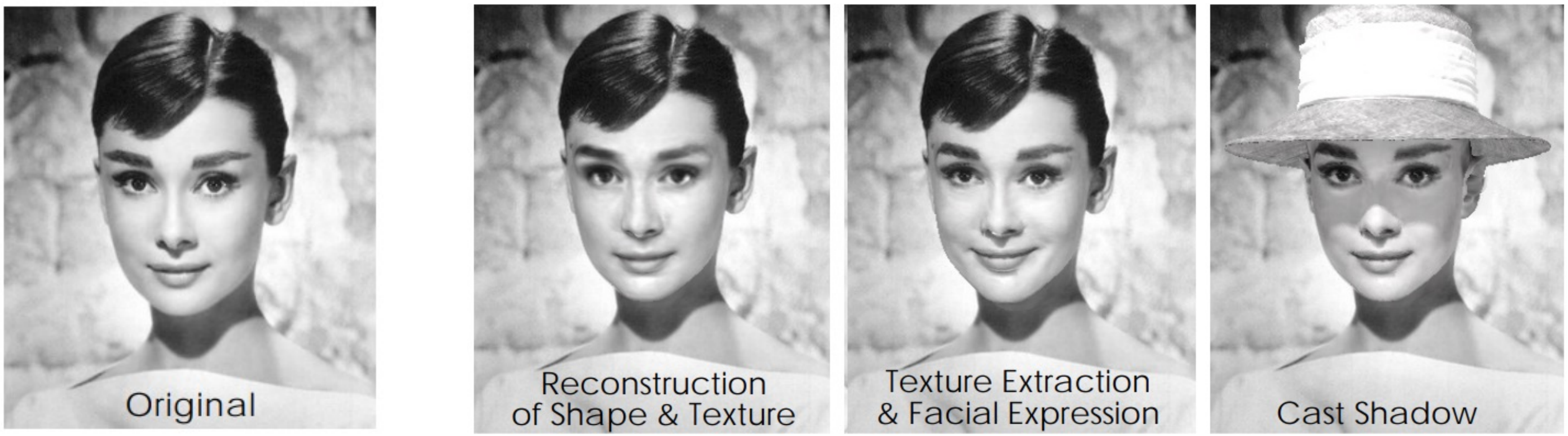


Face modeling (part I)

Jun-Yan Zhu

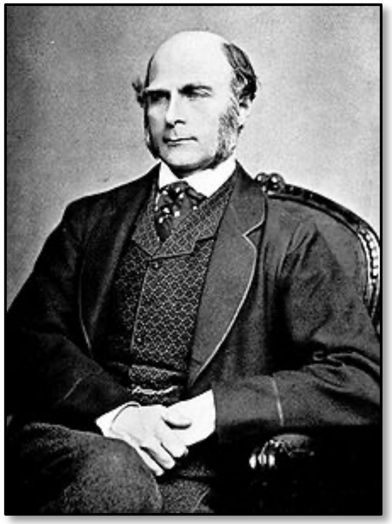
16-726 Learning-based Image Synthesis, Spring 2022

Slides adopted from Alexei A. Efros

Why Human Faces?

- Face is an important subject.
  - We are humans.
  - Many commercial applications.
- Lots of useful tools
  - 3D data: geometry-based synthesis.
  - 2D/3D Computer vision works for faces.

Image Composites



Sir Francis Galton 1822-1911

Multiple Individuals

Composite

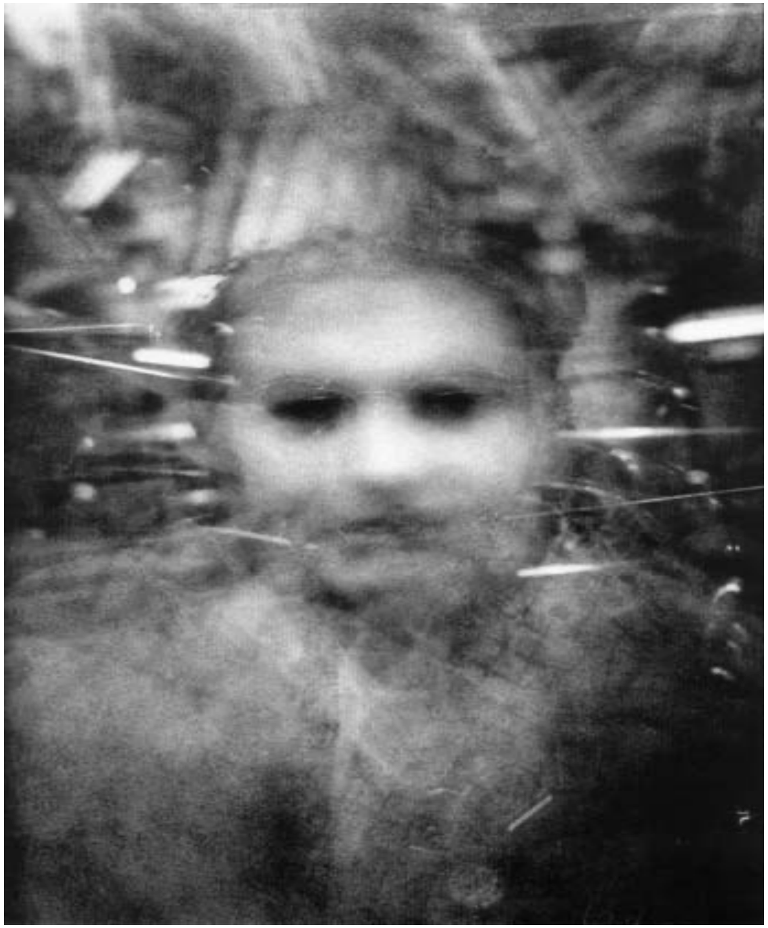
[Galton, “Composite Portraits”, Nature, 1878]

The Power of Averaging

8-hour exposure

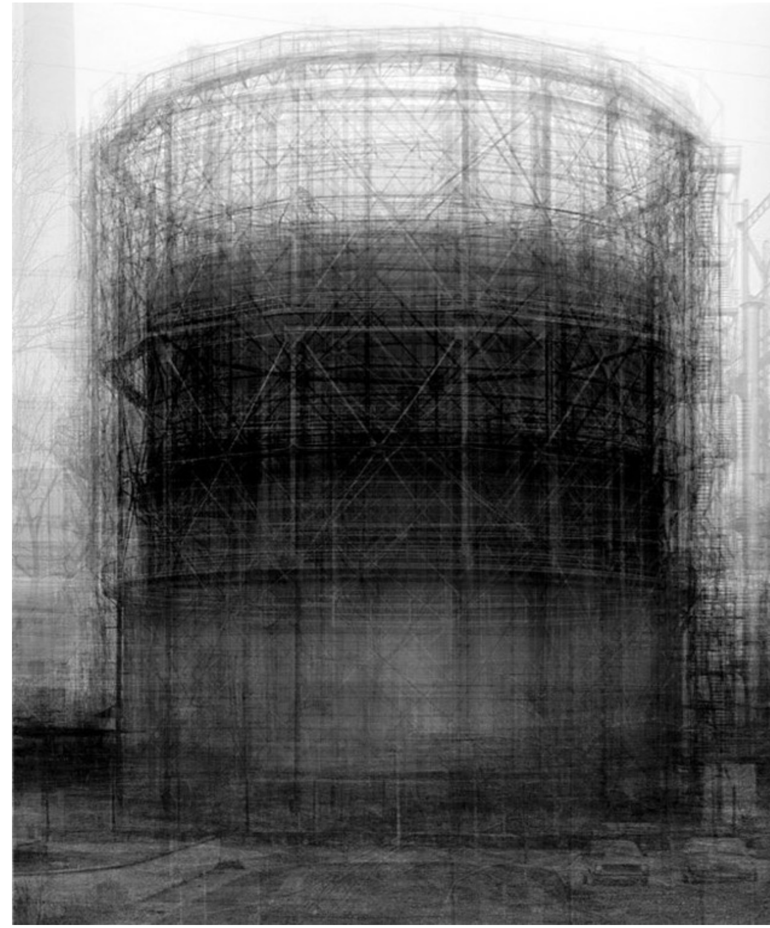
© Atta Kim

Average Images in Art



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

Krzysztof Pruszkowski

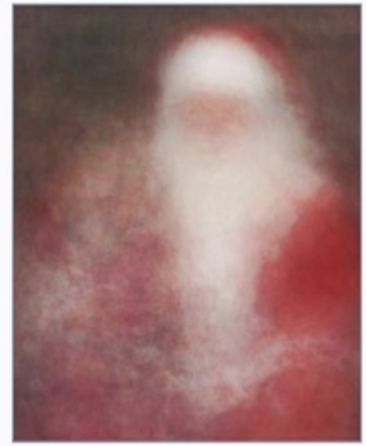


"Spherical type gasholders" (2004)

Idris Khan

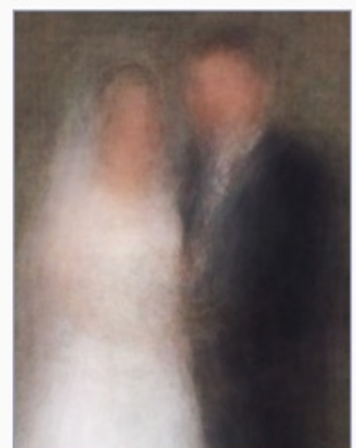
“100 Special Moments” by Jason Salavon

Little Leaguer



Kids with Santa

The Graduate

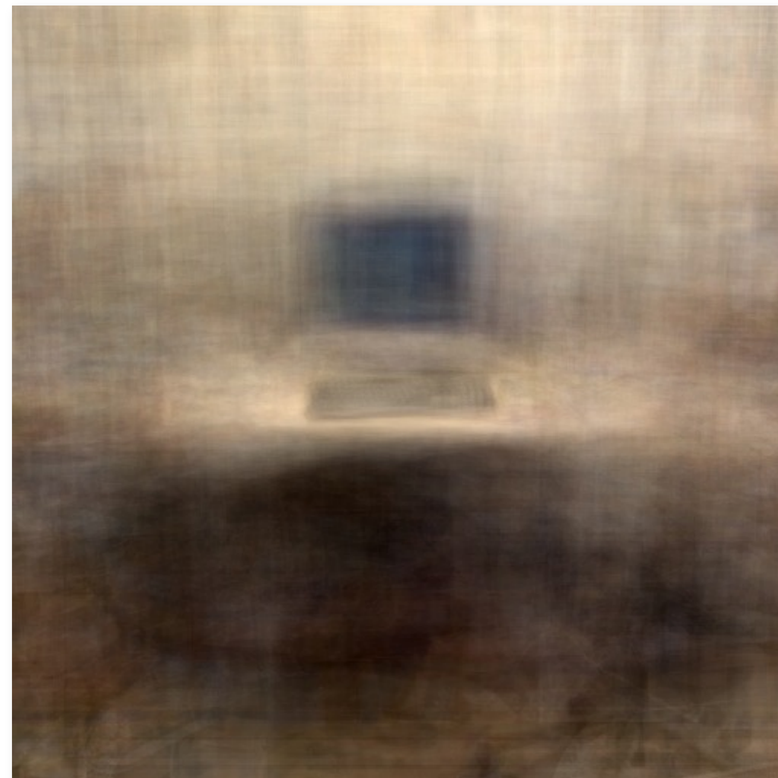


Newlyweds

Why blurry?

Object-Centric Averages by Torralba (2001)

Manual Annotation and Alignment



Average Image

Computing Means

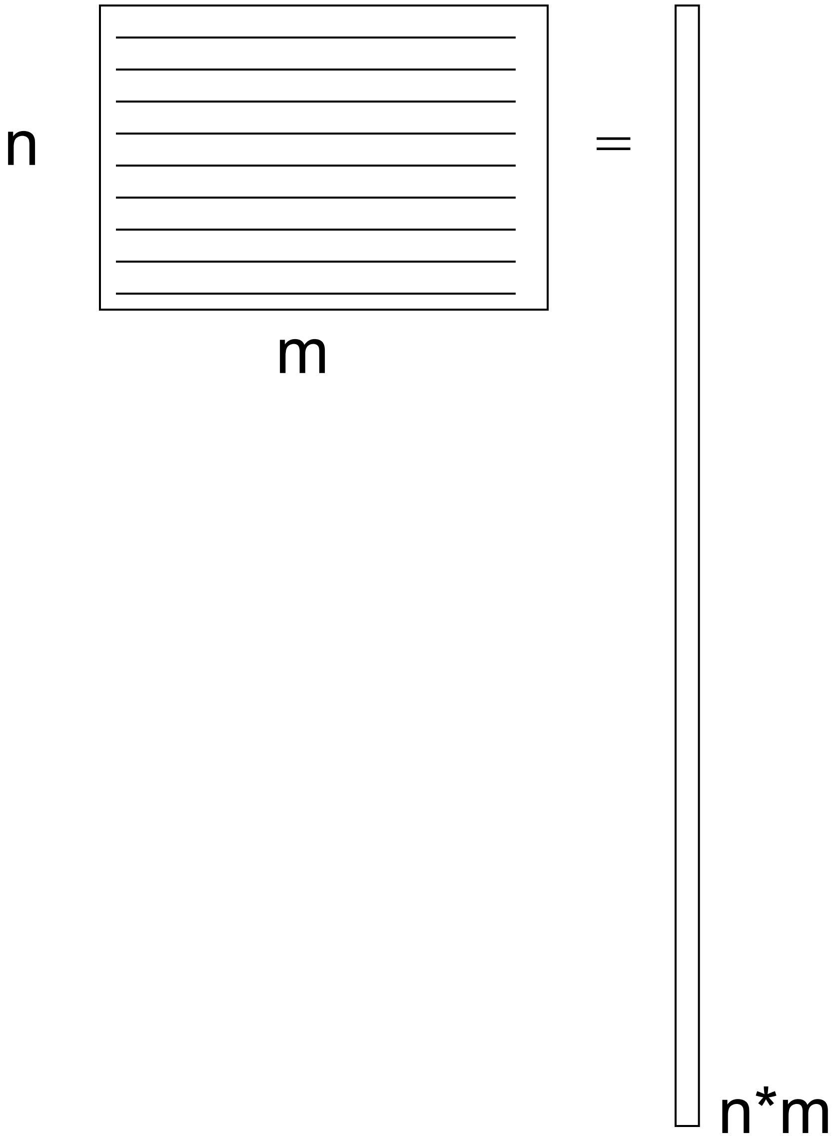
Two Requirements:

