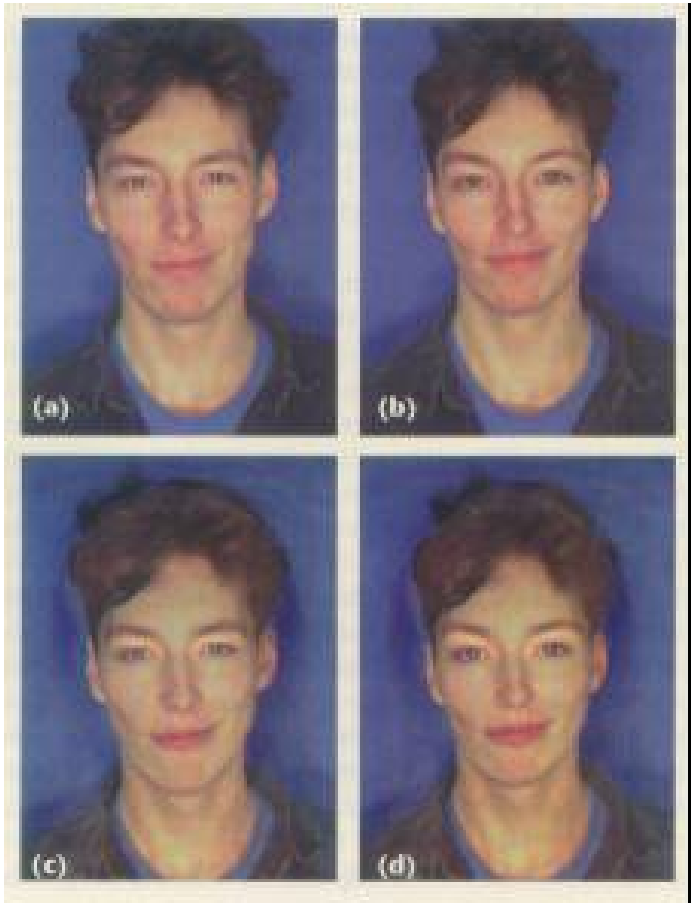
Deform shape and/or color of an input face in the direction of "more female"

