3D-Aware Expression Flow for 2D Face Compositing

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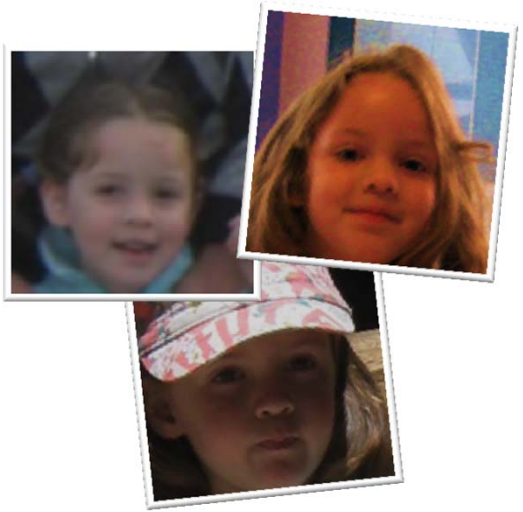
Hard to capture the moment

Photometric flaws



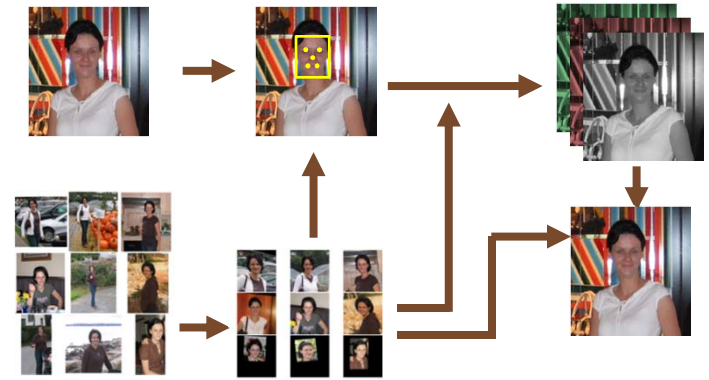
Non-desirable expression

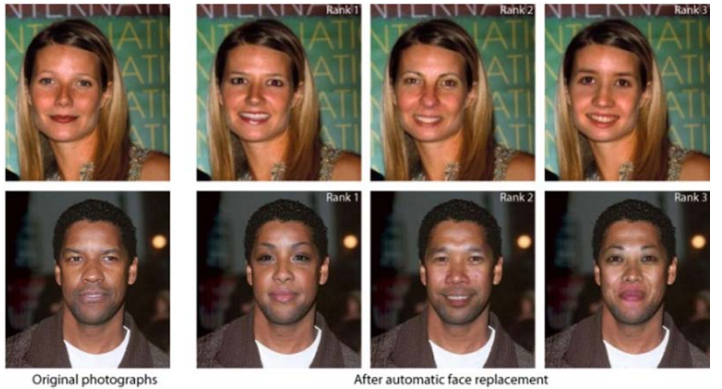
Goal

Reference | Target | **Our result**

Previous work

- Photo enhancement
  - Joshi et al. [2010]
- Face swapping
  - Bitouk et al. [2008]





Face editing

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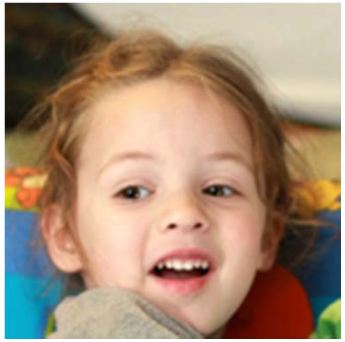
Replace whole face