- Alignment of objects
- Objects must span a subspace

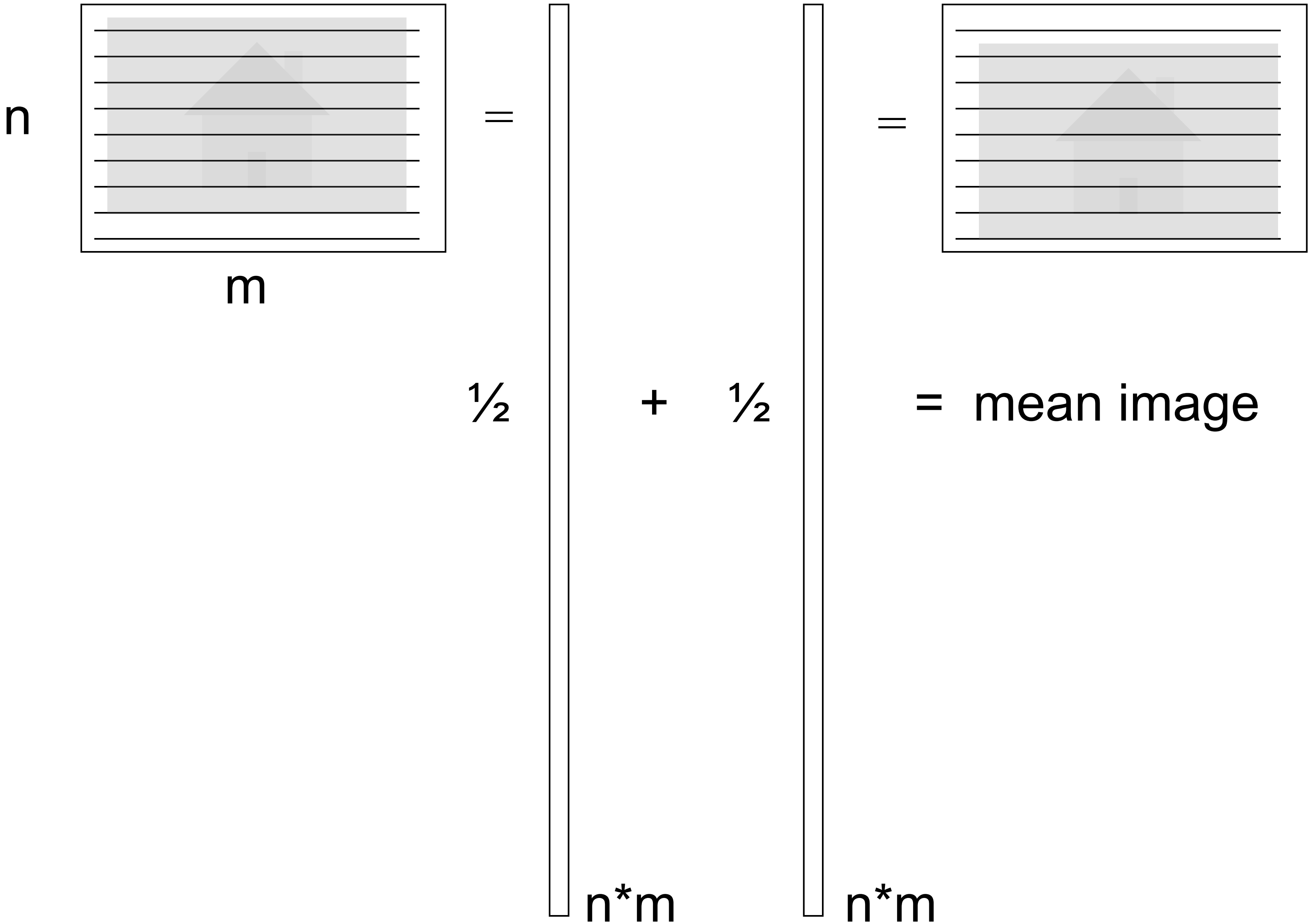
Useful concepts:

- Subpopulation means
- Deviations from the mean

Images as Vectors



Vector Mean: Importance of Alignment

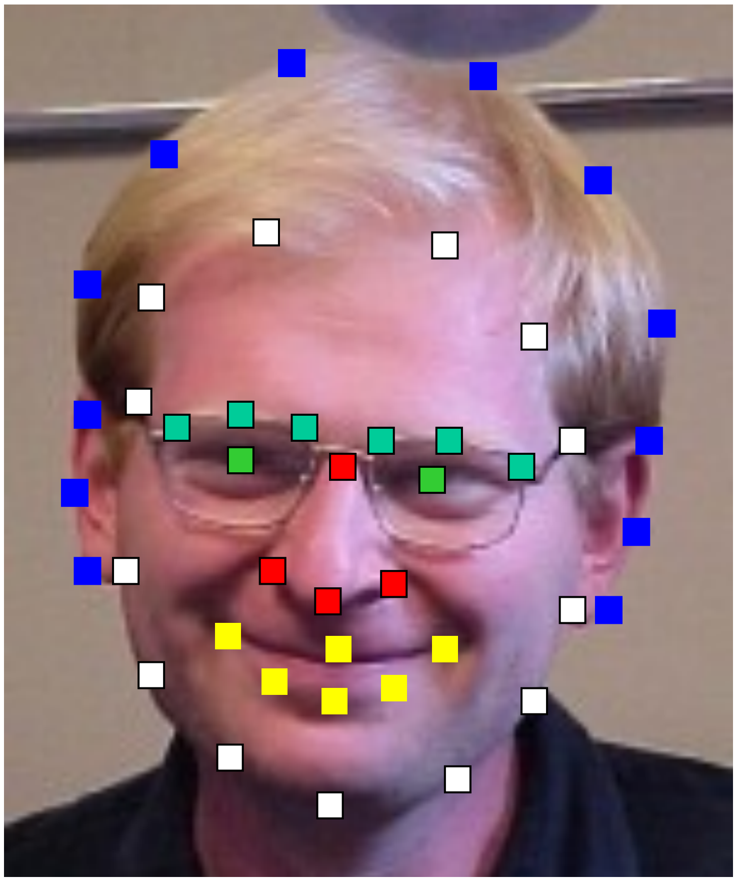


How to align faces?

Students and staff from Technical University of Denmark

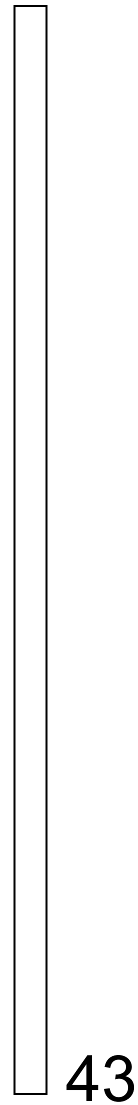
http://www2.imm.dtu.dk/~aam/datasets/datasets.html

Shape Vector



Landmark annotation

=



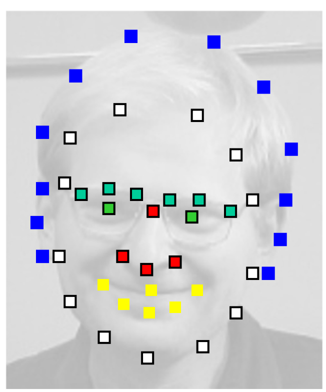
Appearance Vectors vs. Shape Vectors

Appearance Vector

200*150 pixels (RGB)

Vector of 200*150*3 Dimensions

Shape Vector



43 coordinates (x,y)

Vector of 43*2 Dimensions

- Manual annotation.

OR

- Face landmark detection.

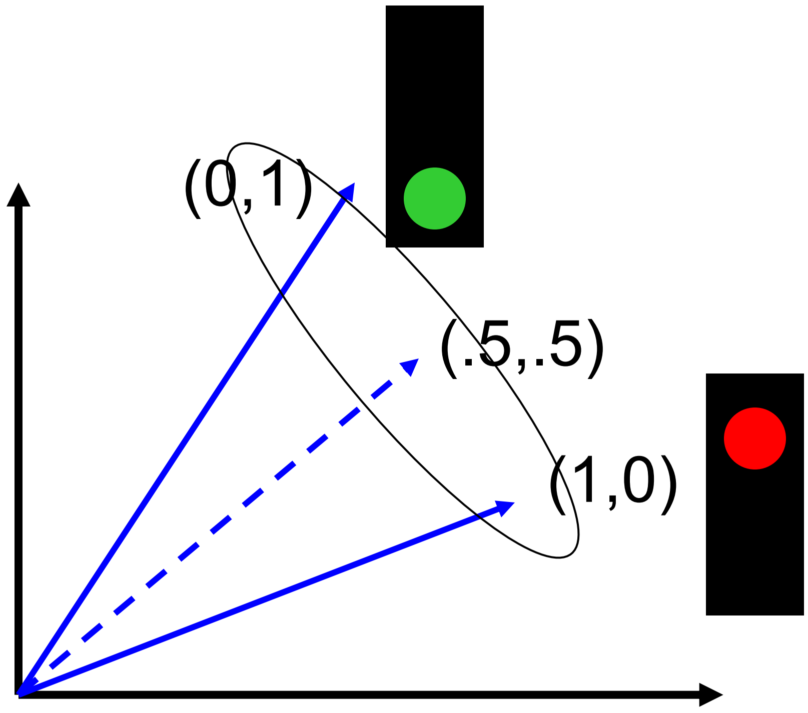
Slide by Kevin Karsch

Average Face

1. Warp to mean shape
2. Average pixels

Students and staff from Technical University of Denmark
http://graphics.cs.cmu.edu/courses/15-463/2004_fall/www/handins/brh/final/

Objects must span a subspace



Subpopulation means

Examples:

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

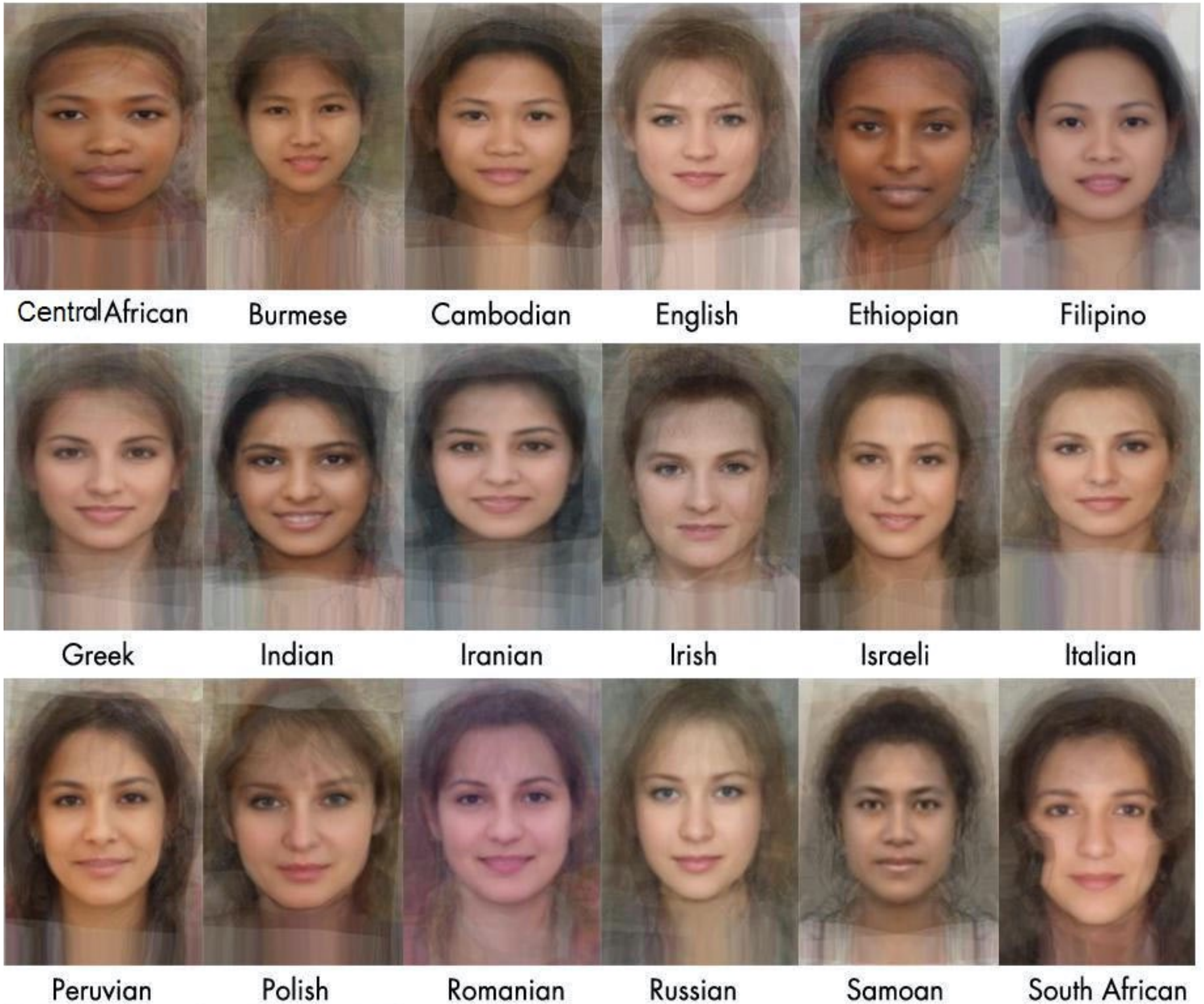
Average female

Average kid

Average happy male

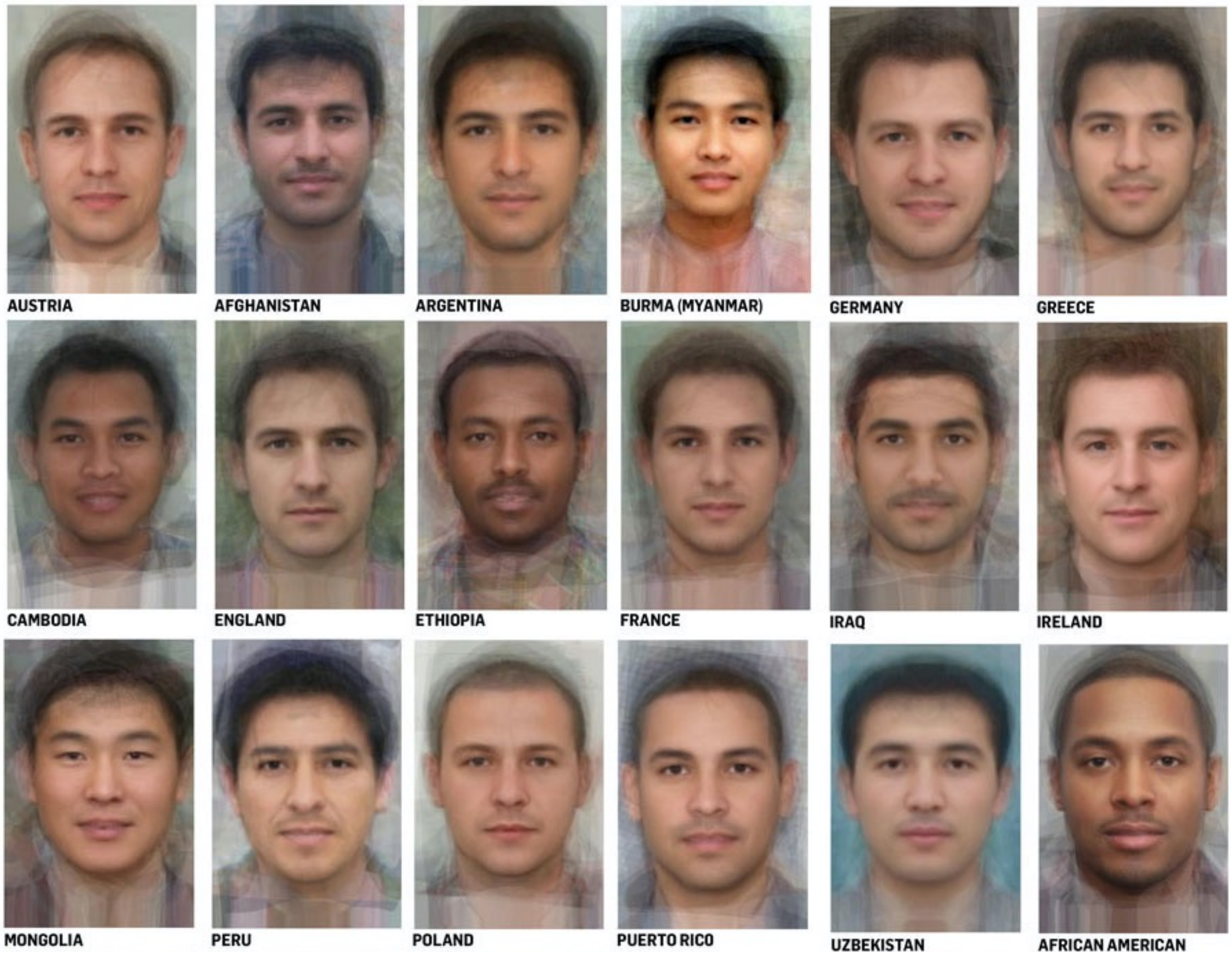
Average male

Average Women of the world



Several issues: 1. country ≠ race. 2. demographic diversity is lost. 3. bias in data source

Average Men of the world



Several issues: 1. country ≠ race. 2. demographic diversity is lost. 3. bias in data source

Deviations from the mean

Image X

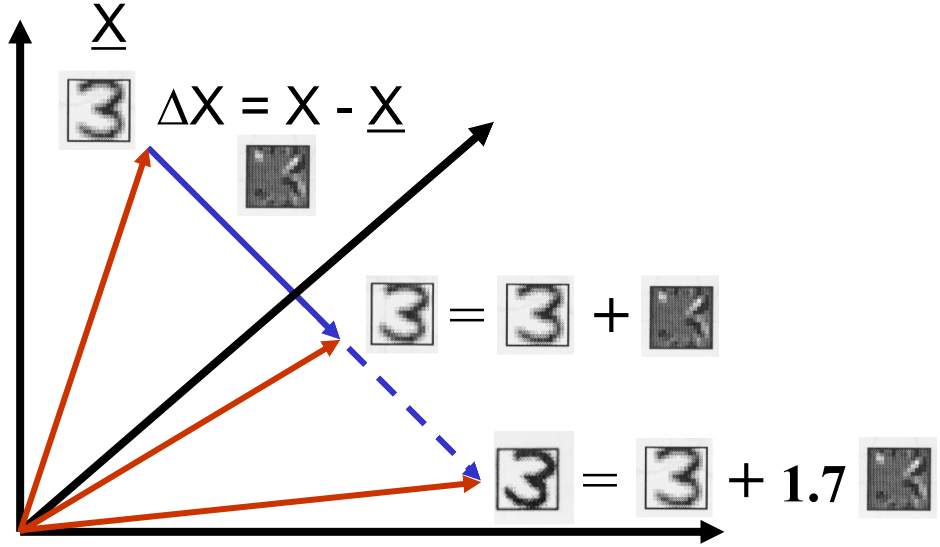
-

Mean $\underline{X}$

=

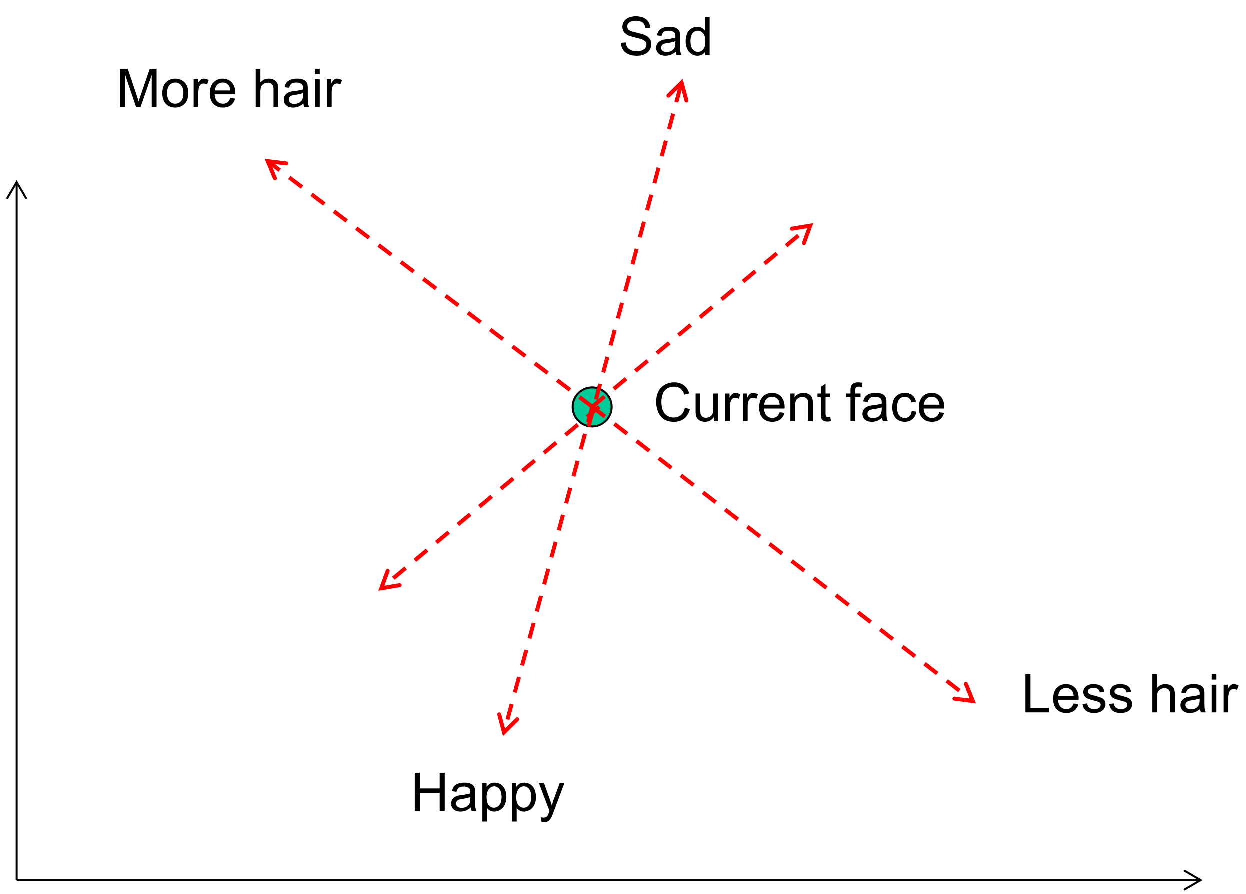
$\Delta X = X - \underline{X}$

Deviations from the mean



Extrapolating faces

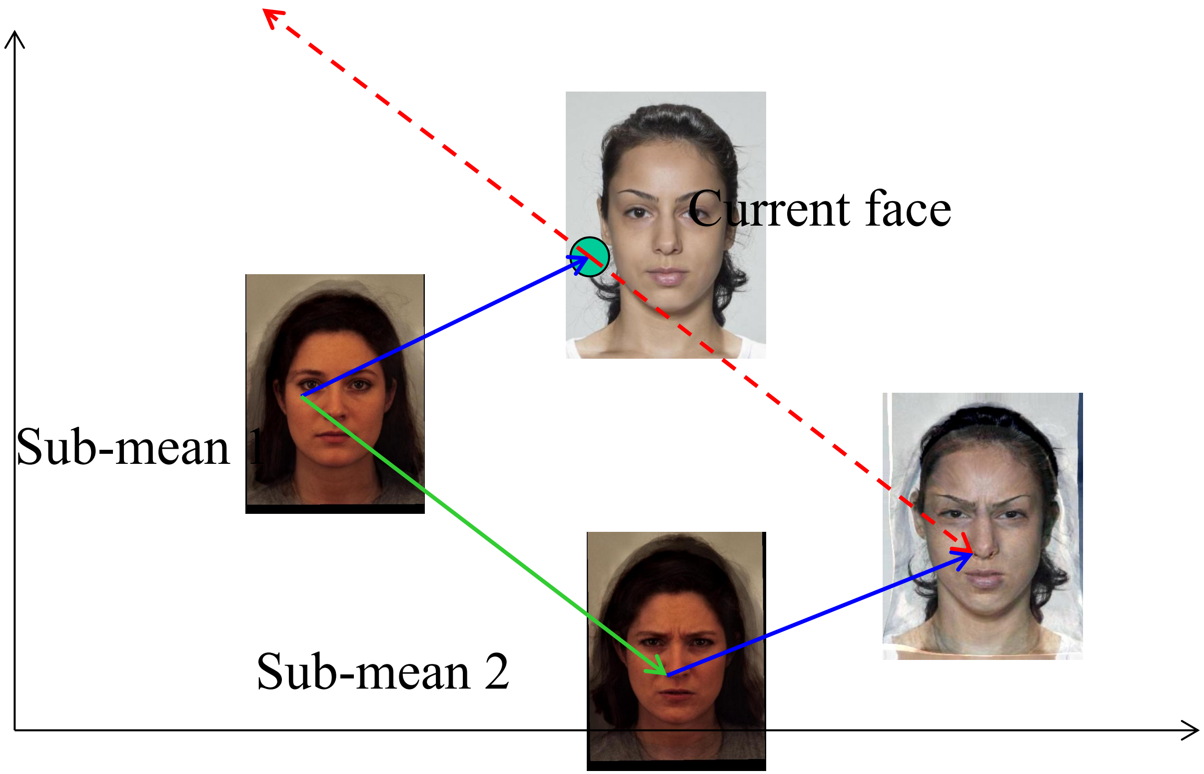
- We can imagine various meaningful directions.



