Image-based Shaving

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Minh Hoai Nguyen, Jean-Francois Lalonde,
Alexei A. Efros & Fernando de la Torre

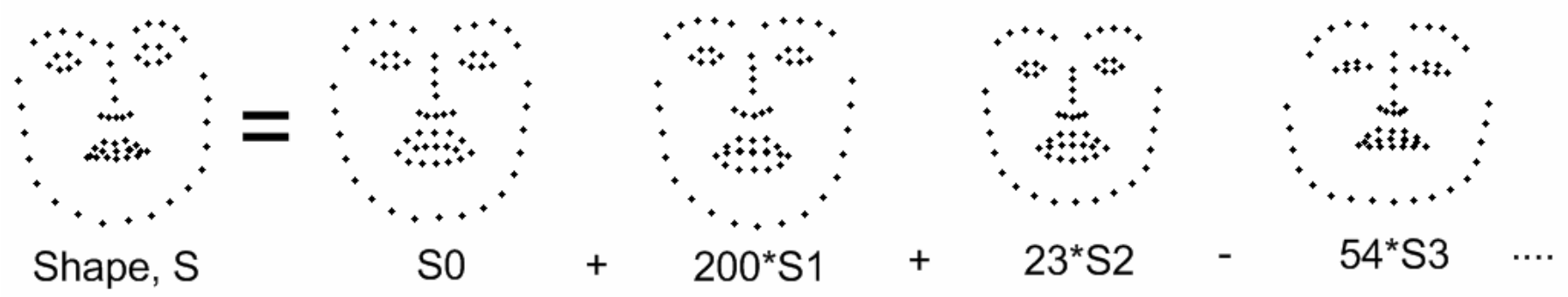
Robotics Institute, Carnegie Mellon University

A goal

synthesize

Nguyen et al., 2008

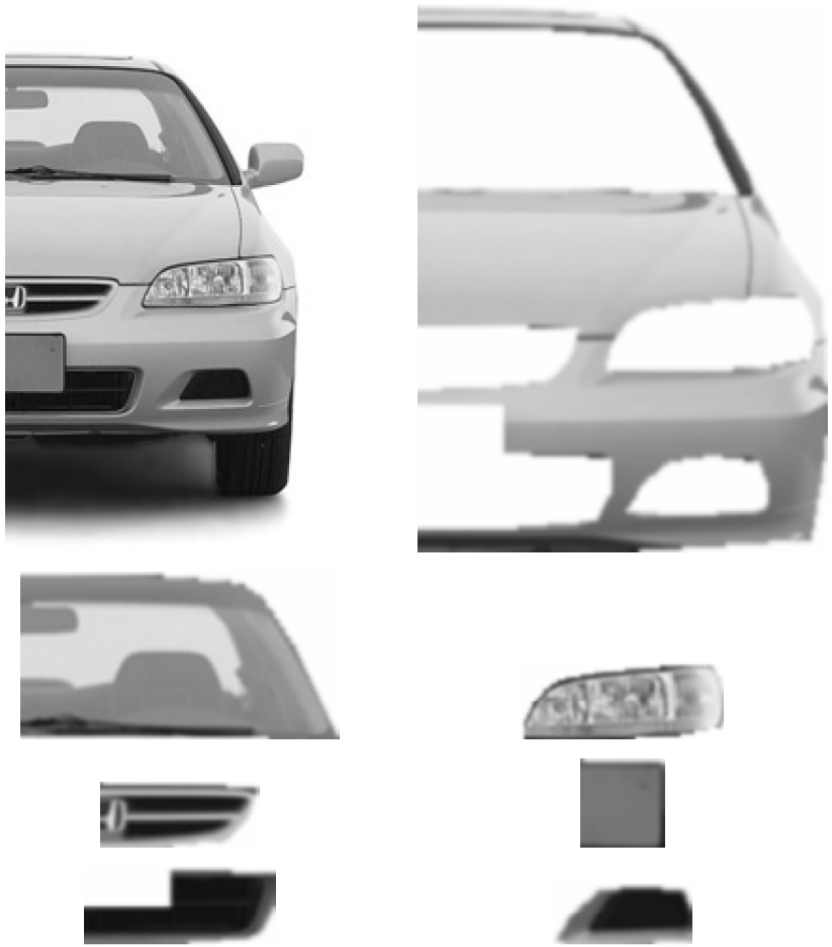
Active Appearance Models (Cootes et al ECCV98)



- Issues:
  - Global model
  - No support for modification of local structure.

Nguyen et al., 2008

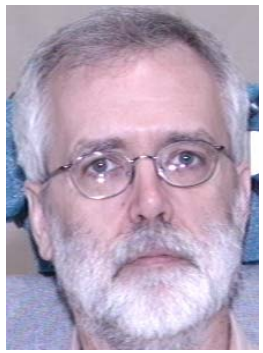
Layered AAMs (Jones & Soatto ICCV05)

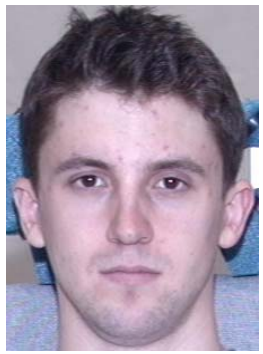


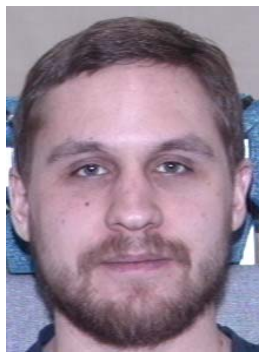
- Layers:
  - Defined manually
  - Require extensive set of hand labeled landmarks.
- This work:
  - Attempt to extract layers automatically.

Nguyen et al., 2008

The idea



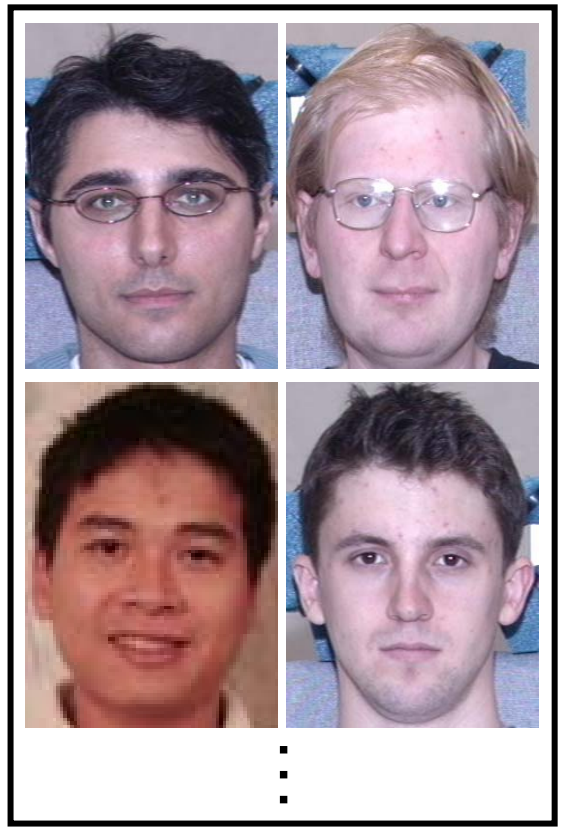


Nguyen et al., 2008

The idea

Differences
???