original

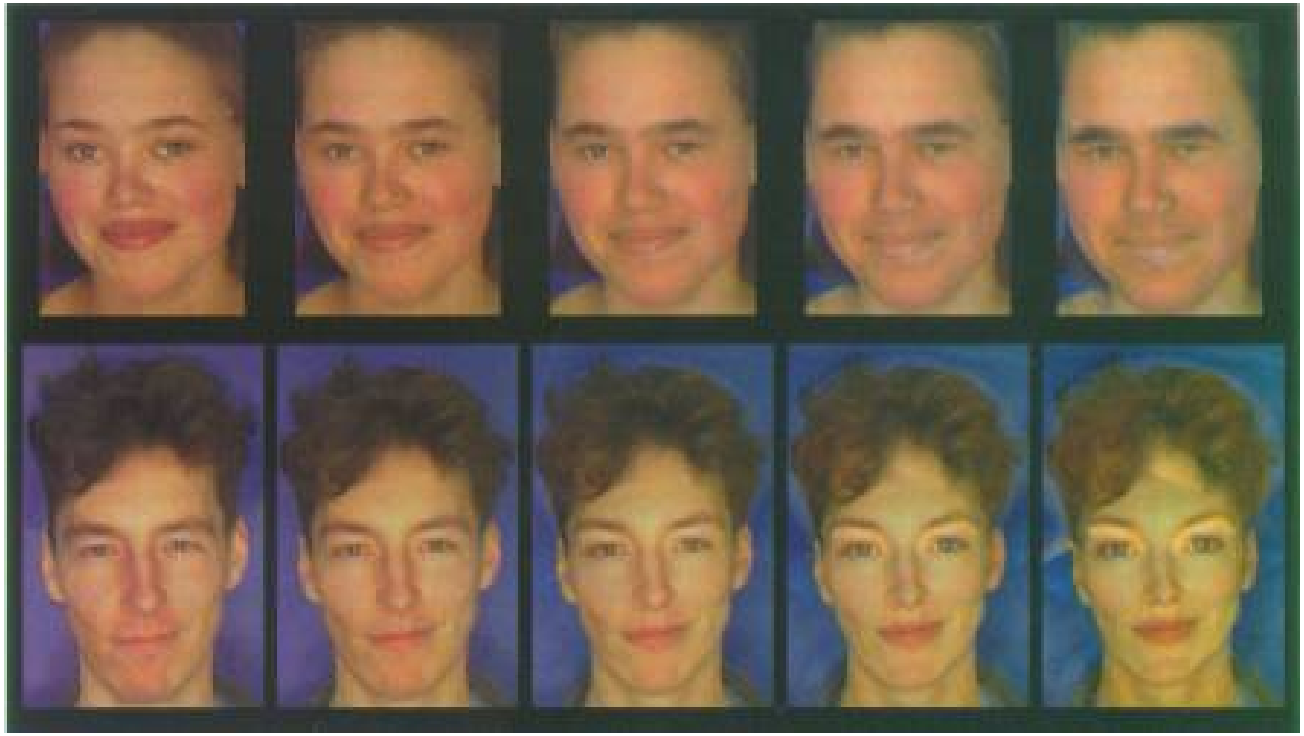
shape

color

both



Enhancing gender



more same **original** androgynous more opposite

Changing age

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

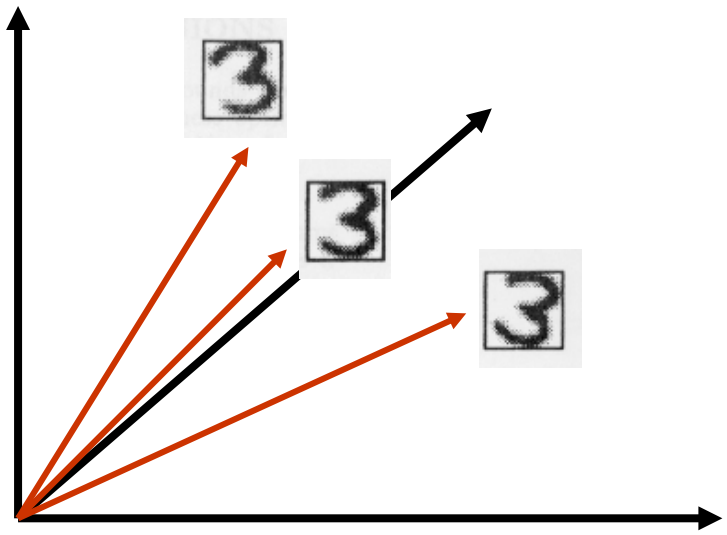
original

shape

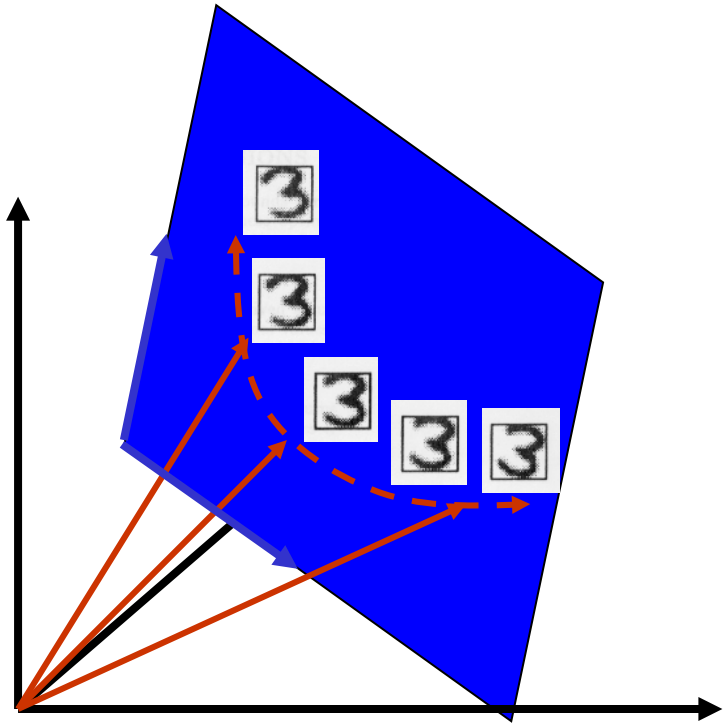
color

both

Back to the Subspace



Linear Subspace: convex combinations



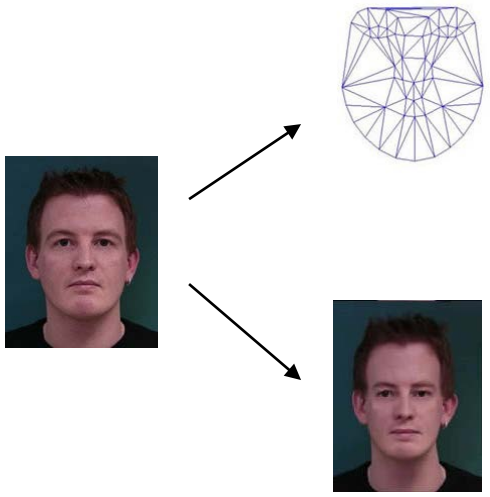
Any new image X can be obtained as weighted sum of stored “basis” images.

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

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 $\mathbf{S} = (x_1, y_1, x_2, \ldots, y_n)^T$, containing the (x, y) coordinates of the n vertices of a face, and the appearance (texture) vector $\mathbf{T} = (R_1, G_1, B_1, R_2, \ldots, G_n, B_n)^T$, 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:

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

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

$t = \beta_1 \cdot$  $+\beta_2 \cdot$  $+\beta_3 \cdot$  $+\beta_4 \cdot$  $+ \ldots = \mathbf{T} \cdot \mathbf{\beta}$

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

Any new face can be represented as a pair of vectors

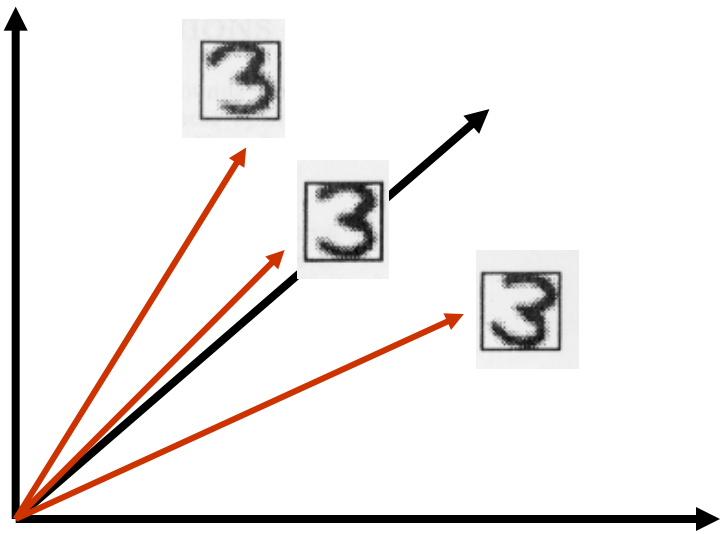
$(\alpha_1, \alpha_2, \ldots, \alpha_m)^T$ and $(\beta_1, \beta_2, \ldots, \beta_m)^T$!

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!

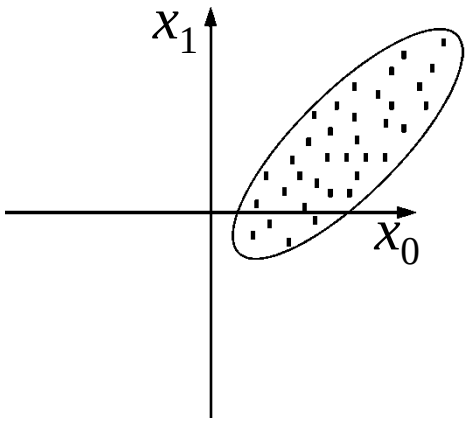
But what's important?