Slide by Kevin Karsch

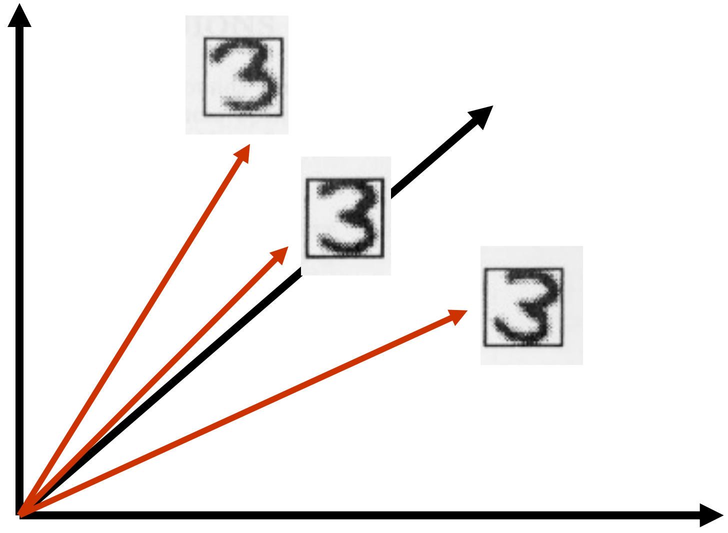
Manipulating faces

- How can we make a face look younger/older, or happy/sad, etc.?
- http://www.faceresearch.org/demos/transform

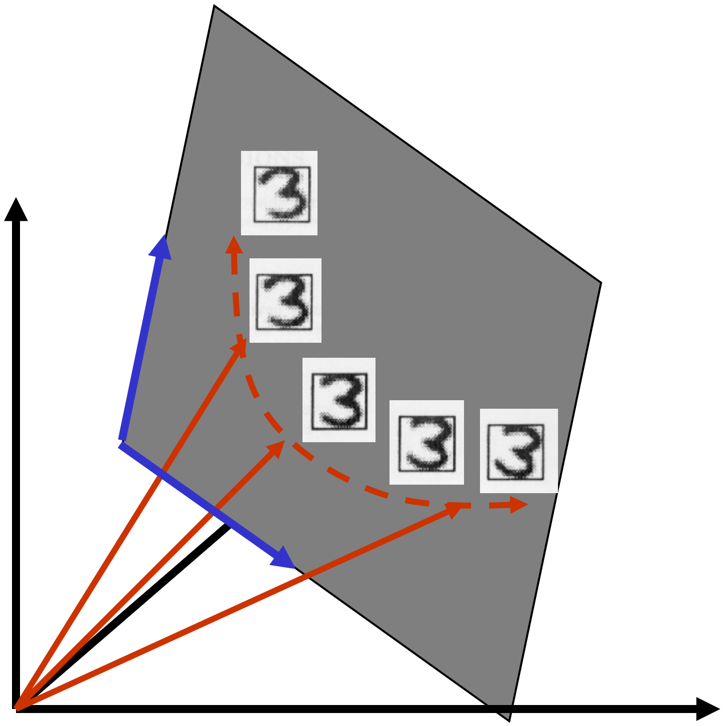


Slide by Kevin Karsch

Back to the Subspace



Linear Subspace: convex combinations



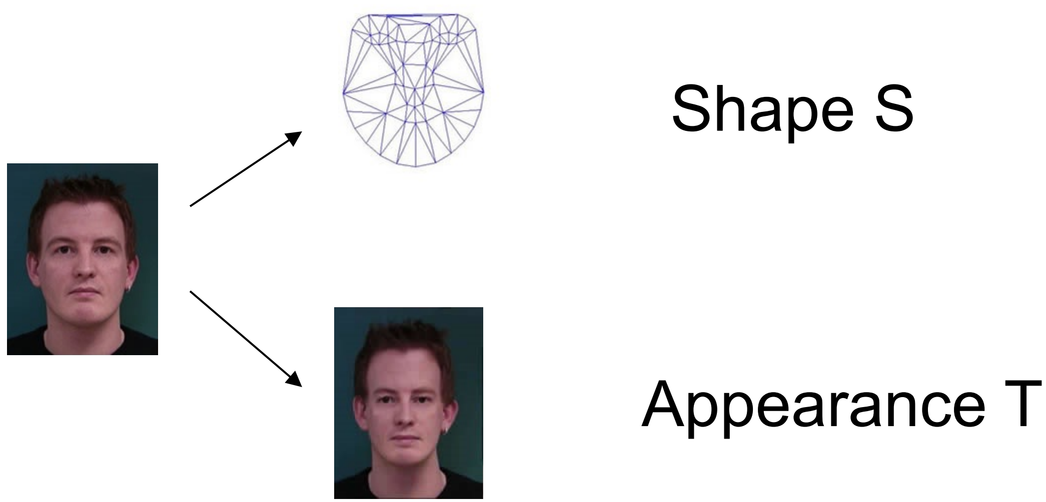
Any new image X can be obtained as weighted sum of stored “basis” images.

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

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

The Morphable Face Model

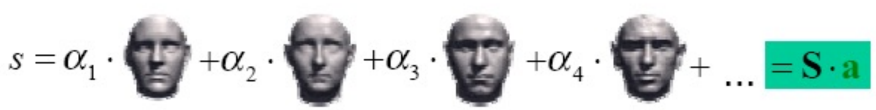
The actual structure of a face is captured in the shape vector **S** = $(x_1, y_1, x_2, \ldots, y_n)^T$, containing the (x, y) coordinates of the n vertices of a face, and the appearance (texture) vector **T** = $(R_1, G_1, B_1, R_2, \ldots, G_n, B_n)^T$, containing the color values of the mean-warped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

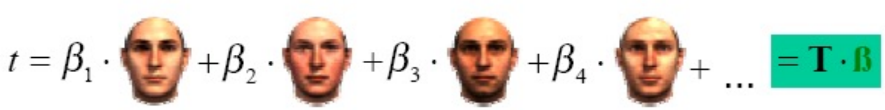


The Morphable face model

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:

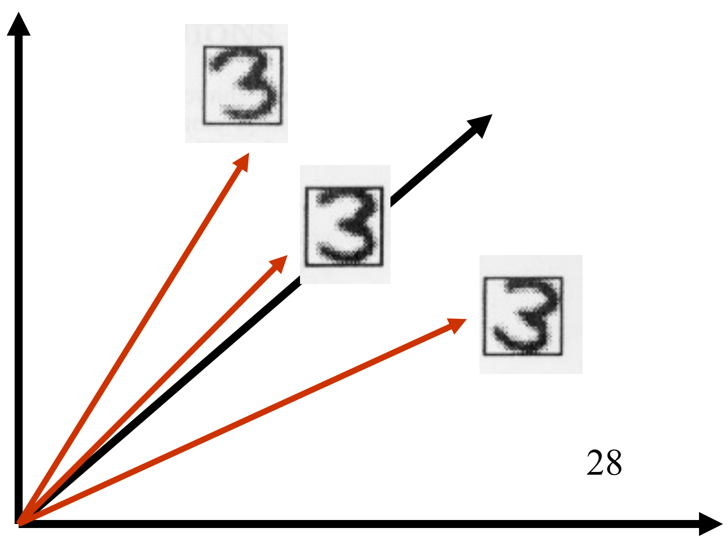
<u>Any new</u> face can be represented as a pair of vectors $(\alpha_1, \alpha_2, \ldots, \alpha_m)^T$ and $(\beta_1, \beta_2, \ldots, \beta_m)^T$!

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!

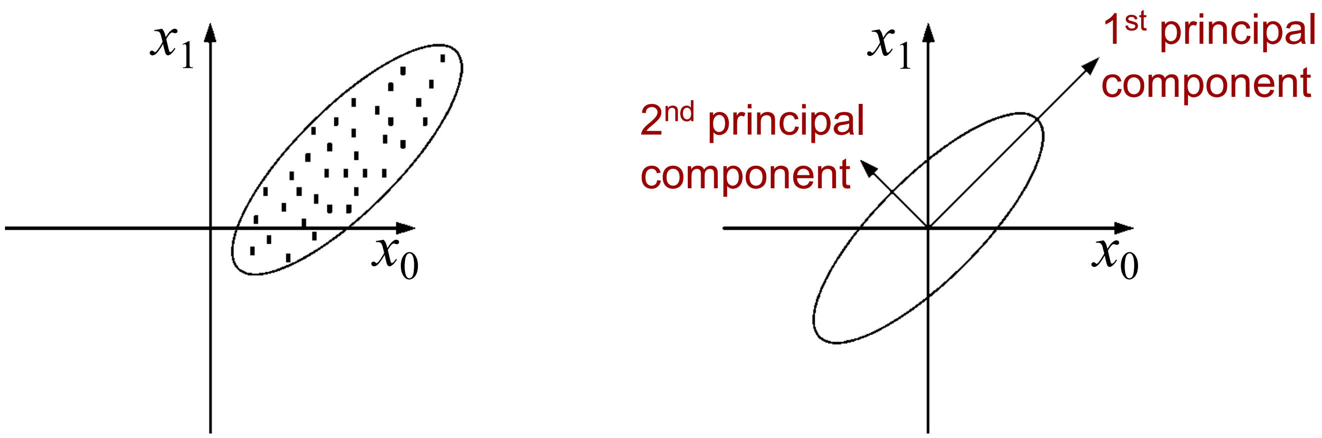
But what's important?



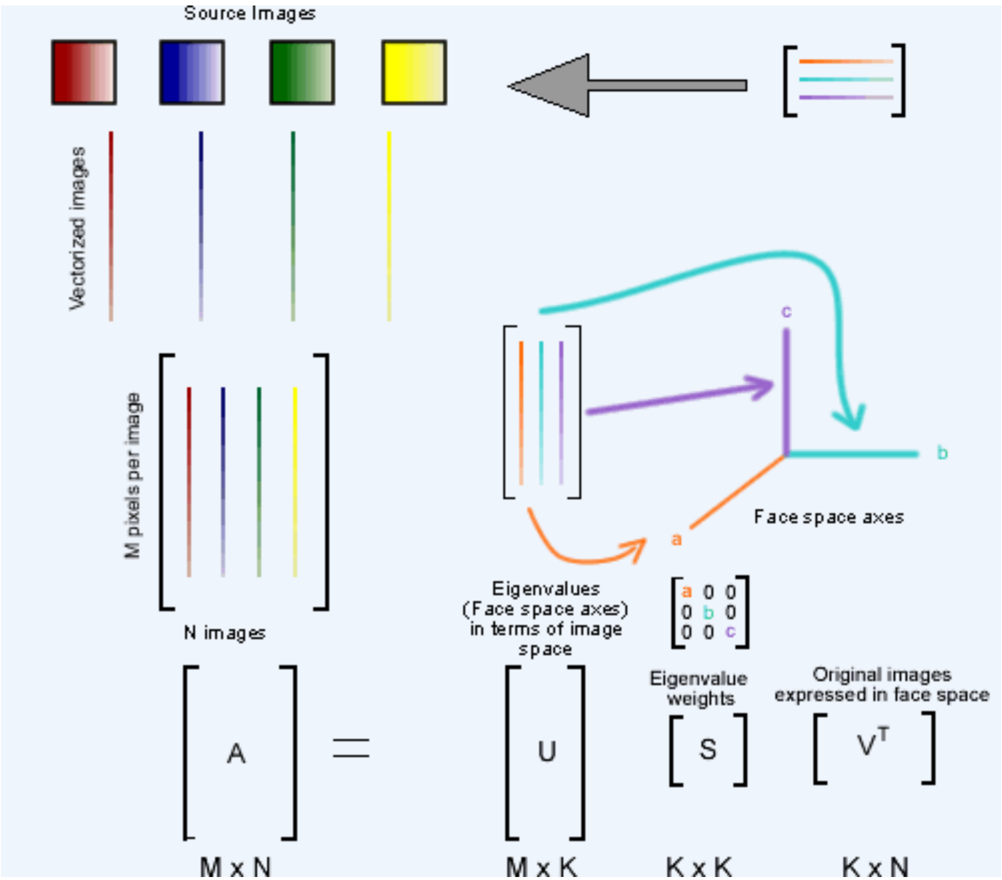
Principal Component Analysis

Given a point set $\{\vec{\mathrm{p}}_j\}_{j=1\ldots P}$, 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



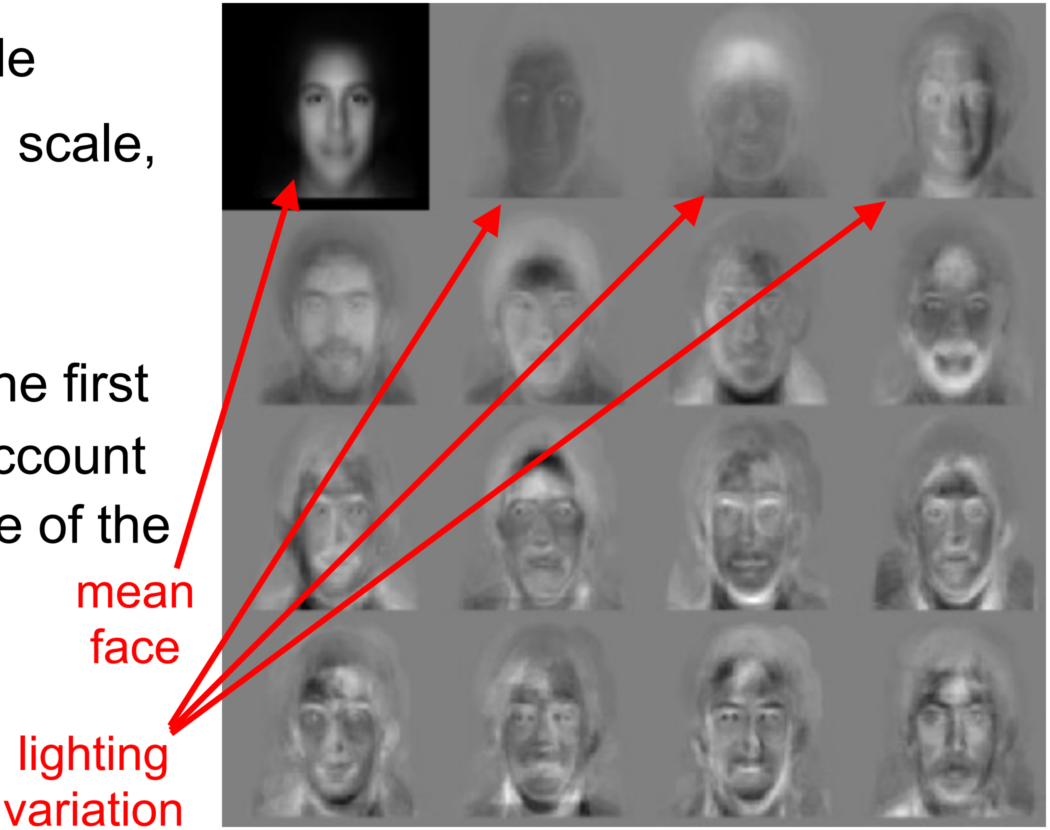
[u,s,v] = svd(A);