Beard Layer
Model



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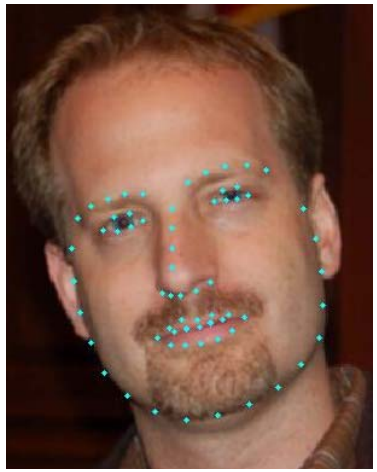
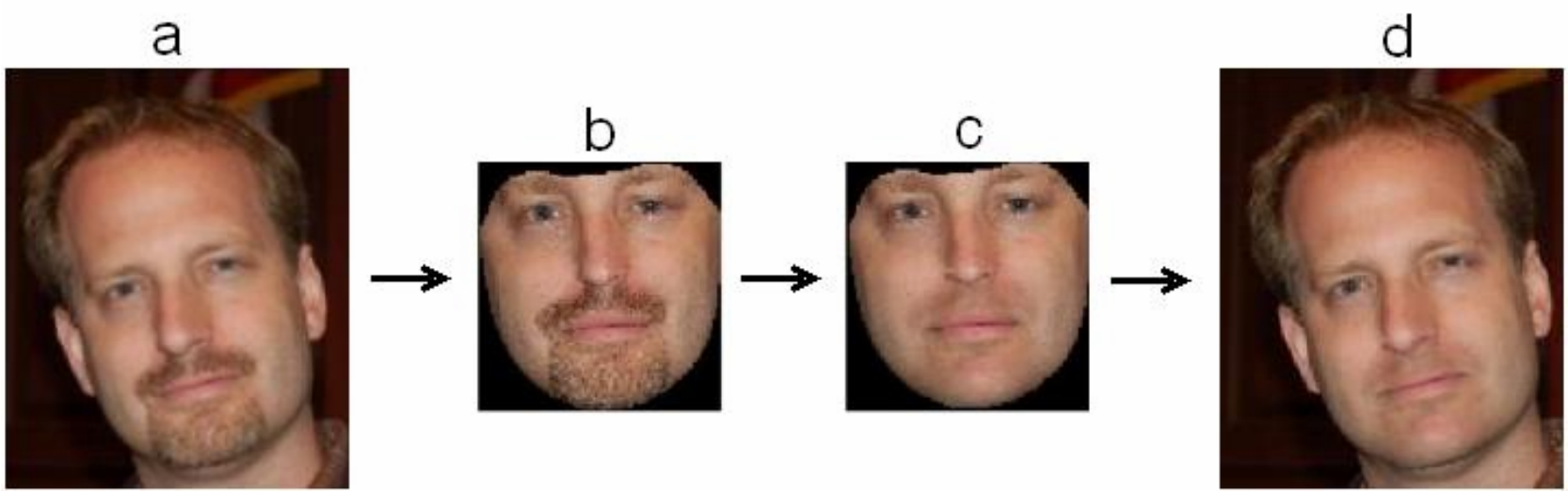
Nguyen et al., 2008

Processing steps



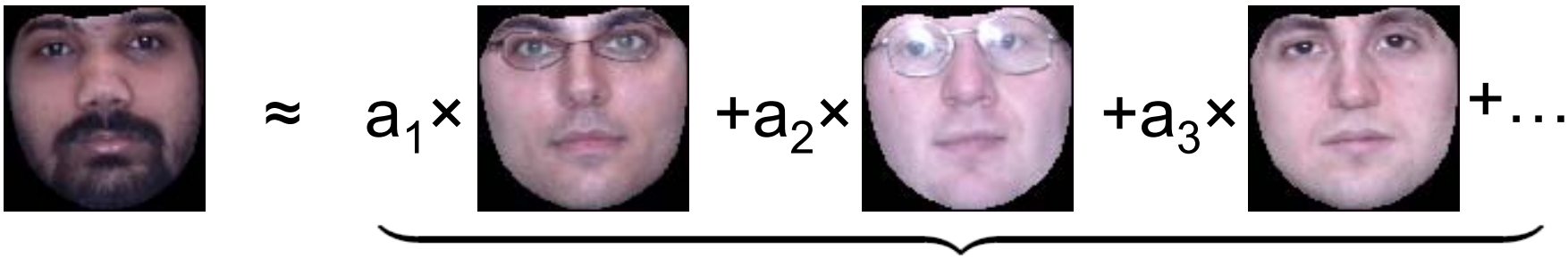
68 landmarks



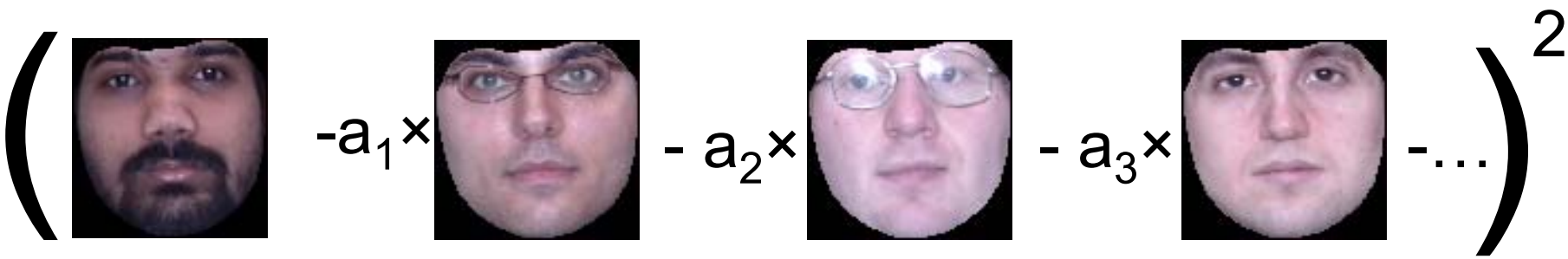
Nguyen et al., 2008

A naïve approach

- Reconstruct a bearded face by non-beard subspace



- This is equivalent to minimizing:



Nguyen et al., 2008

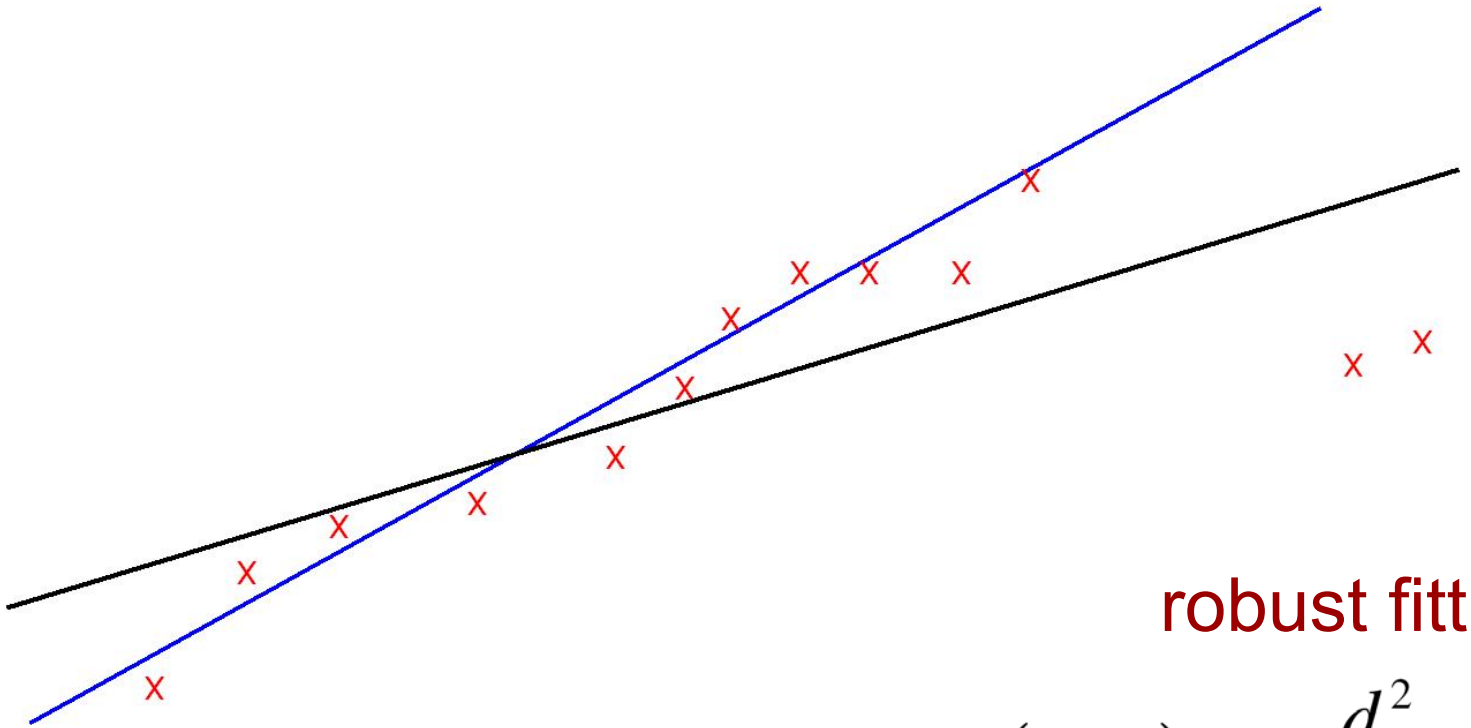
Naïve reconstruction

Problem: reconstruct what we don't want to!

$$\left(\text{input} - a_1 \times \text{face}_1 - a_2 \times \text{face}_2 - a_3 \times \text{face}_3 - \ldots \right)^2$$

Nguyen et al., 2008

Least square fitting



robust fitting

$$\rho(d,\sigma)=\frac{d^2}{\sigma^2+d^2}$$

Iteratively Reweighted Least Square Fitting

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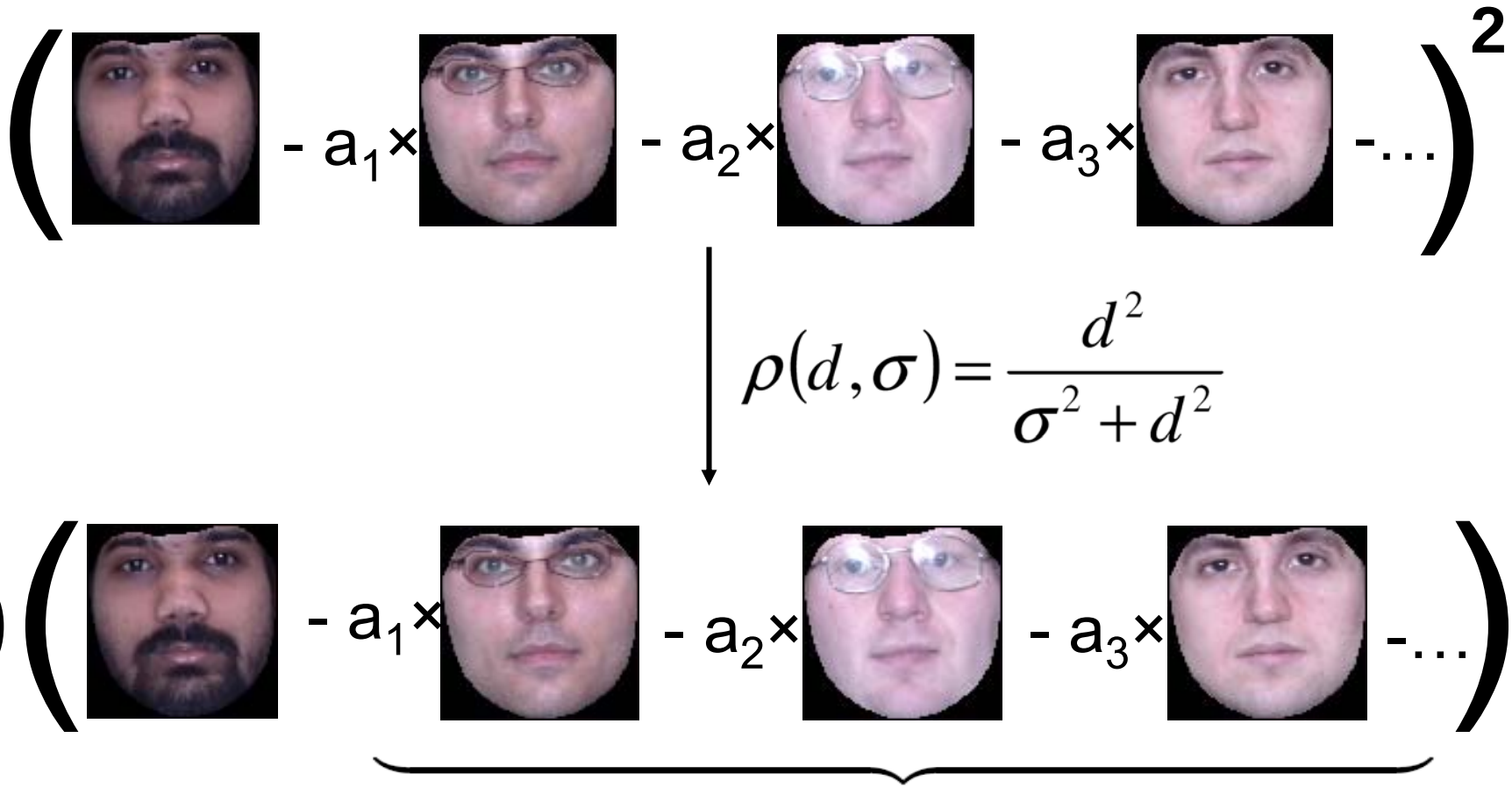
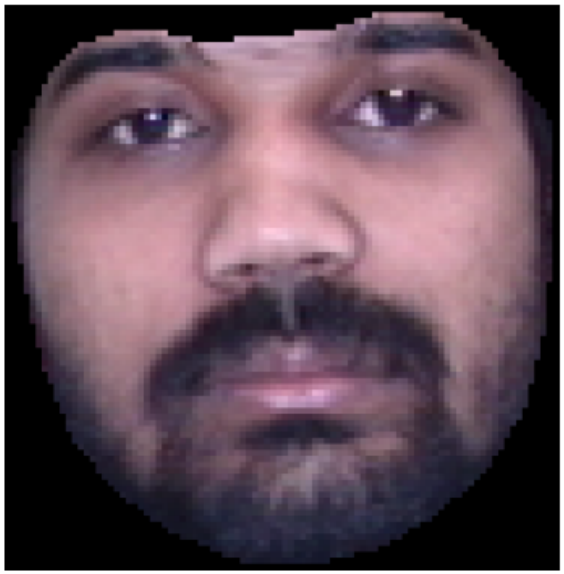
Robust Fitting