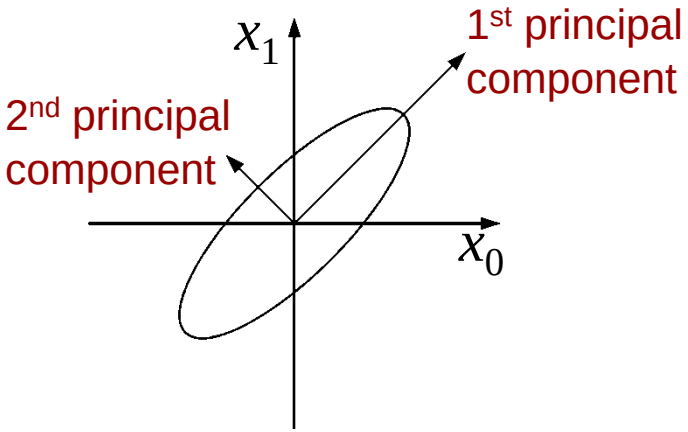


Principal Component Analysis

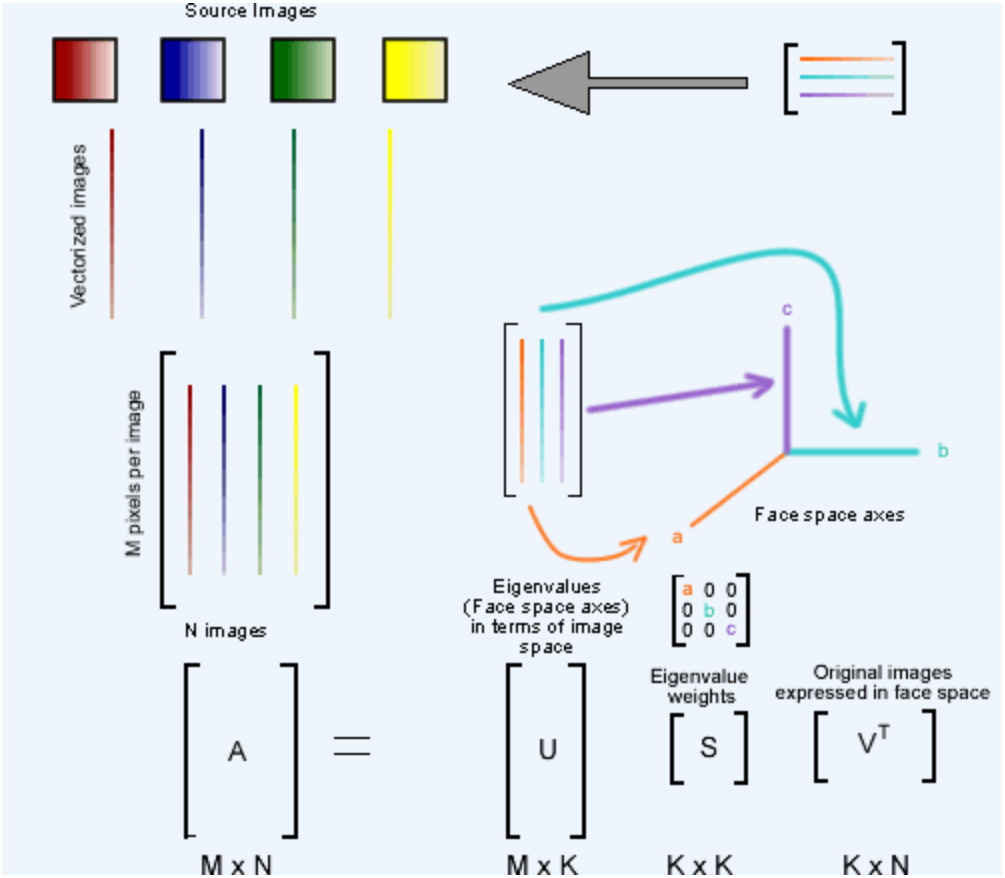
Given a point set $\{\vec{\mathrm{p}}_j\}_{j=1\ldots P}$, in an M-dim space, PCA finds a basis such that

- 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



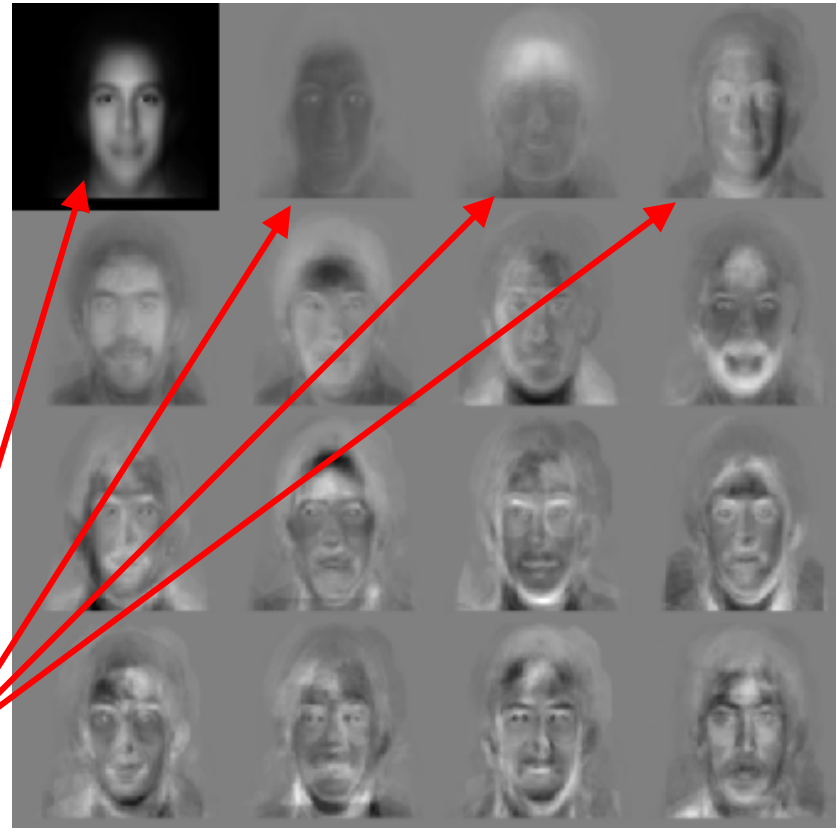
[u,s,v] = svd(A);