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

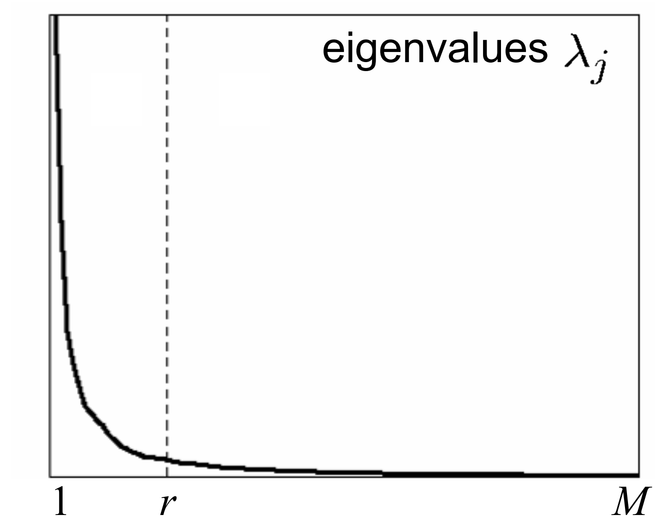
Mean appearance

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

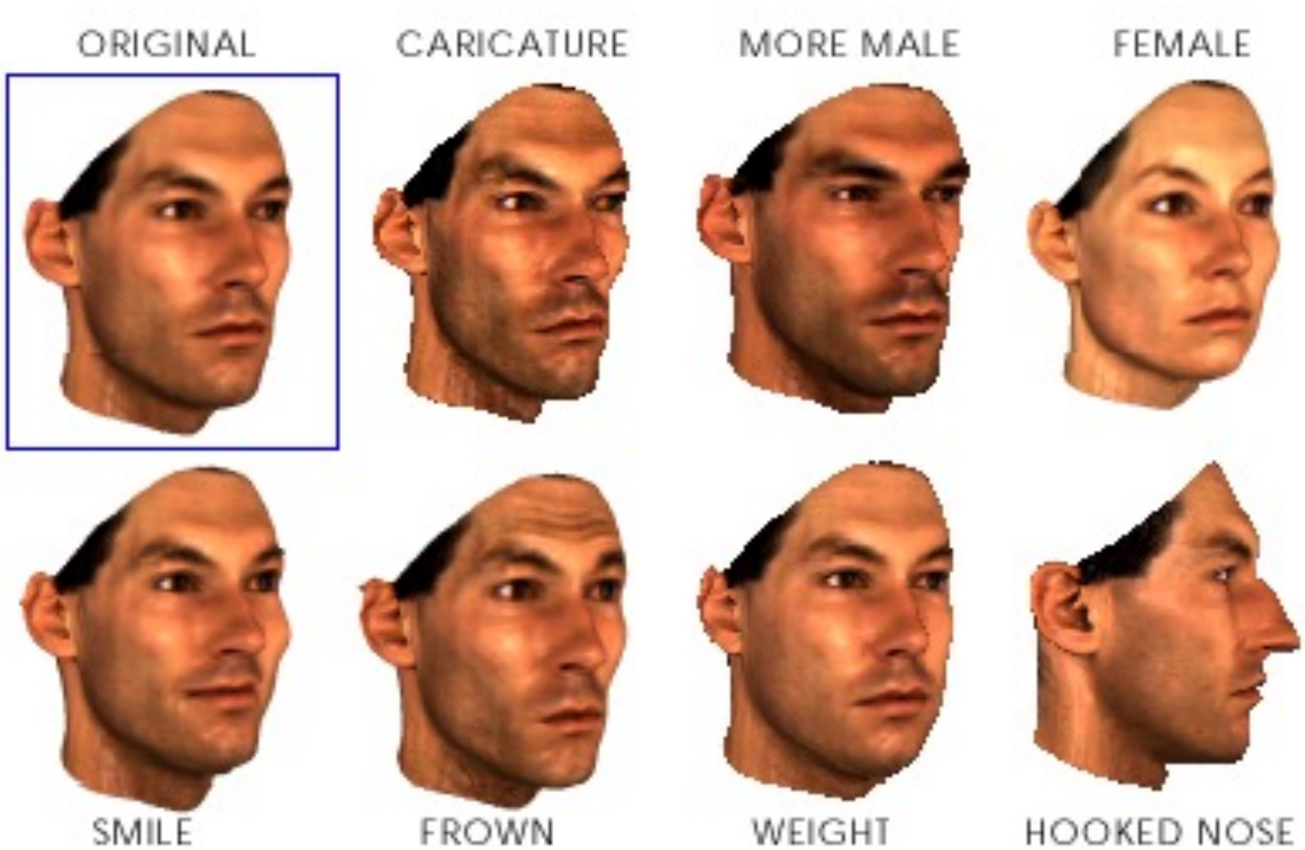
Principal Component Analysis

Choosing subspace dimension r:

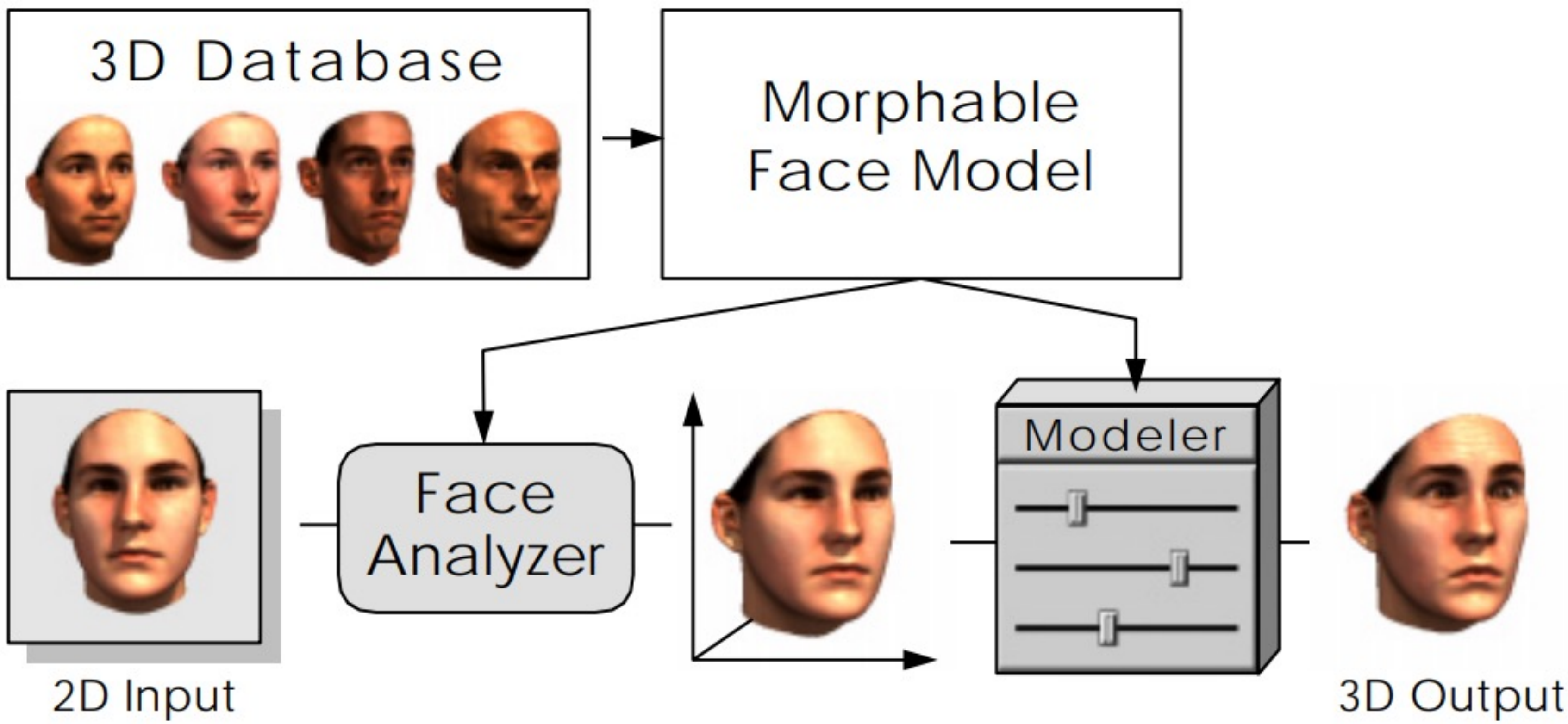
- look at decay of the eigenvalues as a function of r
- Larger r means lower expected error in the subspace data approximation