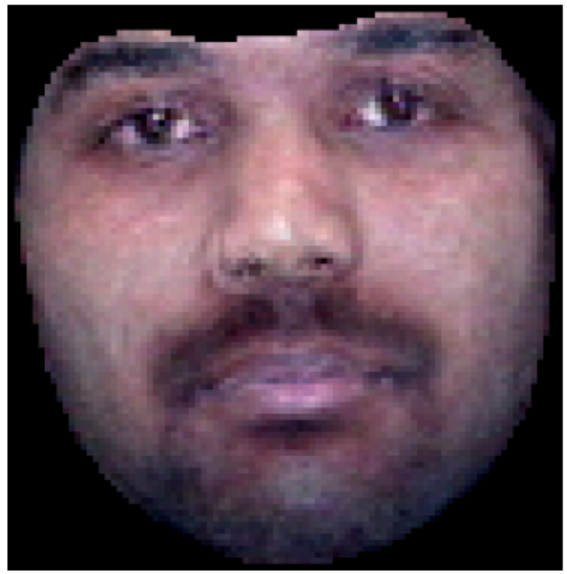


Nguyen et al., 2008

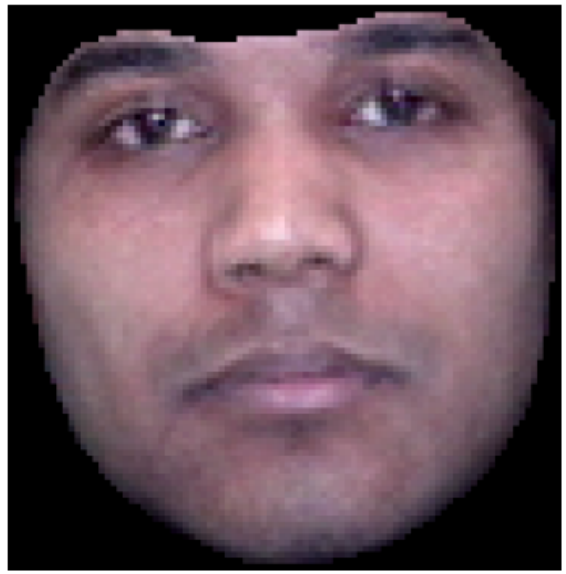
Reconstruction Results



Original



Naive reconstruction



Robust reconstruction

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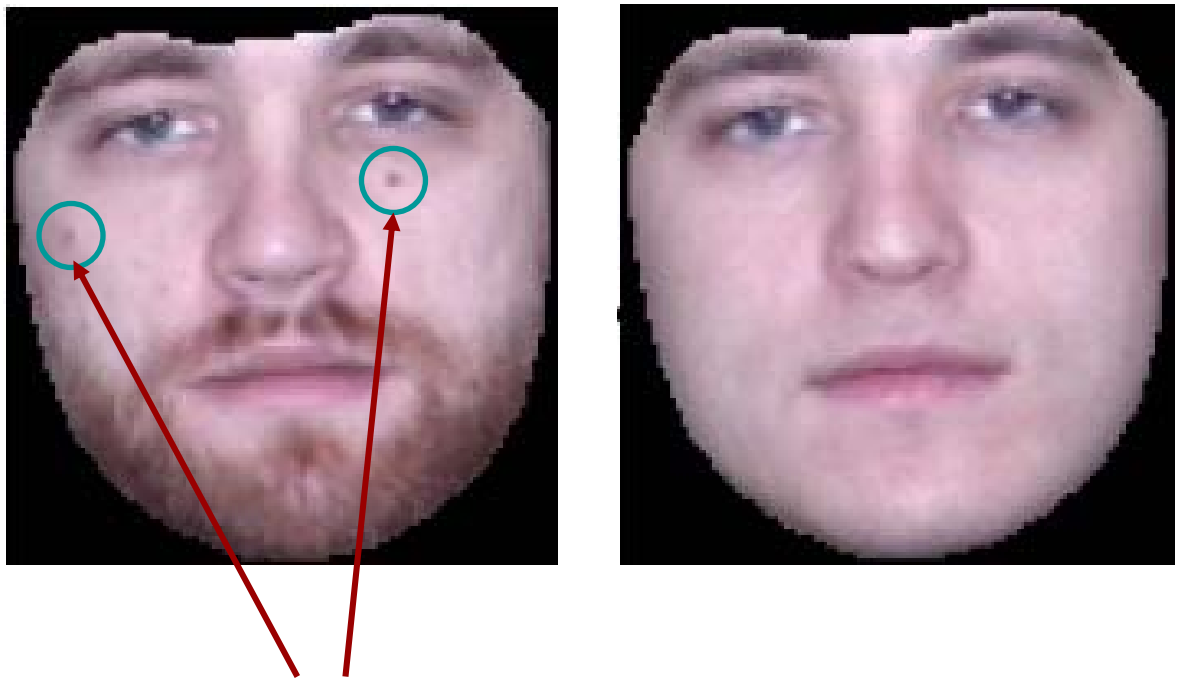
There is a problem



Characteristic moles are also removed

- Beards are outliers of non-beard subspace.
- But there are other outliers

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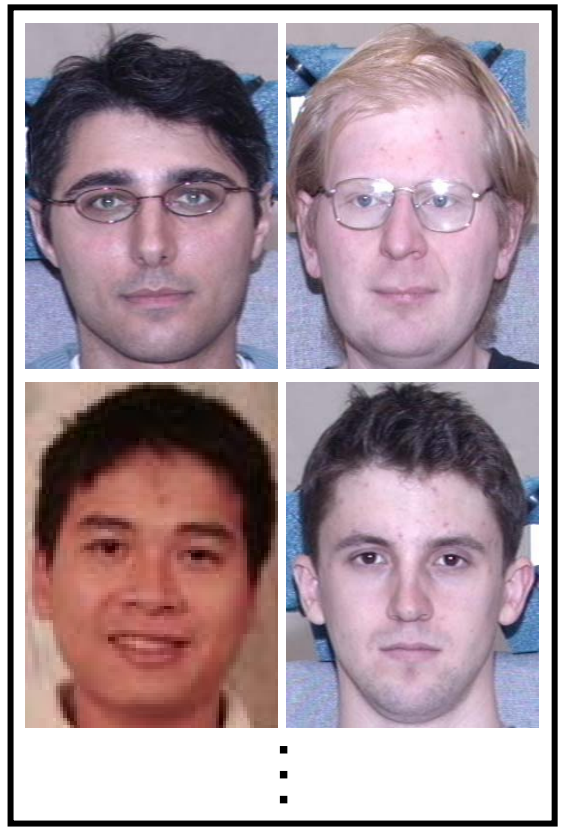
The idea

Differences
???