Reference

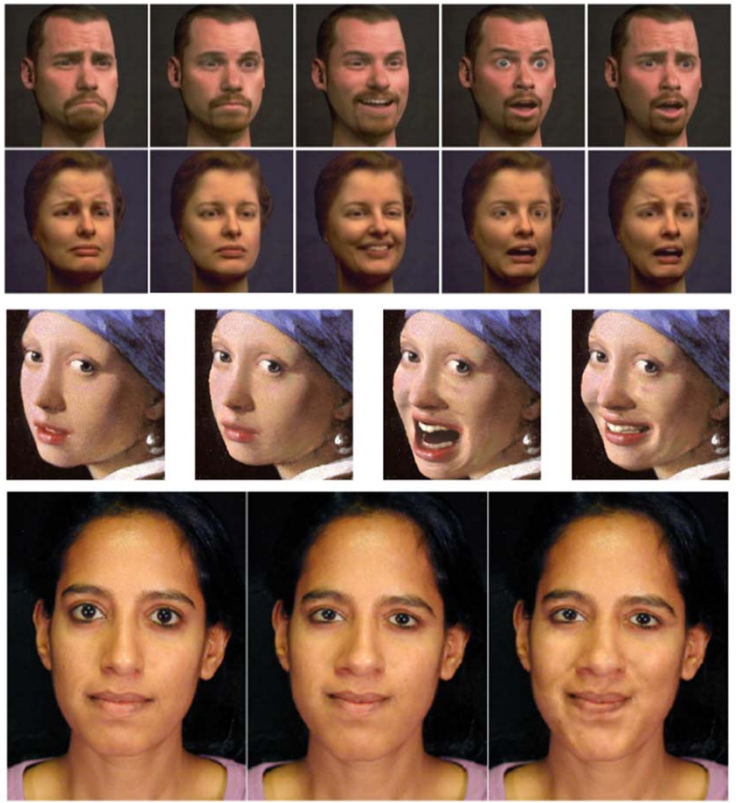
Target

Replace whole face



Previous work

- Expression mapping
  - 3D approaches
    - Pighin et al. [1998]
    - Blanz et al. [2003]
    - Metaxas et al. [2004]
  - 2D approaches
    - Williams [1990]
    - Liu et al. [2001]

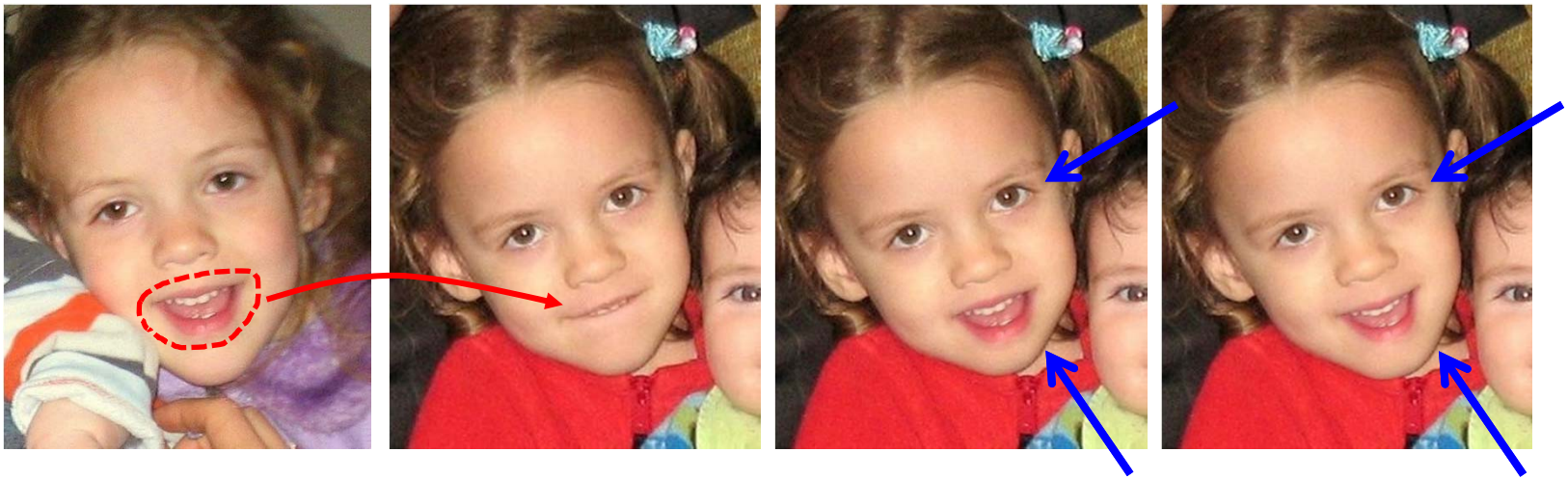


Previous work

- Interactive Digital Photomontage
  - Agarwala et al. [2004]