Using 3D Geometry: Blinz & Vetter, 1999



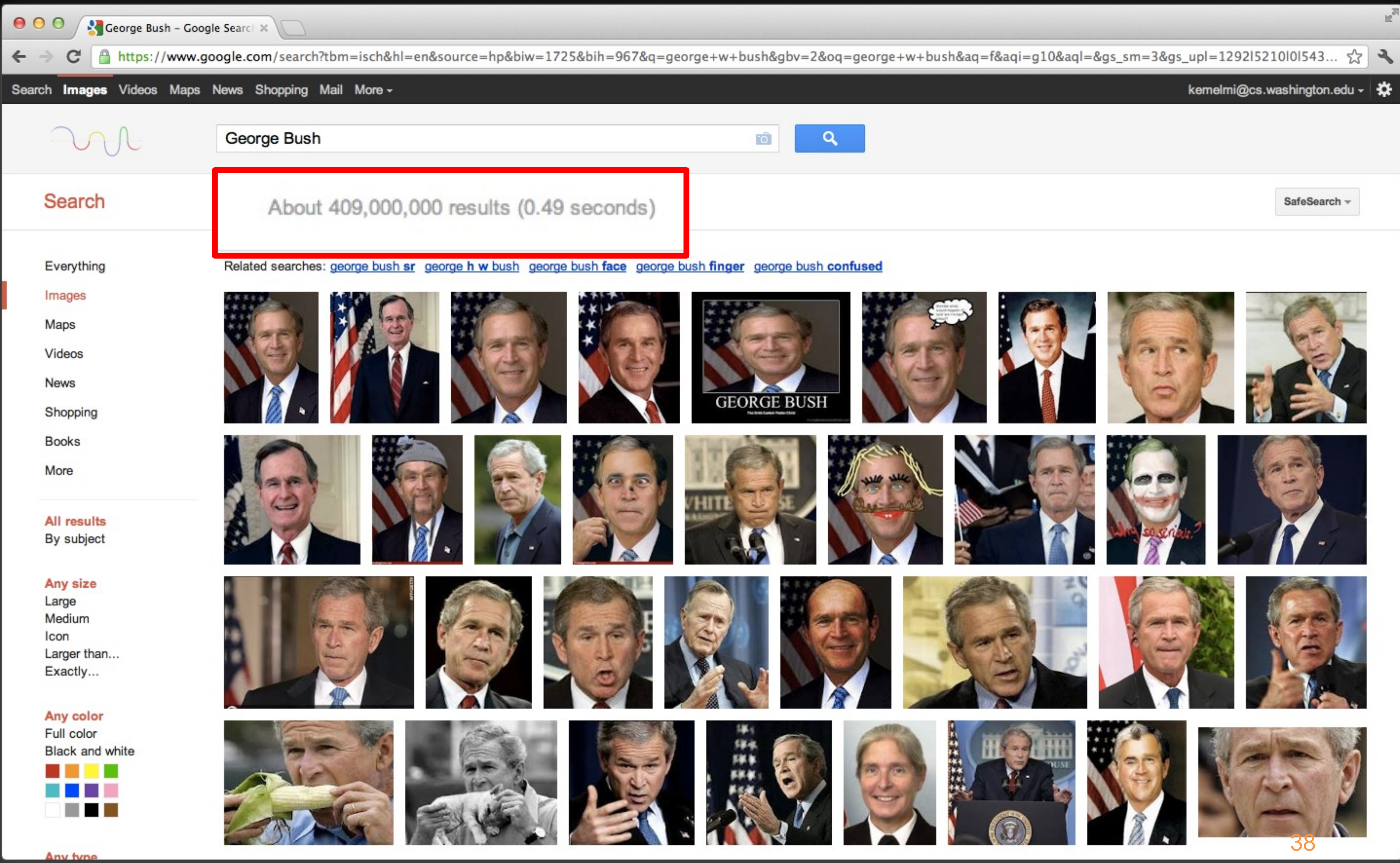
Using 3D Geometry: Blinz & Vetter, 1999



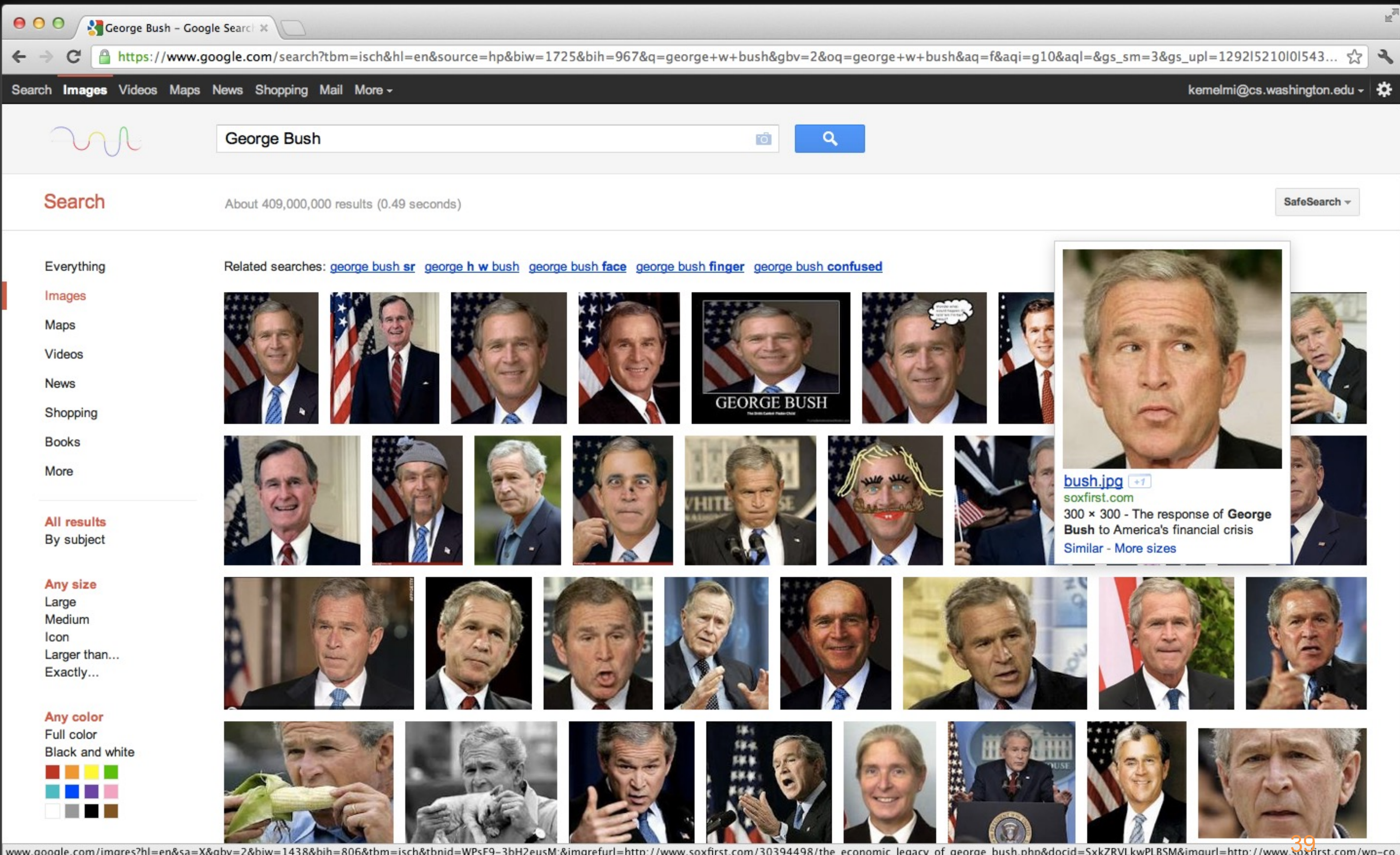
Using 3D Geometry: Blinz & Vetter, 1999

Face + Internet Images

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

Photobio


George Bush - Google Search
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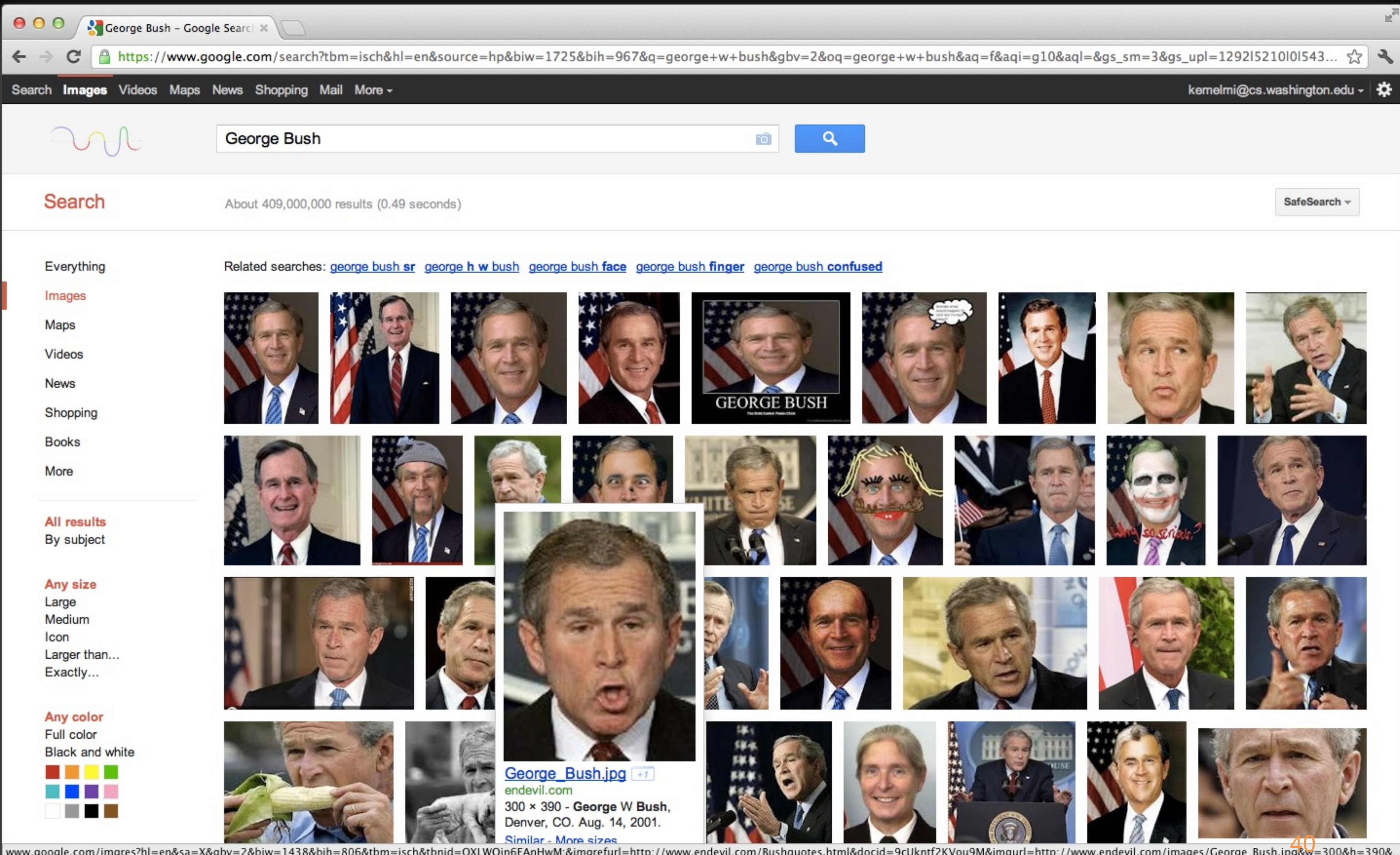
Search Images Videos Maps News Shopping Mail More
kemelmi@cs.washington.edu
George Bush
Search
About 409,000,000 results (0.49 seconds)
SafeSearch
Everything
Images
Maps
Videos
News
Shopping
Books
More
All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
Full color
Black and white
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
GEORGE BUSH
bush.jpg
soxfirst.com
300 × 300 - The response of George Bush to America's financial crisis
Similar - More sizes
www.google.com/imgres?hl=en&sa=X&gbv=2&biw=1438&bih=806&tbm=isch&tbnid=WPsF9-3bH2eusM:&imgrefurl=http://www.soxfirst.com/30394498/the_economic_legacy_of_george_bush.php&docid=SxkZRVLkwPLBSM&imgurl=http://www.soxfirst.com/wp-co...

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
Related searches: george bush sr george h w bush george bush face george bush finger george bush confused
All results
By subject
Any size
Large
Medium
Icon
Larger than...
Exactly...
Any color
Full color
Black and white
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&...

Challenges

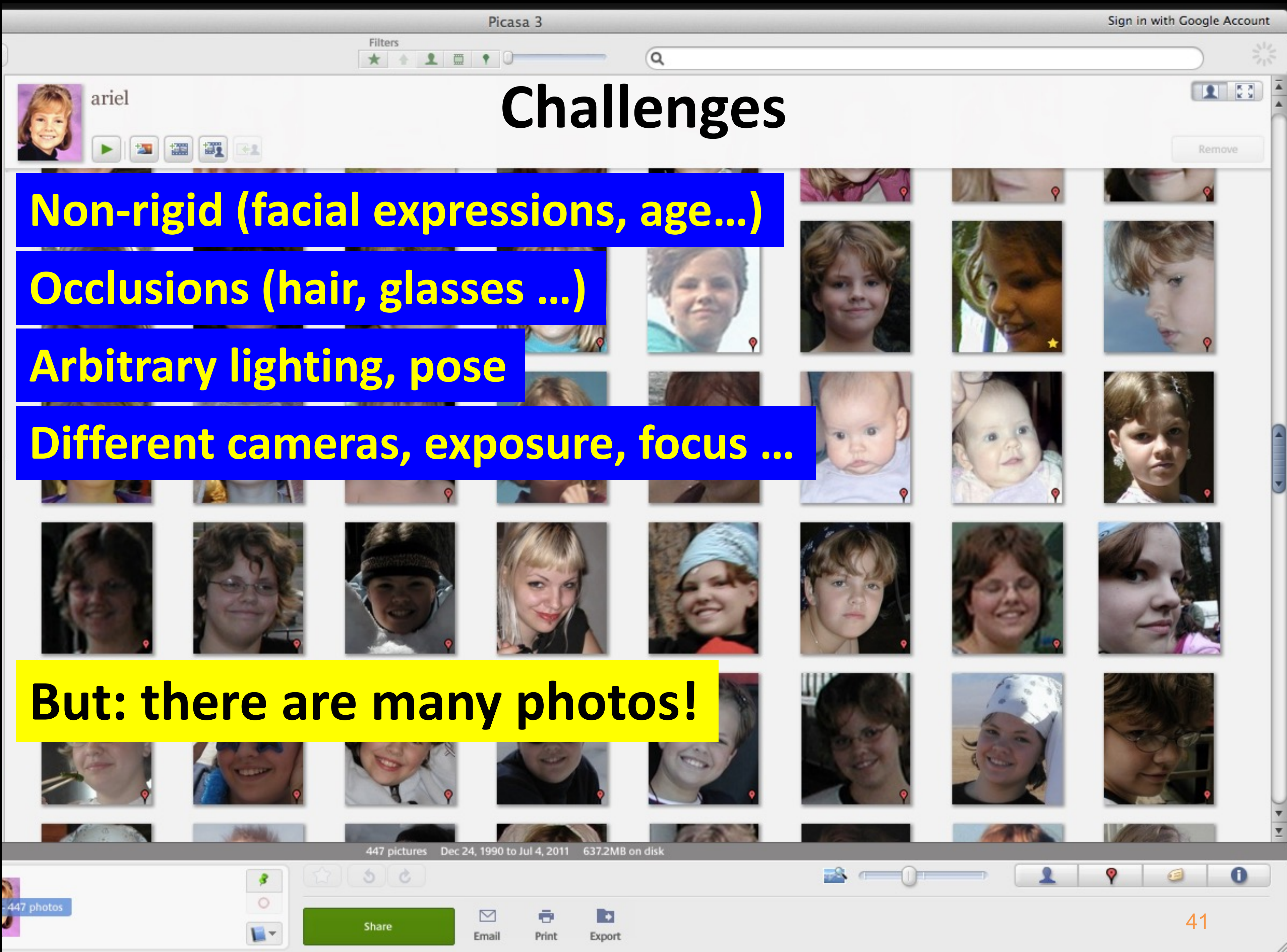
Non-rigid (facial expressions, age…)

Occlusions (hair, glasses …)

Arbitrary lighting, pose

Different cameras, exposure, focus …

But: there are many photos!



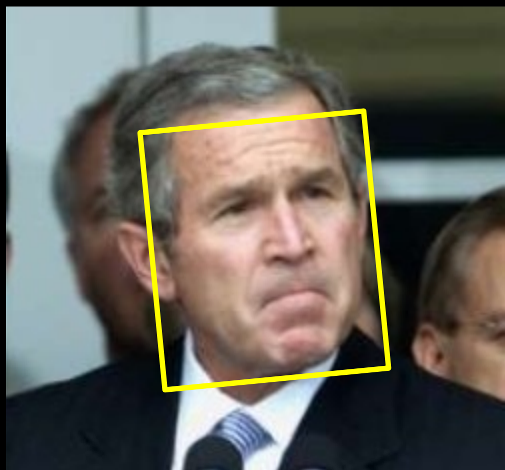
Walking in the Face-graph!