Beard Layer
Model



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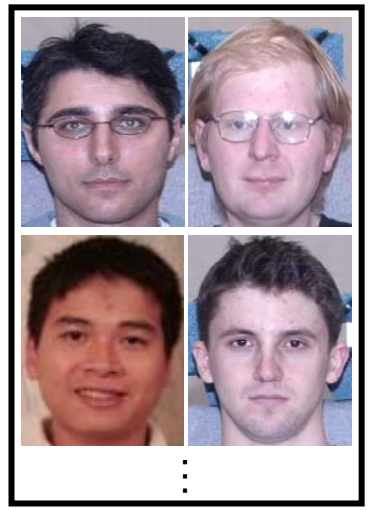
Subspace for beard layer



$$\mathbf{U} = [\mathbf{u}_1 \ldots \mathbf{u}_n] \in \Re^{d \times n} \qquad \mathbf{V} = [\mathbf{v}_1 \ldots \mathbf{v}_m] \in \Re^{d \times m}$$

$$\mathbf{u}_i \xrightarrow[\text{Fitting}]{\text{Robust}} \mathbf{u}_i^*$$

Perform PCA on the residuals:

$$\mathbf{u}_1 - \mathbf{u}_1^*, \ldots, \mathbf{u}_n - \mathbf{u}_n^*$$

retaining 95% energy to get $\mathbf{B}$ subspace for beard layers

Nguyen et al., 2008

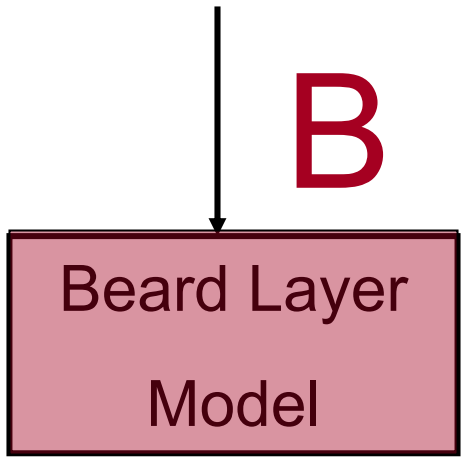
The first 6 principal components of B

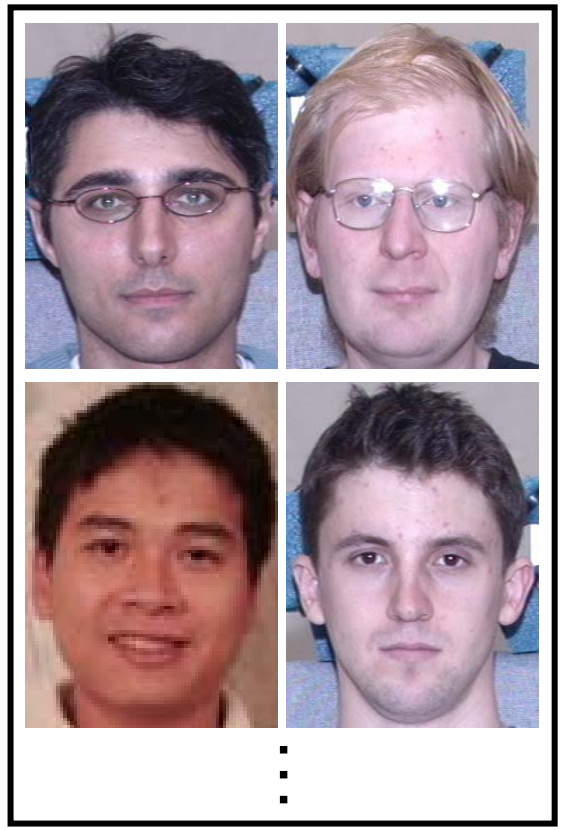
super-imposed on the mean face

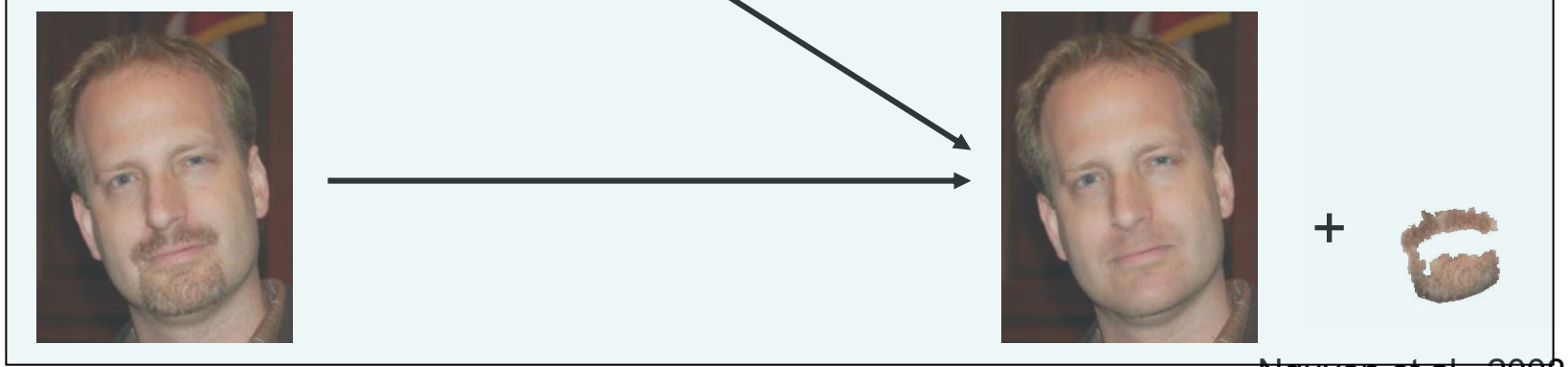
Nguyen et al., 2008

Where we are

Differences
???







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Factorizing beard layer

Given a face: $\mathbf{d}$

Non-beard subspace

Beard-layer subspace

$$\hat{\alpha}, \hat{\beta} = \arg\min_{\alpha,\beta} ||\mathbf{d} - \mathbf{V}\alpha - \mathbf{B}\beta||_2^2$$

$$\mathbf{d} = \mathbf{V}\hat{\alpha} + \mathbf{B}\hat{\beta} + \bar{\mathbf{d}}$$

Non-beard layer

Beard layer

Residual (*e.g.* scar, mole)

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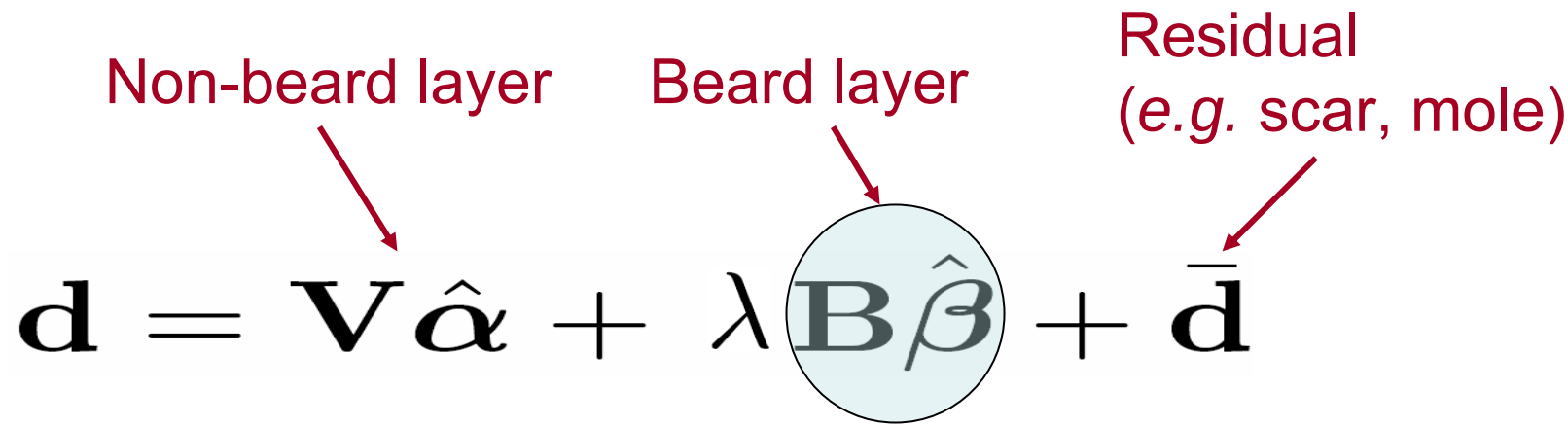
Using the beard layer



$\lambda = 0$ Remove beard

$\lambda > 1$ Enhance beard

$0 < \lambda < 1$ Reduce beard

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Changing contribution of the beard layer

Original

$\lambda = 1$

Beard removed

$\lambda = 0$

Beard reduced

$\lambda = 0.5$

Beard enhanced

$\lambda = 1.5$

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Some results

Nguyen et al., 2008

More results

Nguyen et al., 2008

Failed cases

Too much beard!