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

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

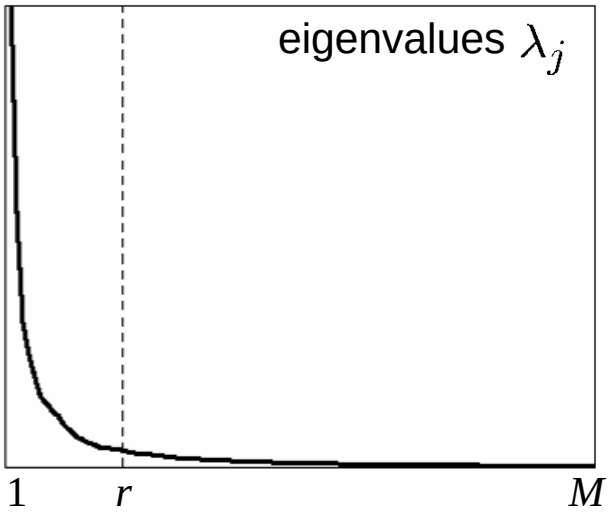
Mean appearance

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

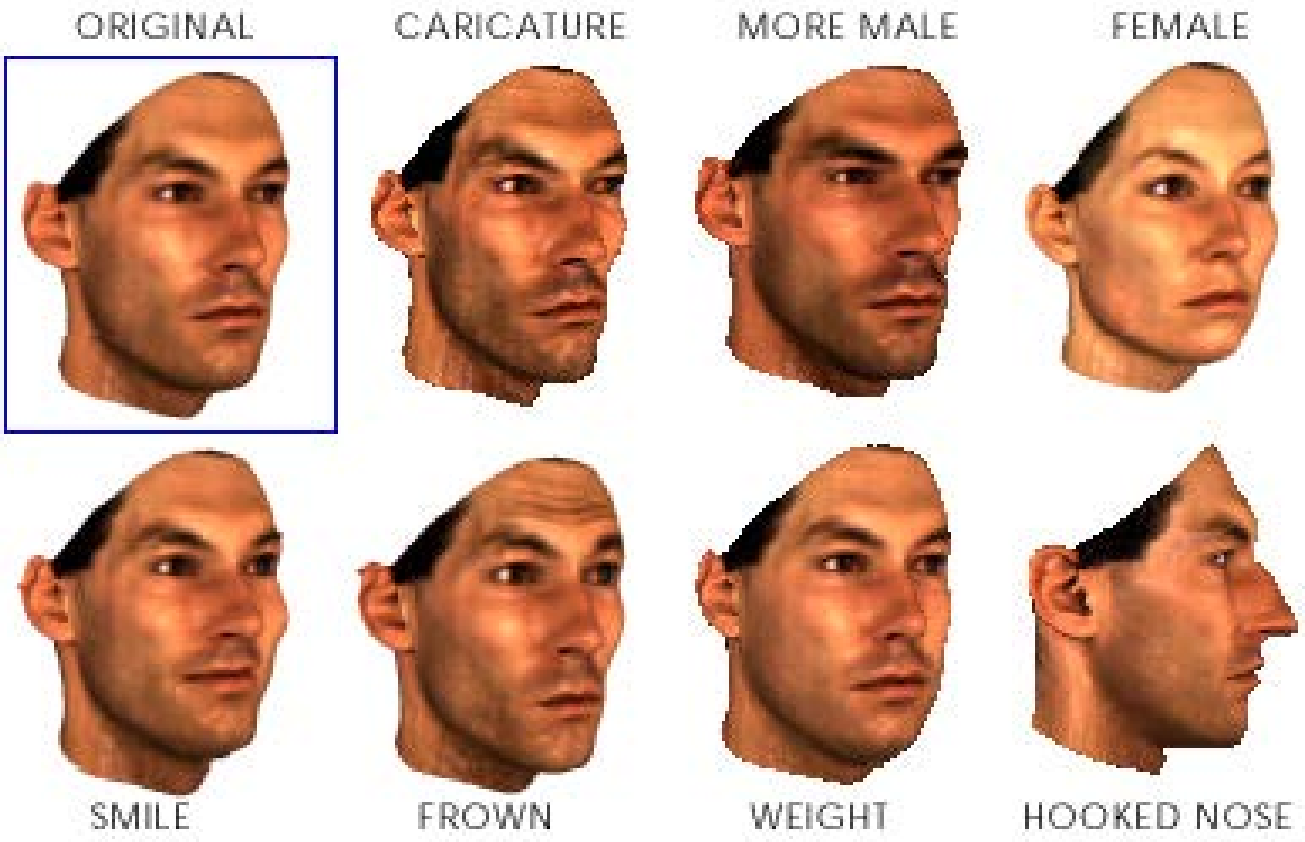
Principal Component Analysis

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

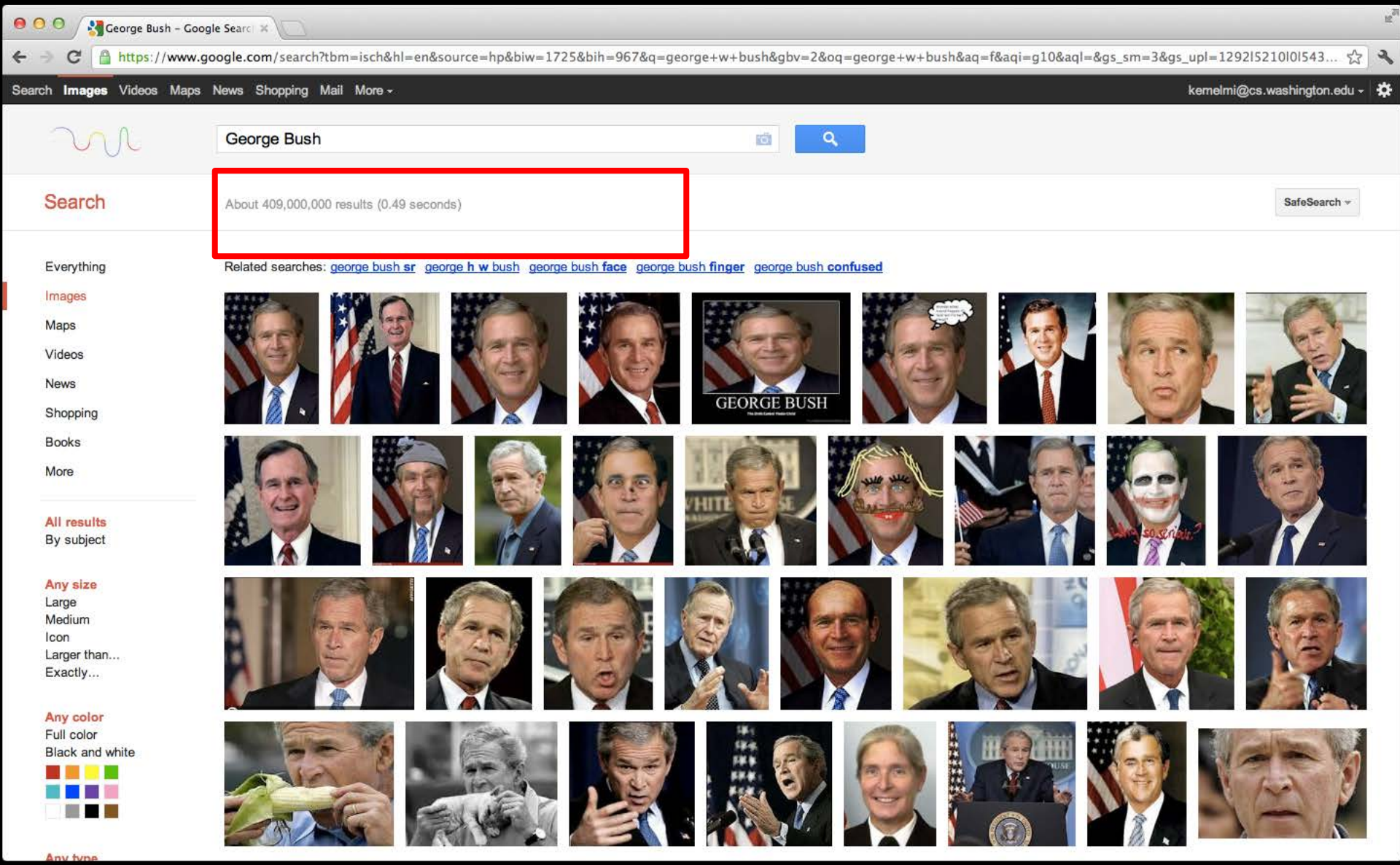