Source Automatically generated transition Target

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

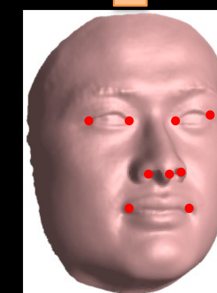


Face detection
Bourdev and Brandt '05

Fiducial points detection
Everingham et al. '06

2D registration

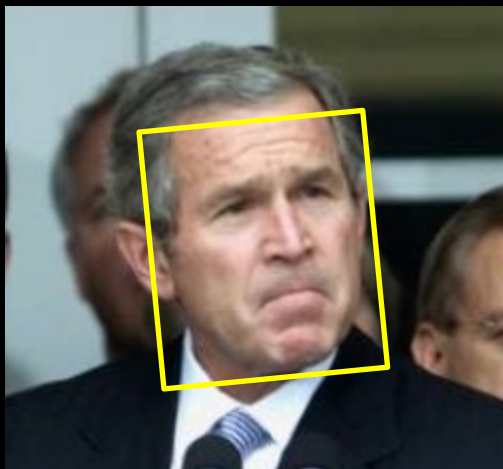
Estimate 3D pose



Template 3D model

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

Image registration

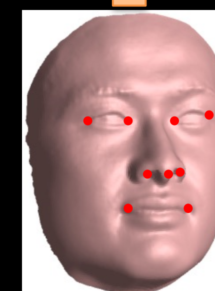


Face detection
Bourdev and Brandt '05

Fiducial points detection
Everingham et al. '06

3D registration

Estimate 3D pose



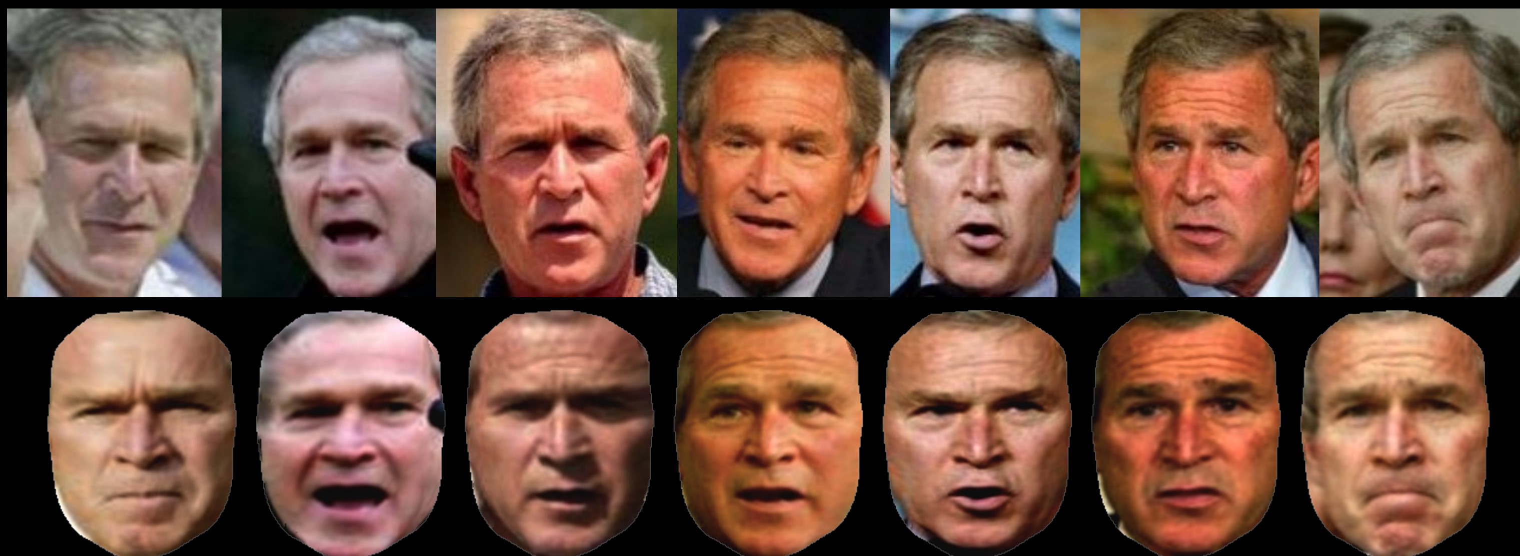
Template 3D model

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

3D transformed photos

before …

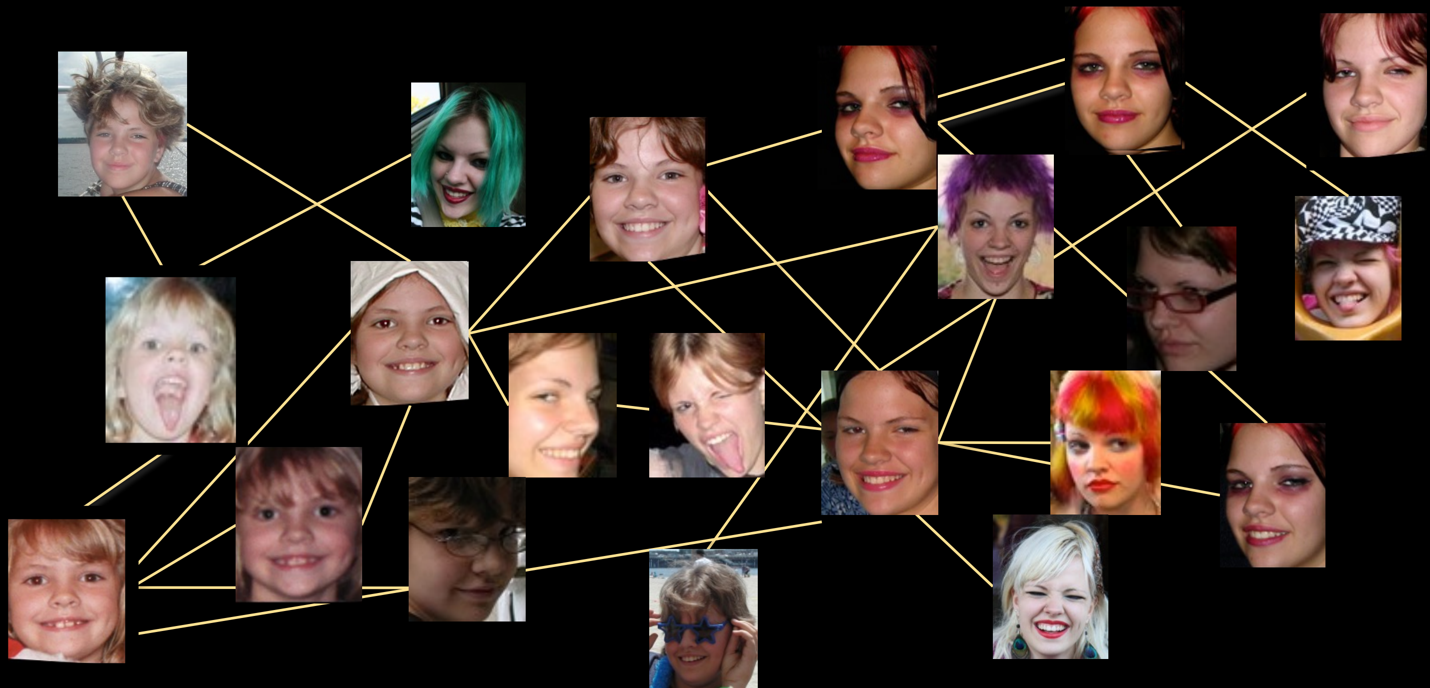
after …



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**

Dreambit

Transfiguring Portraits

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

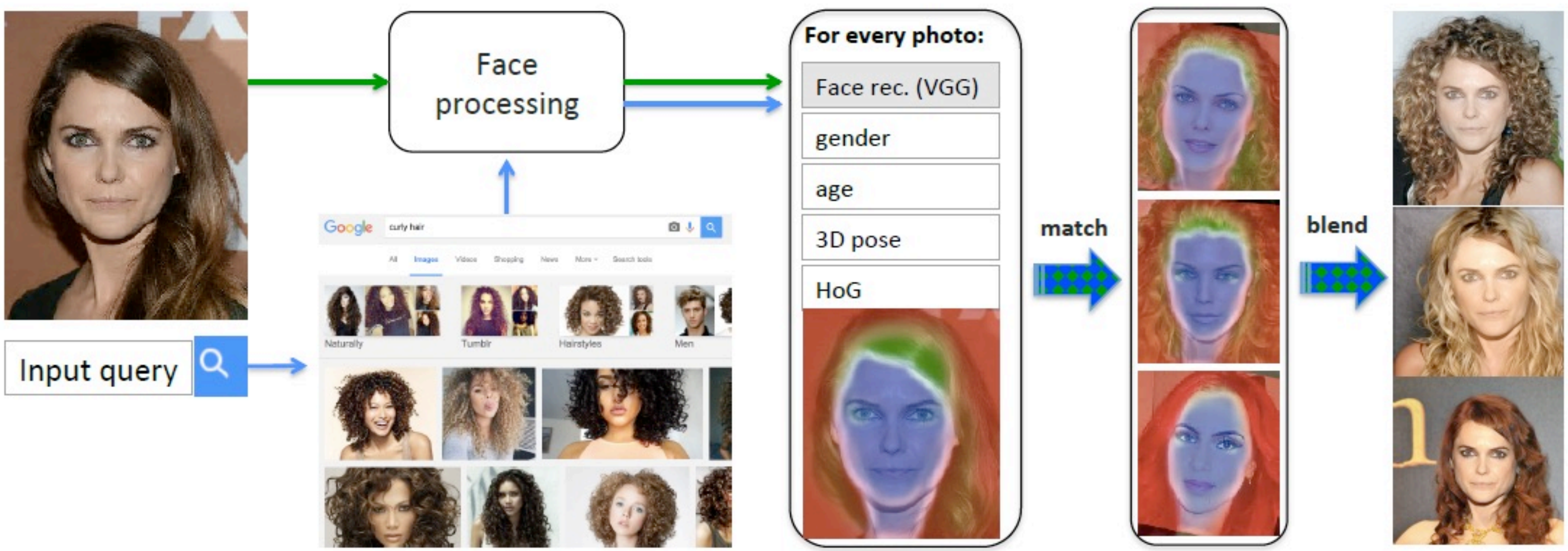
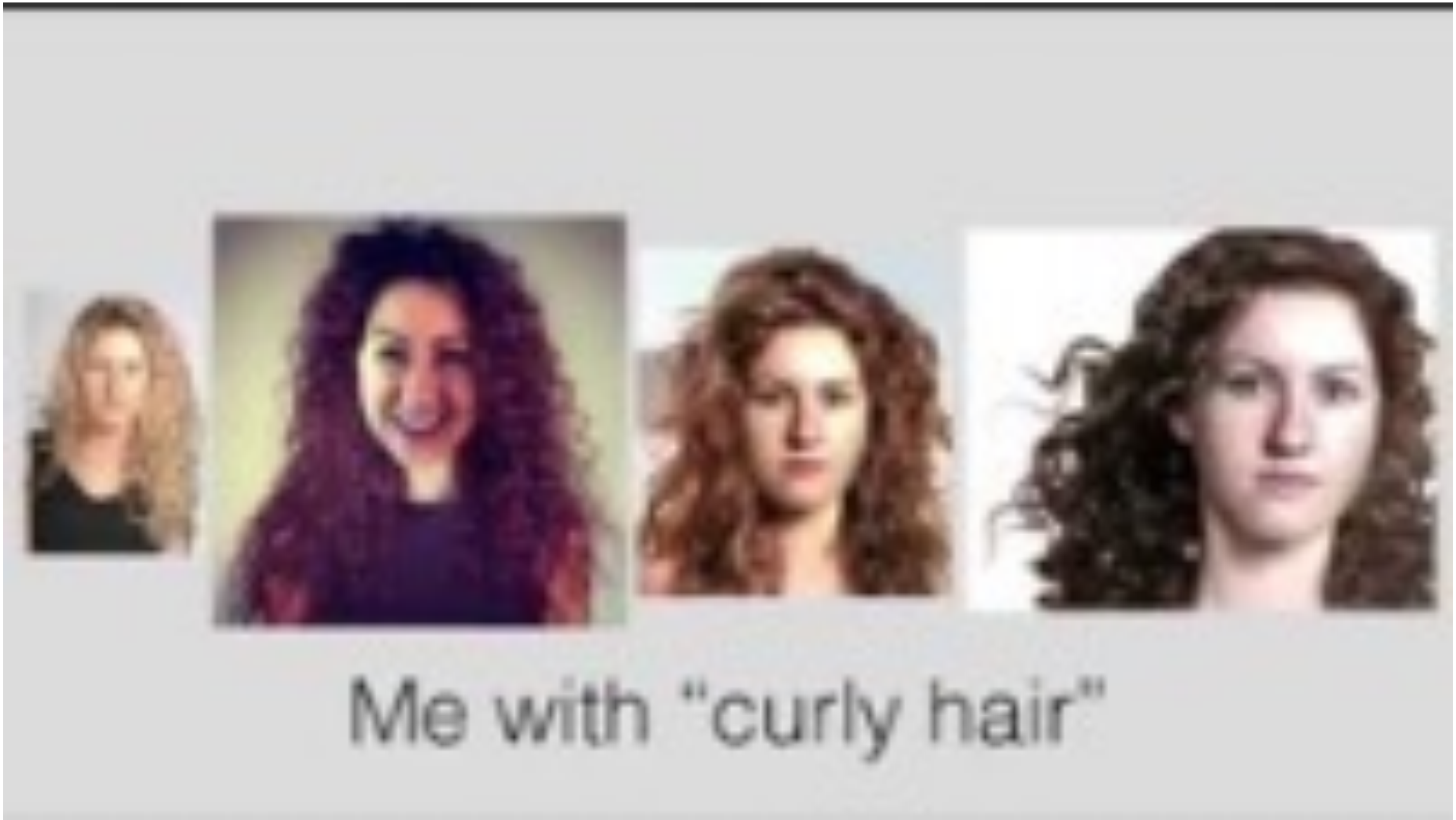