Local component transfer

- Copy mouth region

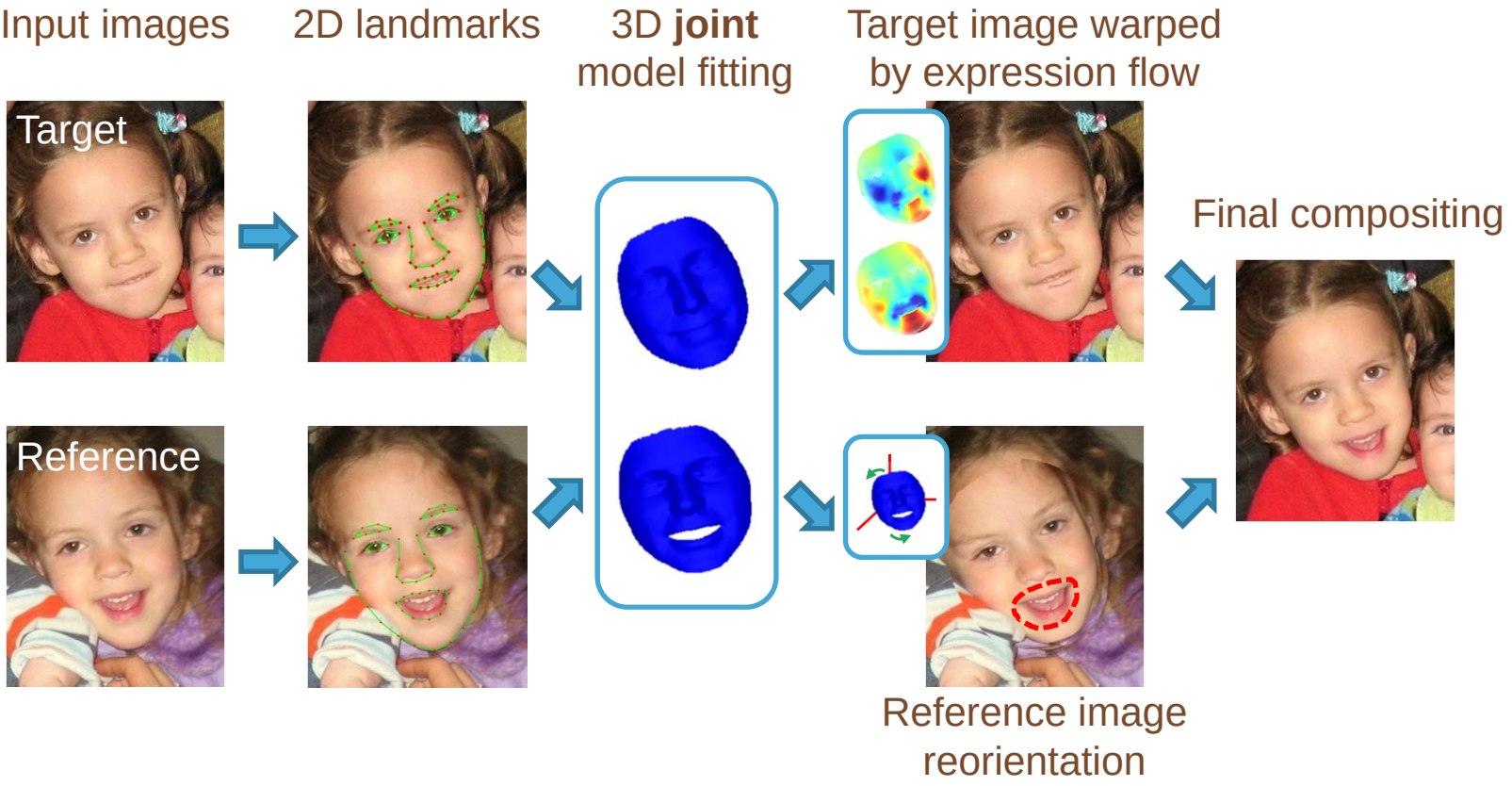


Reference | Target | Photomontage (unnatural) | **Our result**

Outline of our approach

- Overview
- 3D Model Fitting
- Image Compositing
- Results and Evaluation

System overview

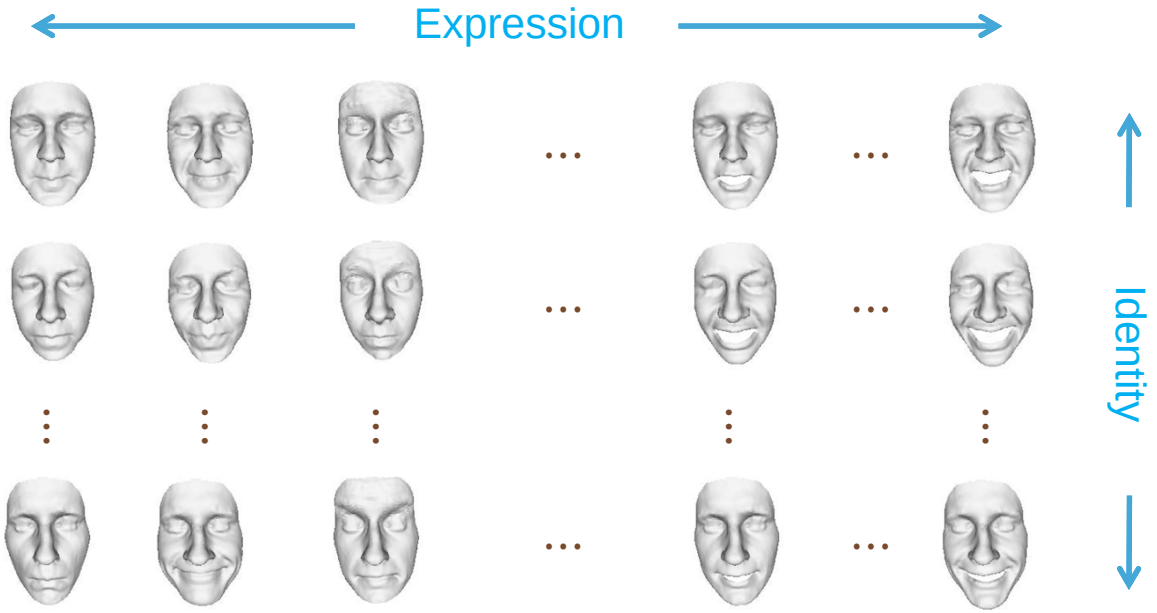


Outline of our approach

- Overview
- 3D Model Fitting
- Image Compositing
- Results and Evaluation

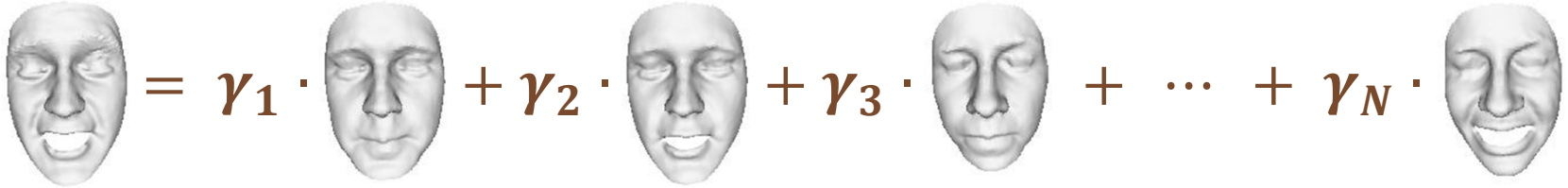
Training dataset

- Vlasic et al. [2005]
  - 16 subjects, 5 expressions, 5 visemes



Face model

- Linear span



- PCA subspace
  - **Mean shape** $\bar{s}$