Using 3D Geometry: Blinz & Vetter, 1999



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

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...
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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
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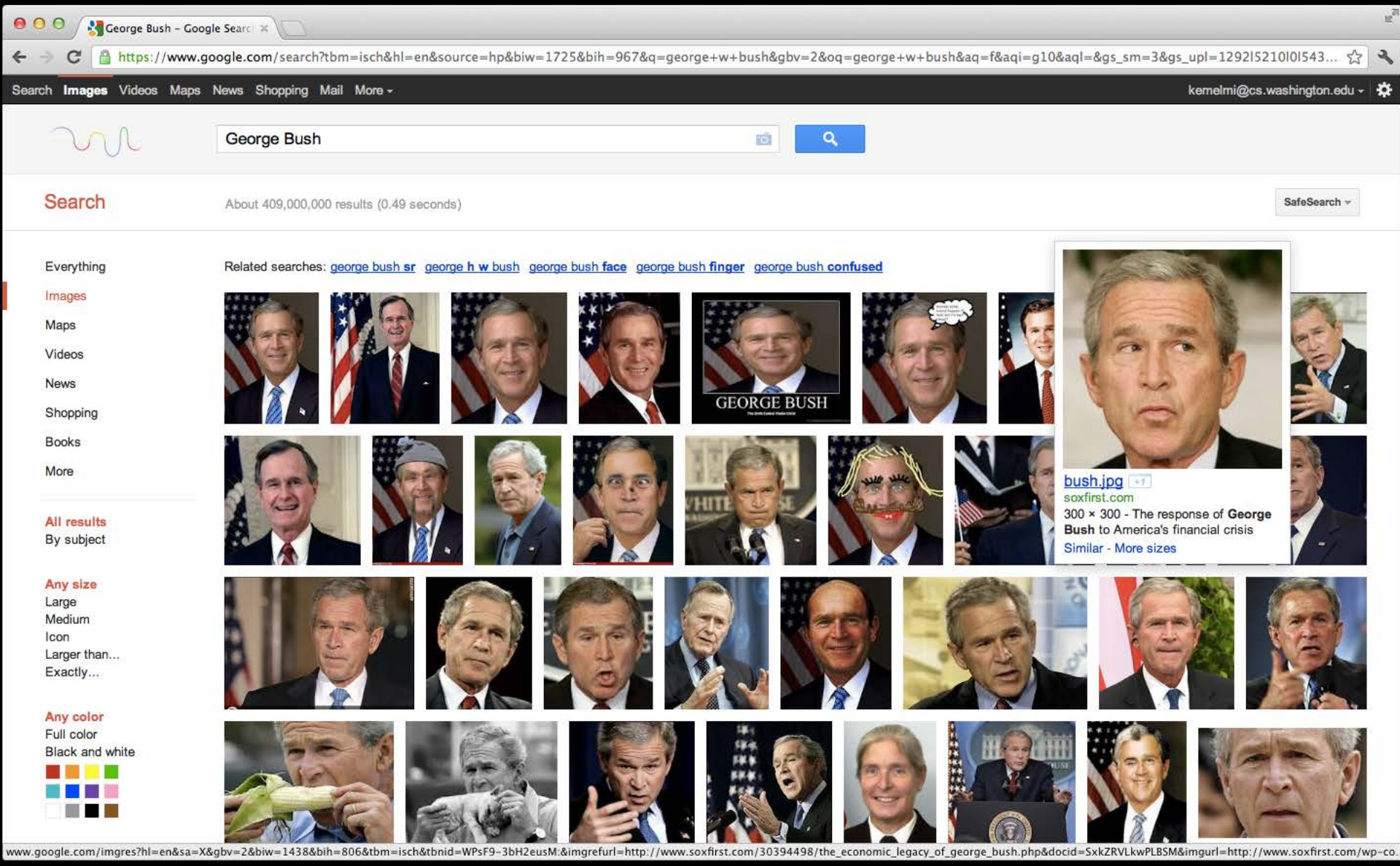
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
GEORGE BUSH