Breakdown point of robust fitting is reached.

Nguyen et al., 2008

Utilizing domain knowledge

- So far:
  - Generic technique
- For beard removal:
  - Additional cues

A pixel is likely to be beard pixel if most of its neighbors are.

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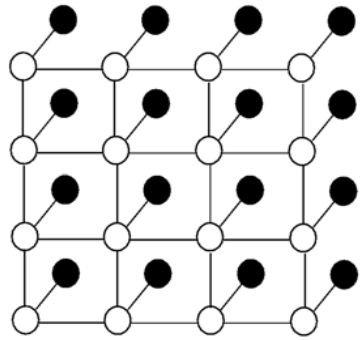
Beard Mask Segmentation

- Formulate as graph labeling problem:

$$\mathcal{G} = \langle \mathcal{V}, \mathcal{E} \rangle$$

One vertex per pixel

Edges for neighboring pixels



Label the vertices $L = \{ l_i | i \in \mathcal{V} \}$

that minimize:

$$E(L) = \sum_{i \in \mathcal{V}} E_i^1(l_i) + \sum_{(i,j) \in \mathcal{E}} E_{ij}^2(l_i, l_j)$$

unary potential

binary potential

Nguyen et al., 2008

Unary Potential

$$\mathbf{d} = \mathbf{V}\hat{\alpha} + \mathbf{B}\hat{\beta} + \overline{\mathbf{d}}$$

Non-beard layer

Beard layer

Residual (*e.g.* scar, mole)

$\mathbf{d}^B$

$\mathbf{d}_i^B$ corresponds to *i*th pixel

Beard pixel

Non-beard pixel

$$E_i^1(l_i) = \begin{cases} 0 & \text{if } l_i = 1 \\ |\mathbf{d}_i^B| - a & \text{if } l_i = 0 \ \& \ ||\mathbf{d}_i^B| - a| \leq b \\ b & \text{if } l_i = 0 \ \& \ |\mathbf{d}_i^B| - a > b \\ -b & \text{if } l_i = 0 \ \& \ |\mathbf{d}_i^B| - a < -b \end{cases}$$

Unary potential: favors beard label if $|\mathbf{d}_i^B|$ is big.

Nguyen et al., 2008

Binary Potential

$$E_{ij}^2(l_i, l_j) = \begin{cases} 0 & \text{if } l_i = l_j \\ \frac{b}{2} & \text{if } l_i \neq l_j \end{cases}$$

Binary potential: prefers same labels for neighboring pixels

Nguyen et al., 2008

Optimization using graph-cuts

(Boykov *et al* PAMI01)

Label the vertices $L = \{l_i | i \in \mathcal{V}\}$

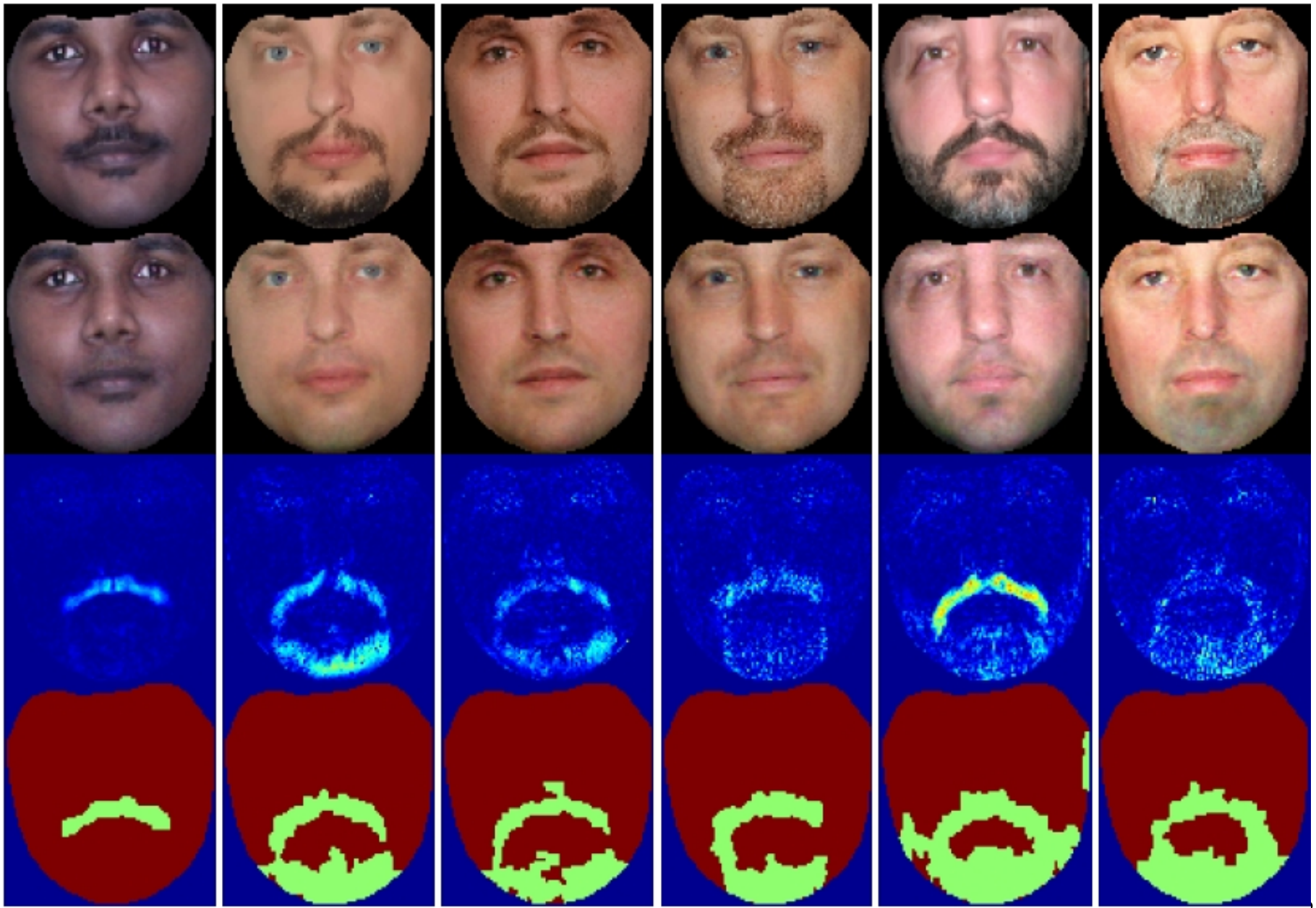
that minimize:

$$E(L) = \sum_{i \in \mathcal{V}} E_i^1(l_i) + \sum_{(i,j) \in \mathcal{E}} E_{ij}^2(l_i, l_j)$$

Exact global optimum solution can be found efficiently!