Figure 2: *Illustration of our system. The system gets as input a photo and a text query. The text query is used to search a web image engine. The retrieved photos are processed to compute a variety of face features and skin and hair masks, and ranked based on how well they match to the input photo.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

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

Dreambit



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

Illumination-aware Age Progression

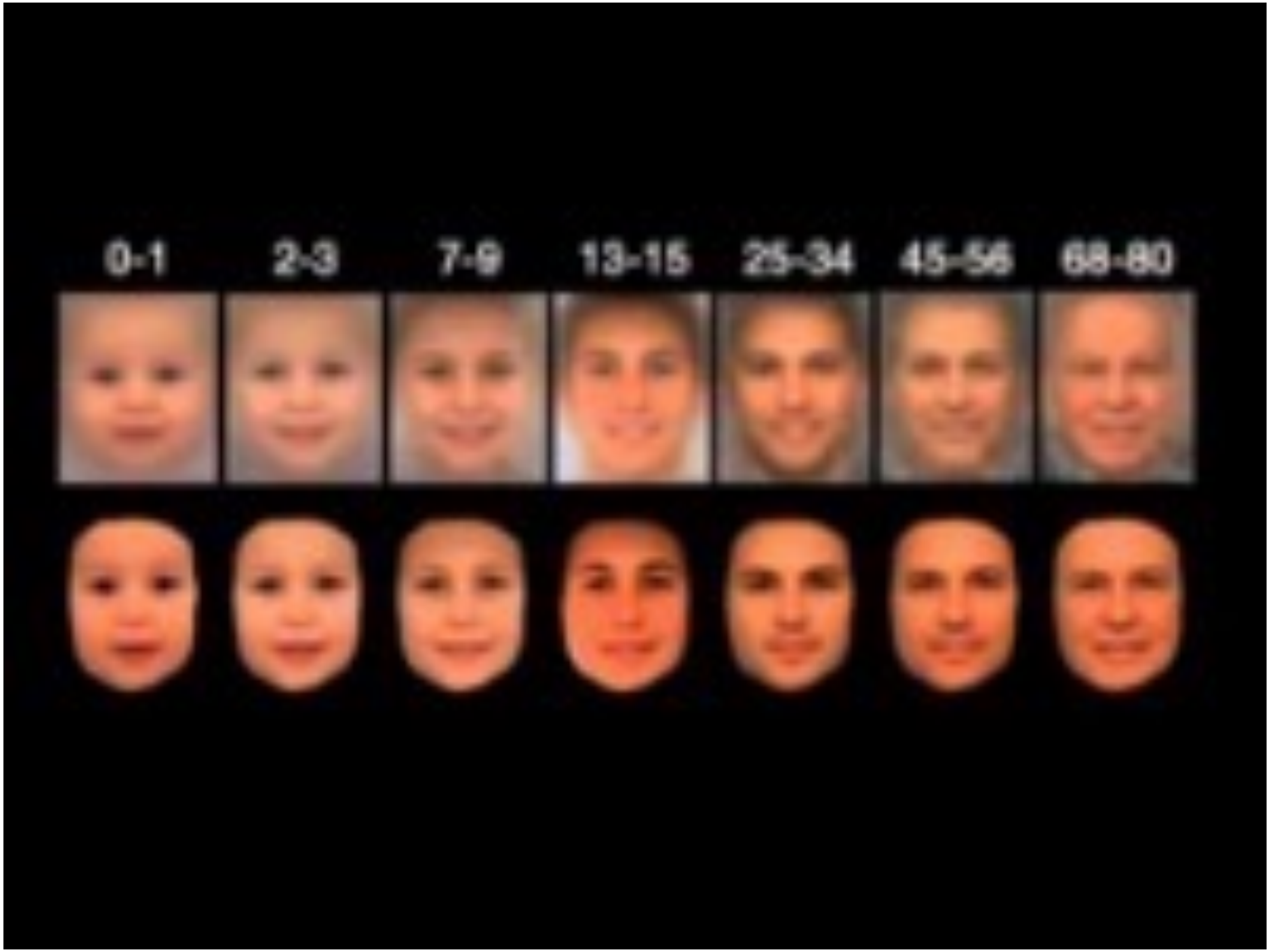
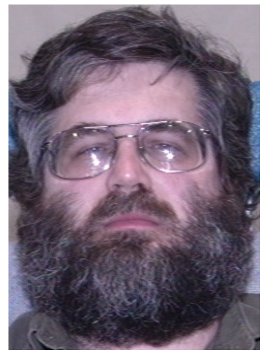
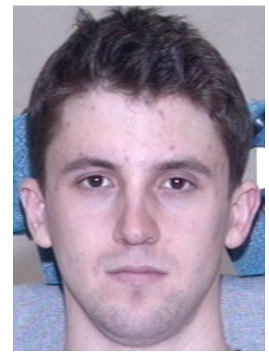
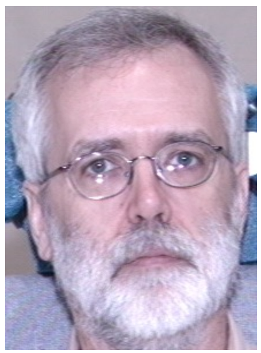
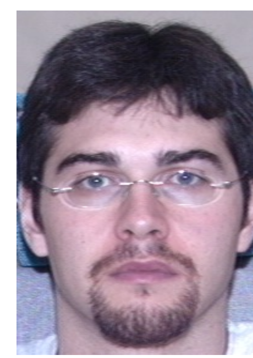


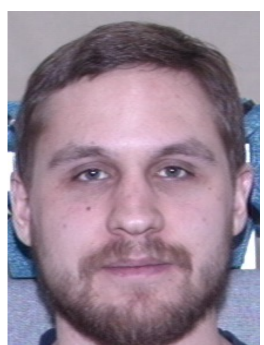
Image-Based Shaving





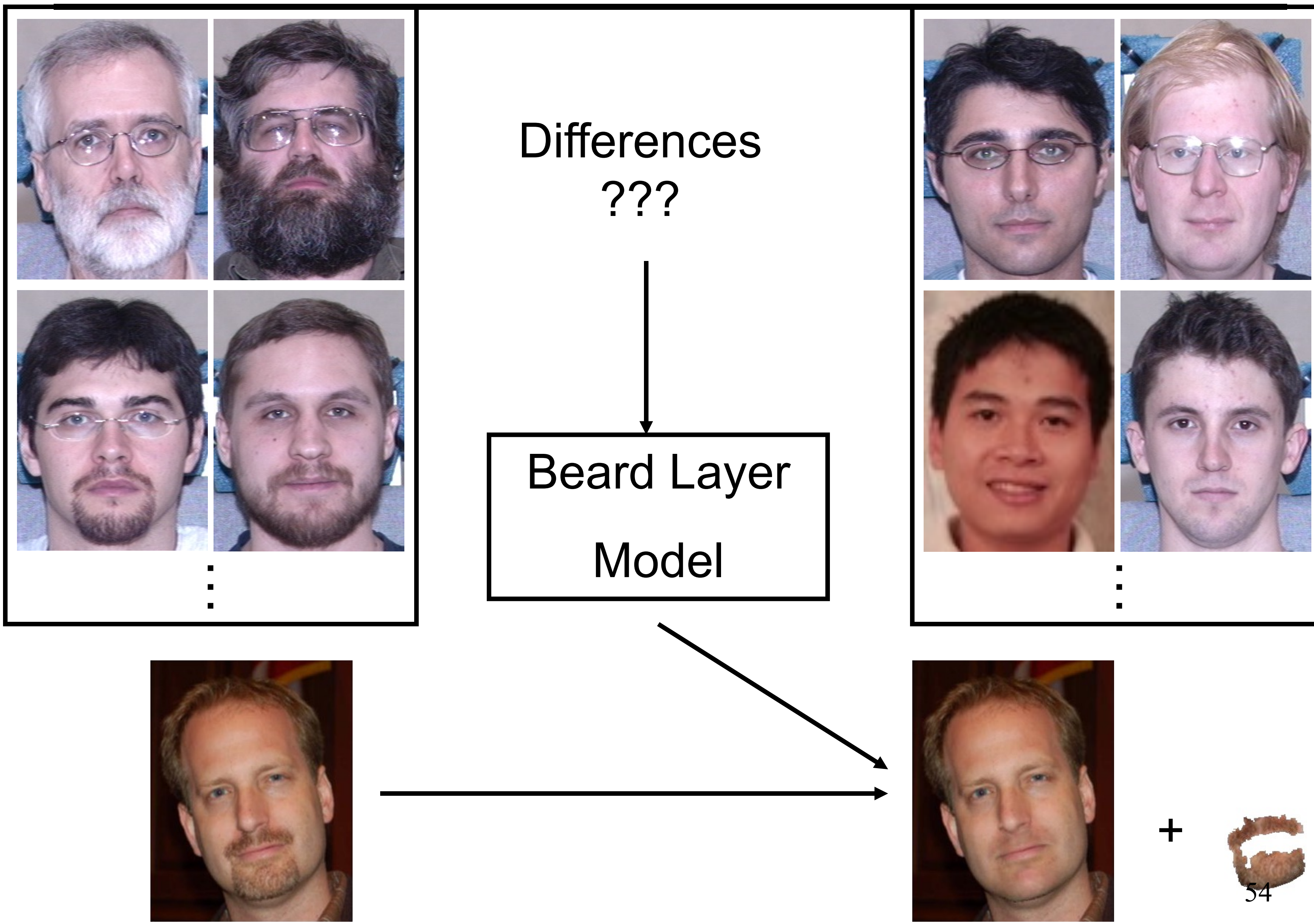




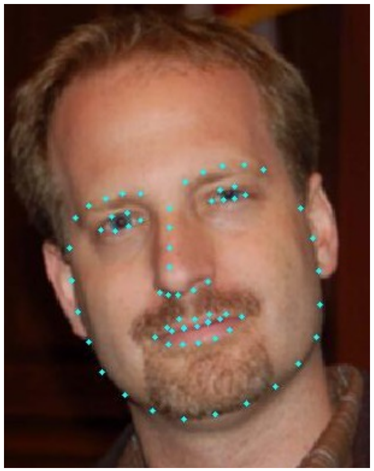


http://graphics.cs.cmu.edu/projects/imageshaving/

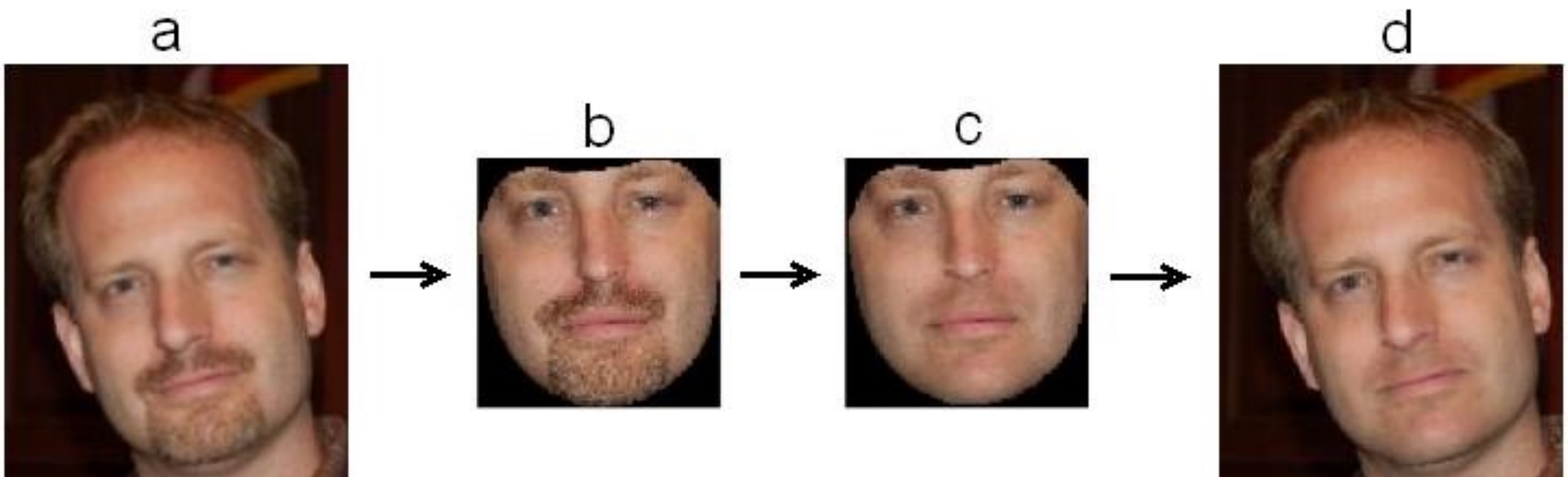
The idea



Processing steps



68 landmarks



Some results

Take-home Message

- Alignment (2D and 3D): 3D is better than 2D.
- Shape + Texture representation.
- Subpopulation mean $\bar{x}$ and deviation Δx
- 3D data and 3D shape representation helps!
  - Easy to change the viewpoint.
- Standard face pipeline:

  Given: Input Image

  Step 1: warp it to canonical pose (2D or 3D)

  Step 2: Calculate distances between faces OR apply image manipulation operations.

  Step 3: Unwarp the result back to the original image

  Step 4: Post-processing (e.g., Poisson blending)

Thank You!

16-726, Spring 2022

https://learning-image-synthesis.github.io/sp22/

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