Photobio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Search
About 409,000,000 results (0.49 seconds)
SafeSearch
Everything
Images
Maps
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Books
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All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
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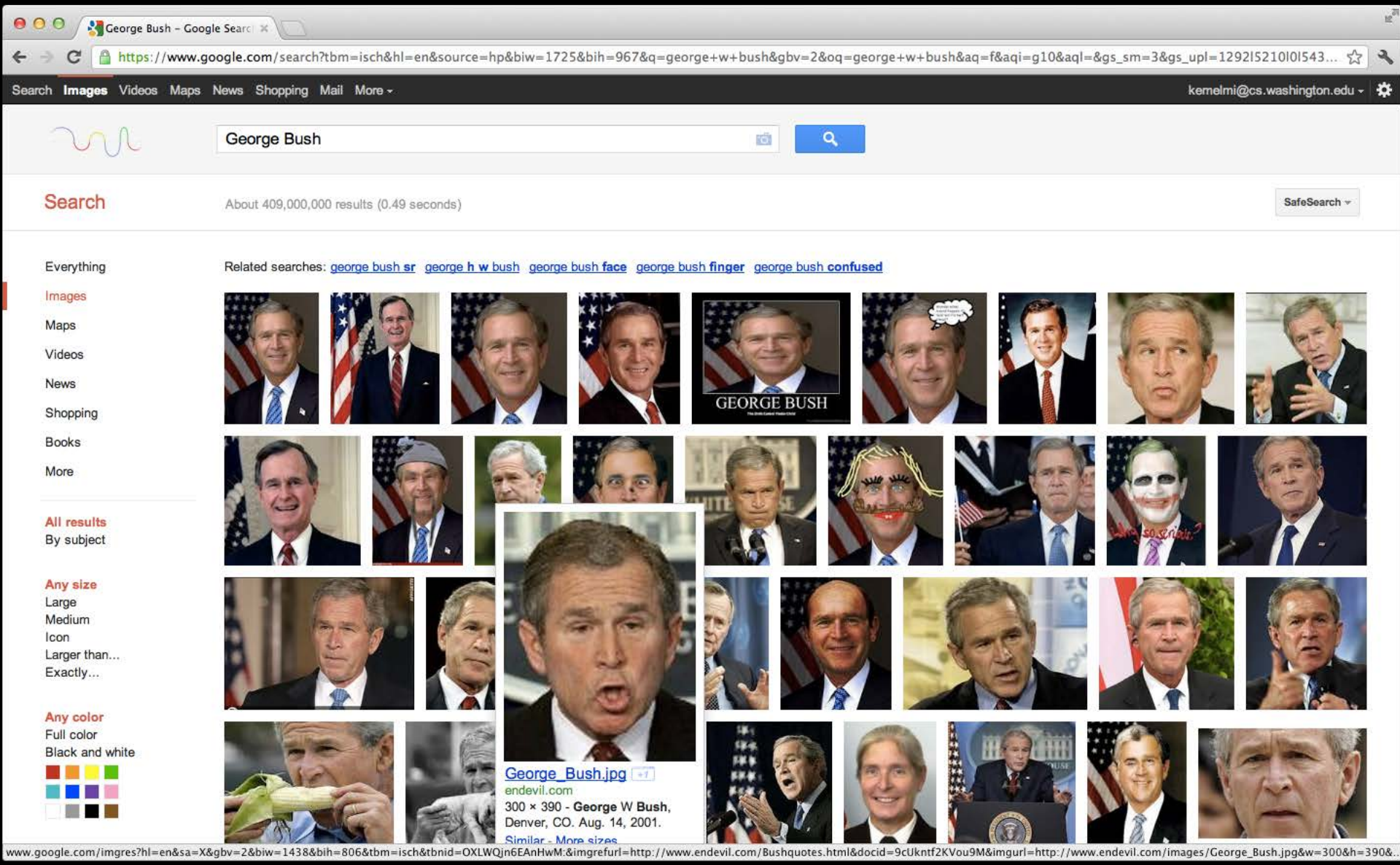
Photobio


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...
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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...
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Any color
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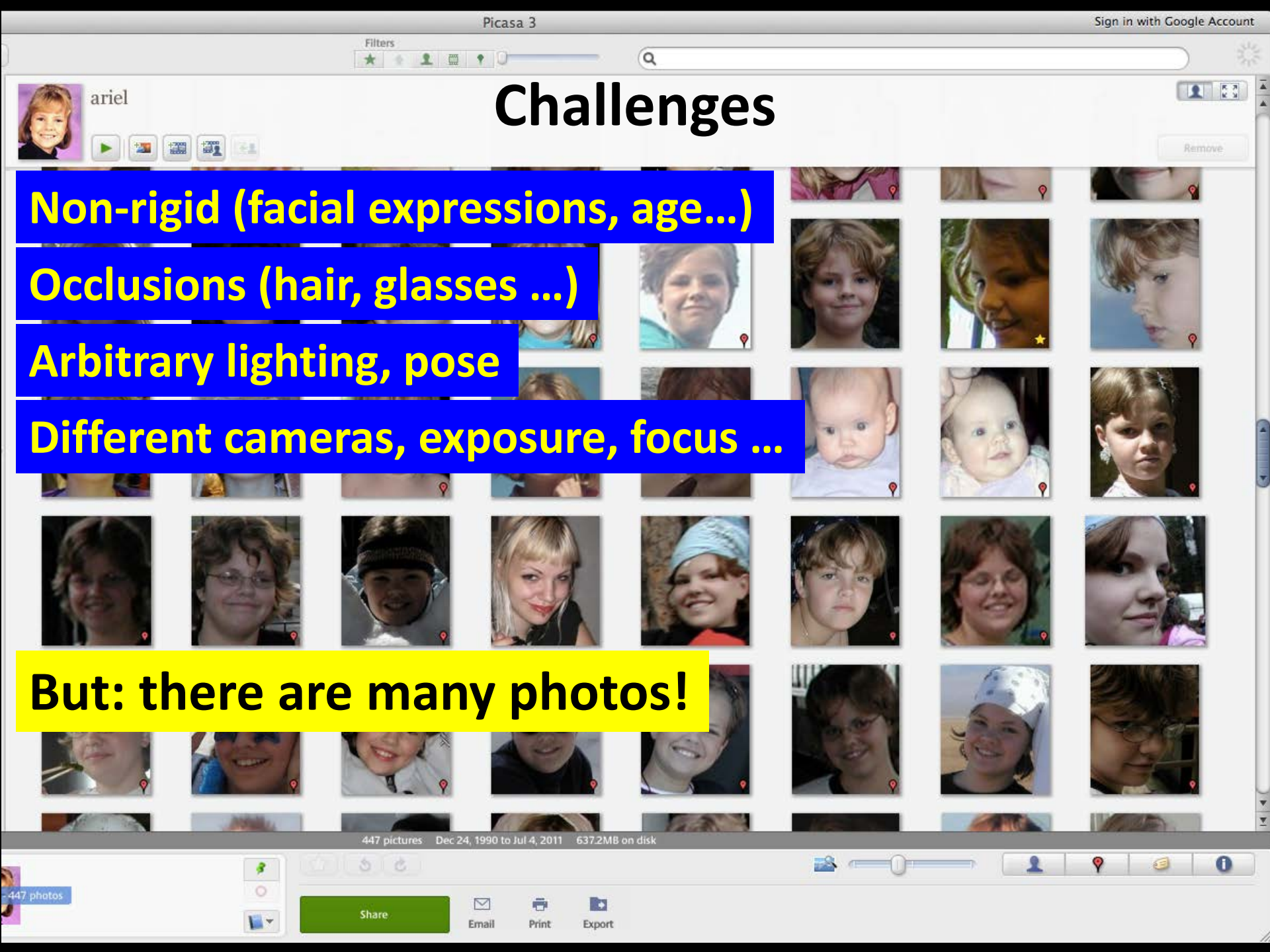
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
GEORGE BUSH
George_Bush.jpg
endevil.com
300 × 390 - George W Bush,
Denver, CO. Aug. 14, 2001.
Similar - More sizes
www.google.com/imgres?hl=en&sa=X&gbv=2&biw=1438&bih=806&tbm=isch&tbnid=OXLWQjn6EAnHwM:&imgrefurl=http://www.endevil.com/Bushquotes.html&docid=9cUkntf2KVou9M&imgurl=http://www.endevil.com/images/George_Bush.jpg&w=300&h=390&...