Nguyen et al., 2008

Beard mask results



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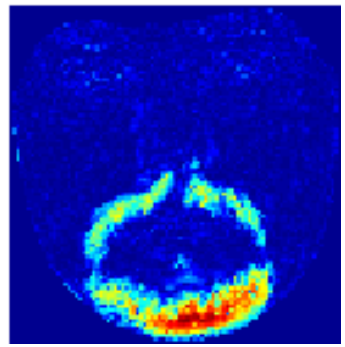
Refinement

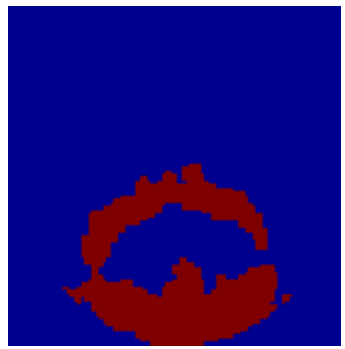
Beard removal Using subspaces



Original image

Linear Feathering

Amount of blending



Beard mask

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Final results 1

Nguyen et al., 2008

Final results 2

Nguyen et al., 2008

Final results 3

Nguyen et al., 2008

Final results 4

Nguyen et al., 2008

Final results 5

Nguyen et al., 2008

Beard removal, failure

Failure occurs at the robust fitting step

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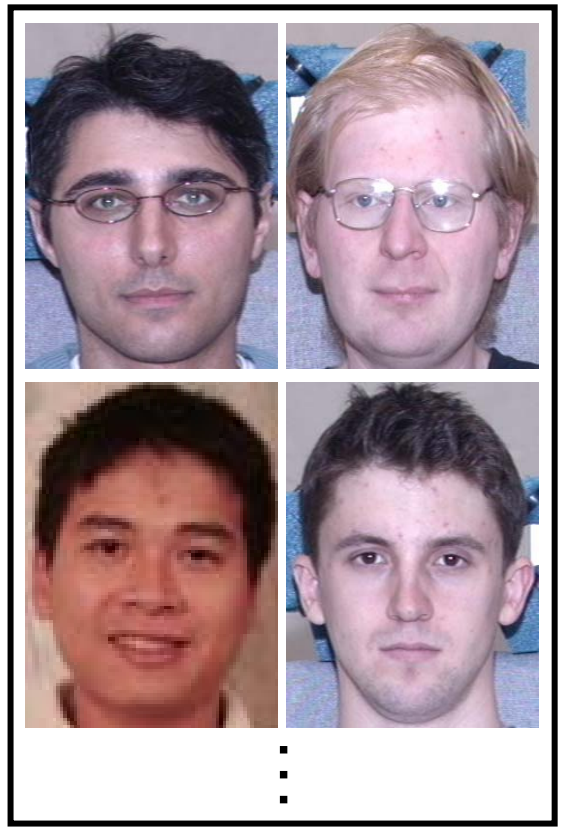
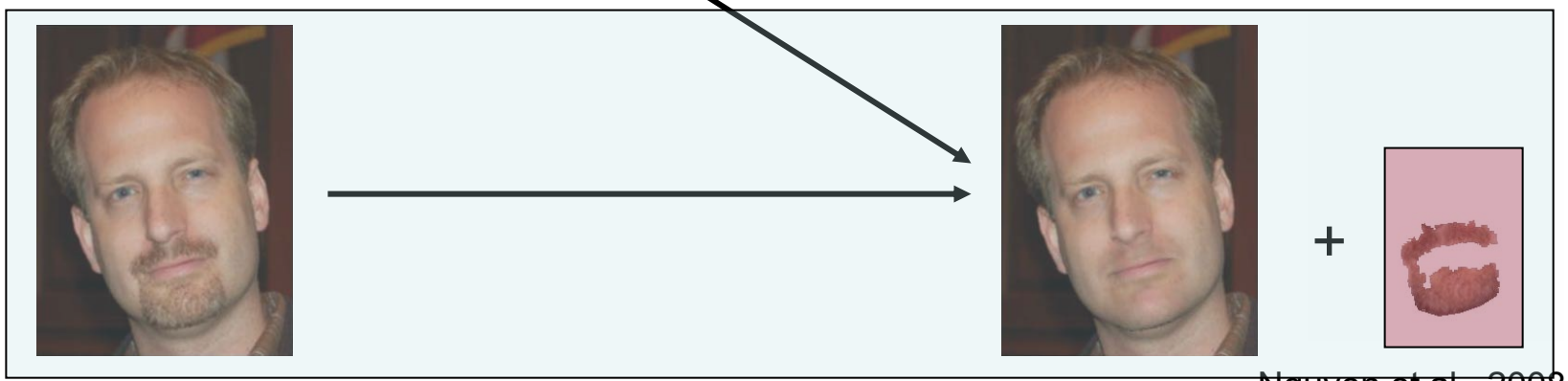
Where we are

Differences
???

Beard Layer
Model





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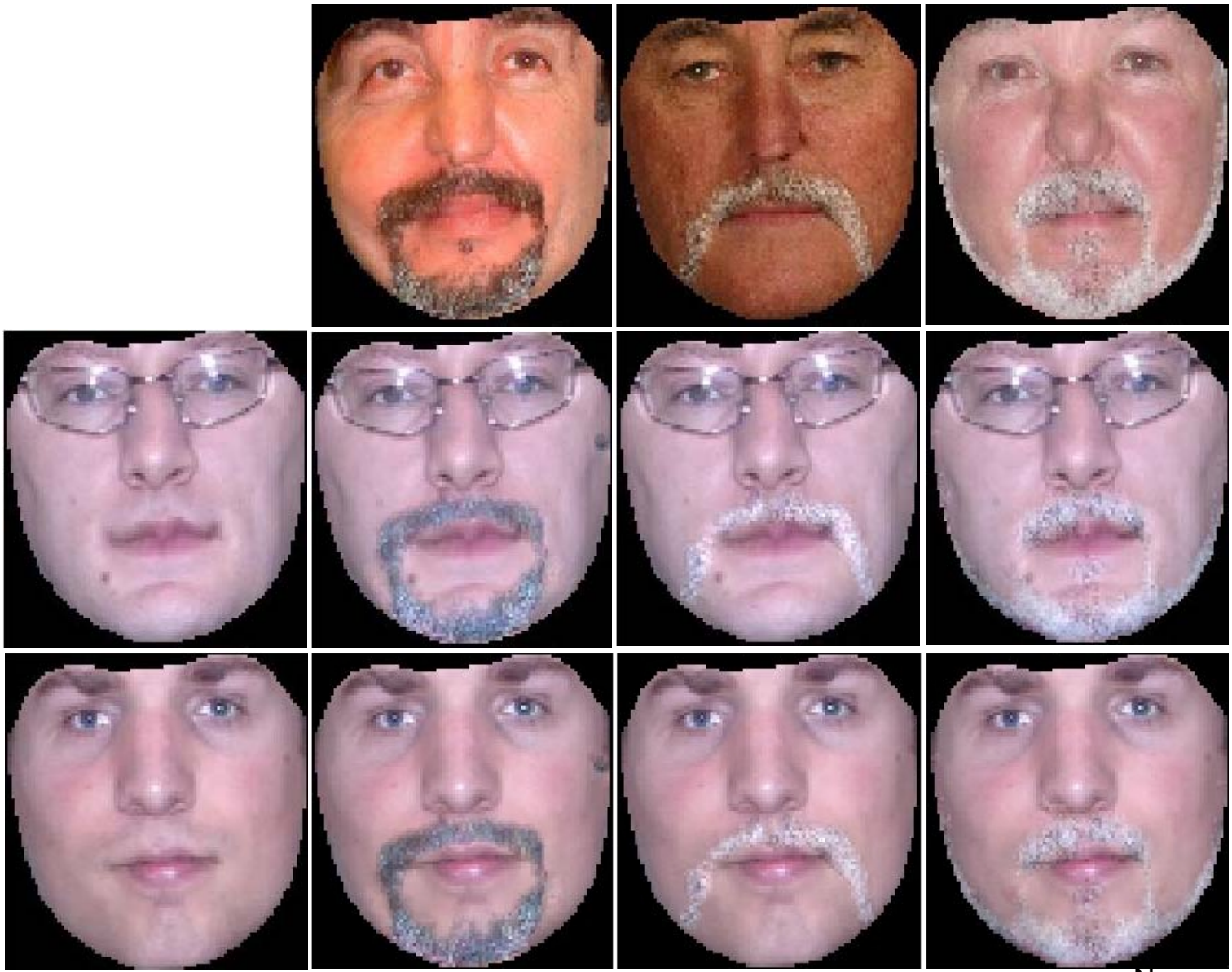
Beard Transfer