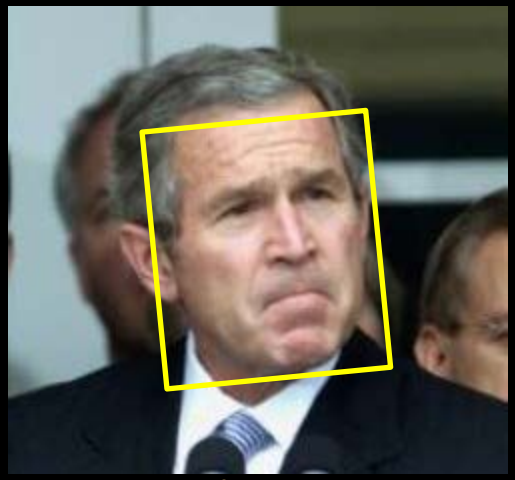

Picasa 3
Sign in with Google Account
Filters
ariel
Challenges
Non-rigid (facial expressions, age…)
Occlusions (hair, glasses …)
Arbitrary lighting, pose
Different cameras, exposure, focus …
But: there are many photos!
447 pictures Dec 24, 1990 to Jul 4, 2011 637.2MB on disk
447 photos
Share
Email
Print
Export

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

Image registration



Face detection

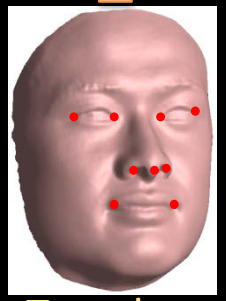
Bourdev and Brandt '05

Fiducial points detection

Everingham et al. '06

2D registration

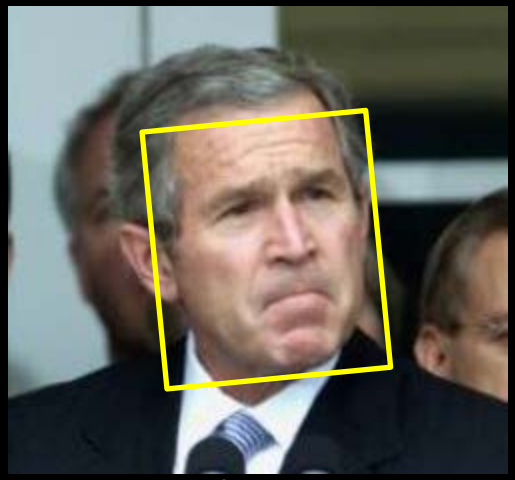
Estimate 3D pose



Template 3D model

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

Image registration



Face detection

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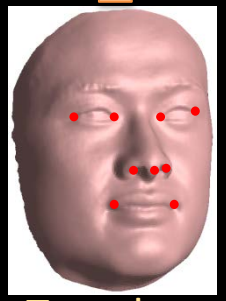


Template 3D model

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**

Dreambit

Transfiguring Portraits

Ira Kemelmacher-Shlizerman*
Computer Science and Engineering, University of Washington

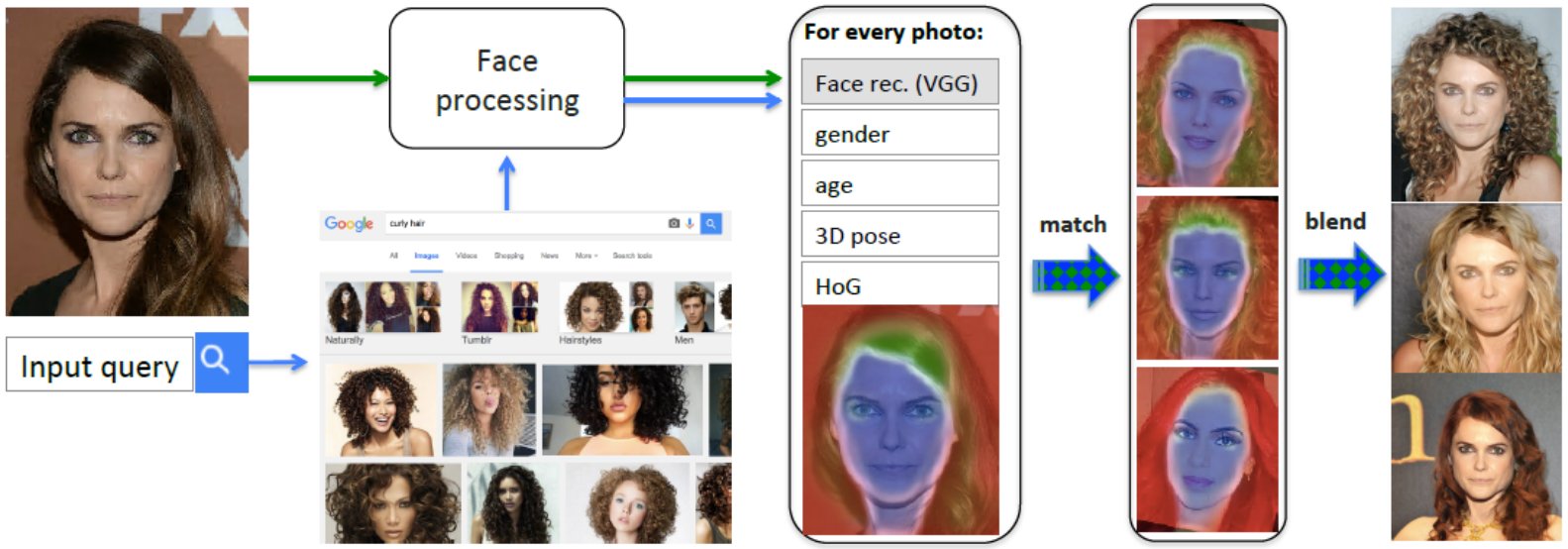


Figure 2: *Illustration of our system. The system gets as input a photo and a text query. The text query is used to search a web image engine. The retrieved photos are processed to compute a variety of face features and skin and hair masks, and ranked based on how well they match to the input photo. Finally, the input face is blended into the highest ranked candidates.*

https://www.youtube.com/watch?v=mILLFK1Rwhk

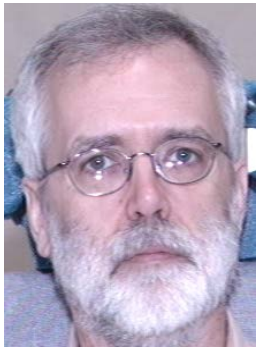
Illumination-Aware Age Progression

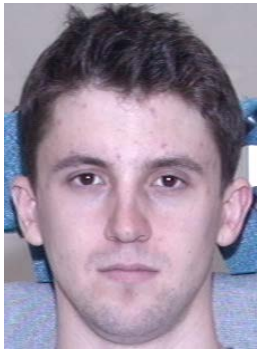
CVPR 2014

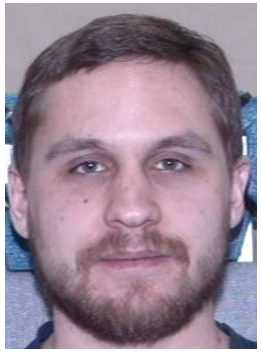
Ira Kemelmacher-Shlizerman, Supasorn Suwajanakorn, Steven M. Seitz

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

Image-Based Shaving





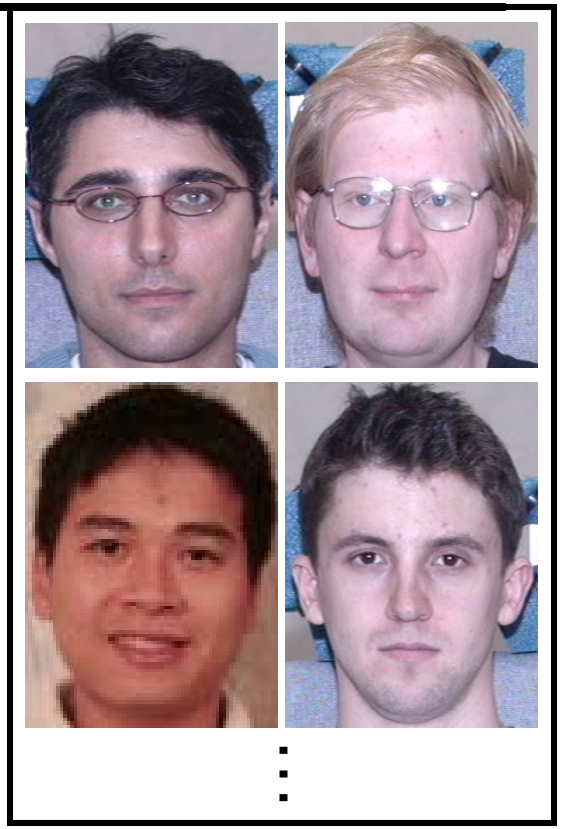
http://graphics.cs.cmu.edu/projects/imageshaving/

Nguyen et al., 2008

The idea

Differences
???

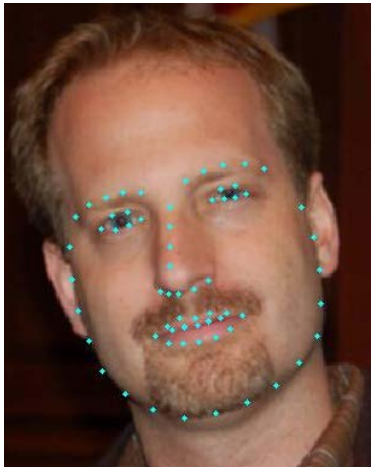
Beard Layer
Model



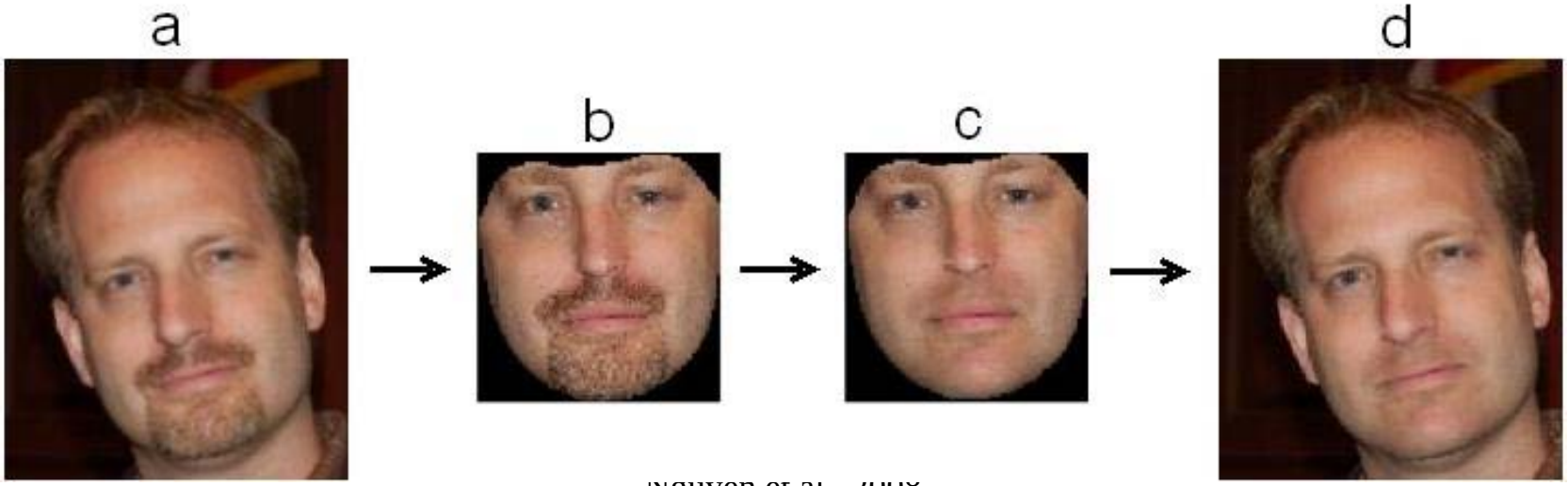
+

Nguyen et al., 2008

Processing steps



68 landmarks



Nguyen et al., 2008

Some results