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So far, we talked about

Beards Beards Lots of Beards

But our method is generic!

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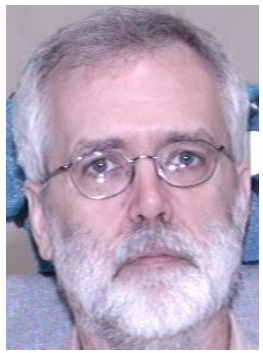
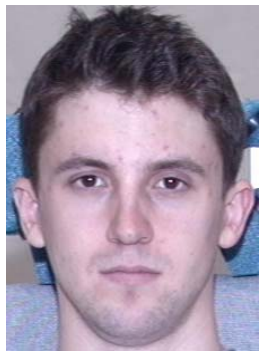
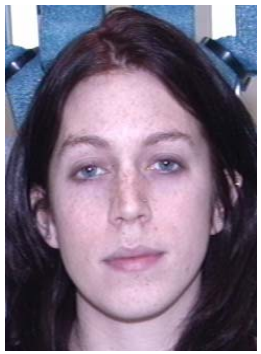
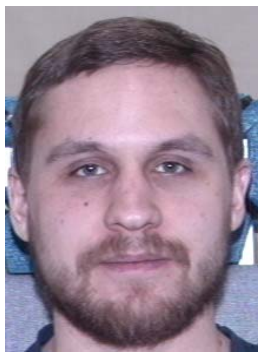
Glasses Removal









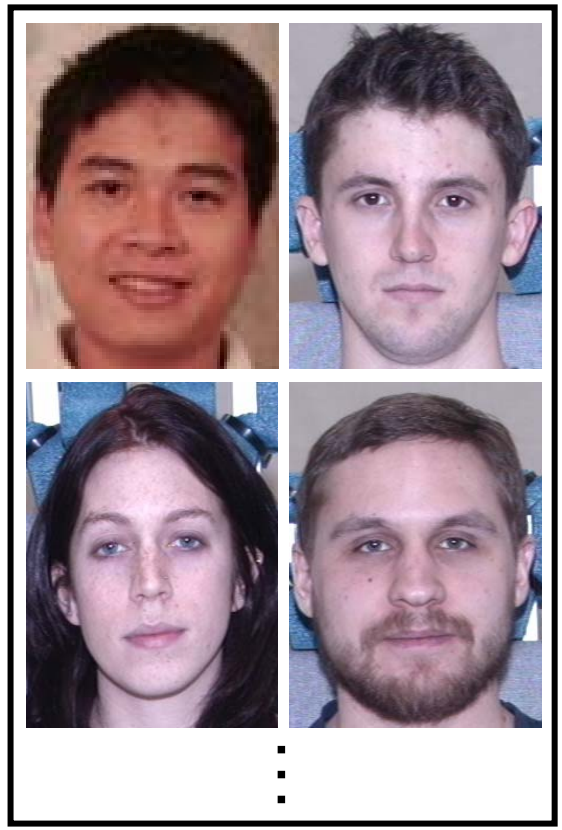
Nguyen et al., 2008

Glasses Removal

Differences
???

Glasses Layer

Model

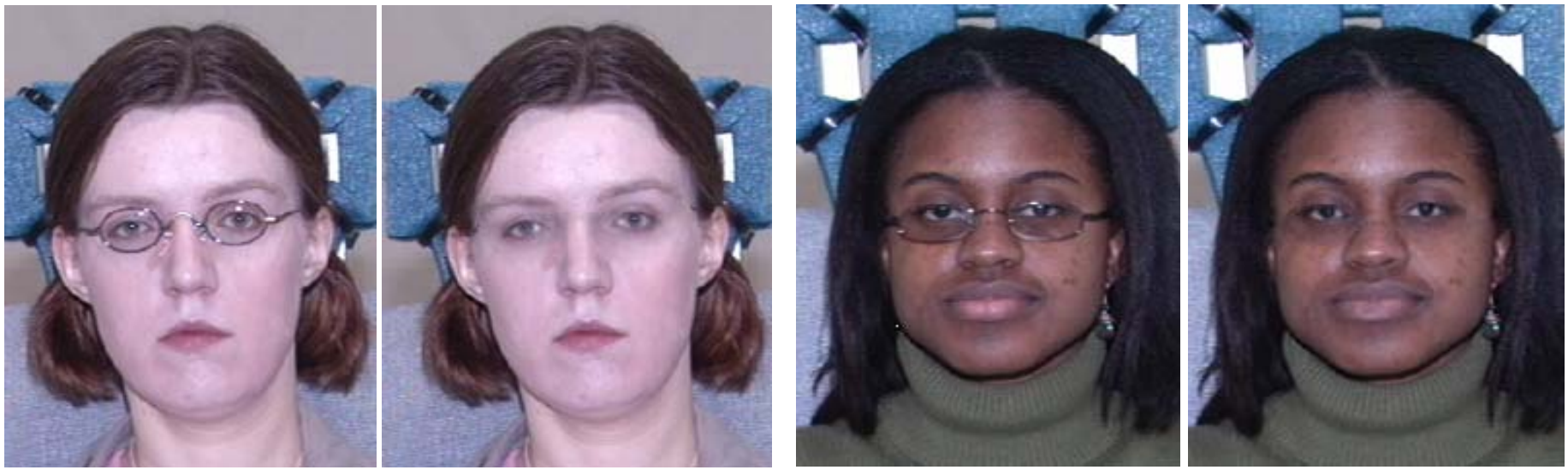


Nguyen et al., 2008

Preliminary results for glasses

Nguyen et al., 2008

Preliminary results for glasses



Nguyen et al., 2008

Glasses removal, failure

Nguyen et al., 2008

Multi-PIE database

- 1140 frontal, neutral faces
  - 68 landmarks
  - From Multipie
- Female: 341
  - With glasses: 82
  - Without glasses: 259
- Male: 799
  - With little or no facial hair: 480
  - With some facial hair: 319
  - With glasses: 340
  - Without glasses: 459

91 additional bearded faces from the Internet.

Nguyen et al., 2008

References

- Nguyen, M.H., Lalonde, J.F., Efros, A.A. & De la Torre, F. '**Image-based Shaving.**' Eurographics 08.
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- Boykov, Y., Veksler, O. & Zabih, R. **'Fast Approximate Energy Minimization via Graph Cuts.'** PAMI01.
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