  - **Eigenvectors** $\mathbf{V} = [v_1, v_1, \ldots, v_n]$
  - **Eigenvalues** $\Lambda = \mathbf{diag}[{\lambda_1}^2, {\lambda_2}^2, \ldots, {\lambda_n}^2]$
  - **New shape** $s_{new} = \bar{s} + V \cdot \beta$

Blanz et al. [1999]

Face model

- Optimization
  - Total energy function:

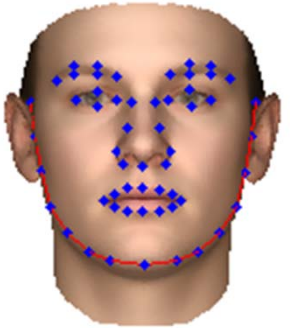
$$E = E_{fid} + c \cdot E_{pca}$$

  - Fidelity term:

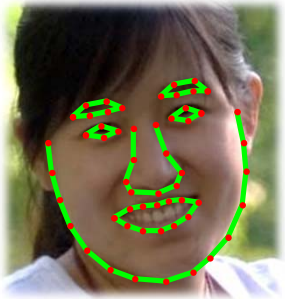
$$E_{fid} = \frac{1}{2}\sum \omega_k ||V_k - X_k||^2$$

  - Subspace energy term:

$$E_{pca} = \frac{1}{2}\beta^T \Lambda^{-1} \beta$$



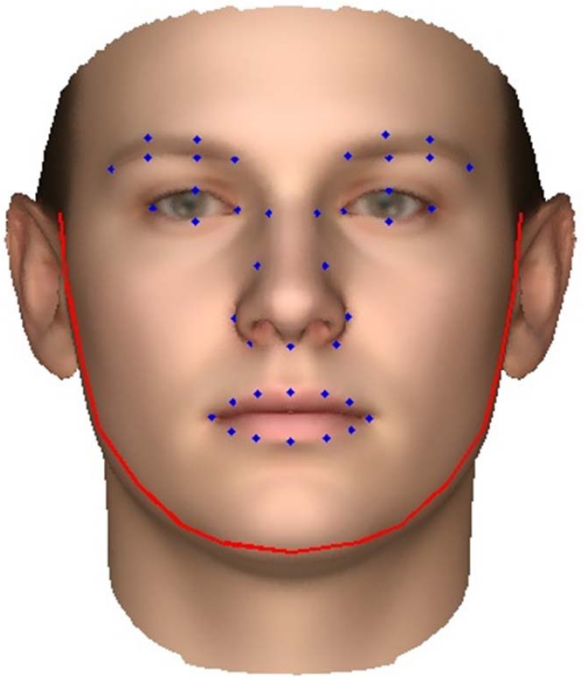
V_k : Projections of 3D landmarks



X_k : Facial features

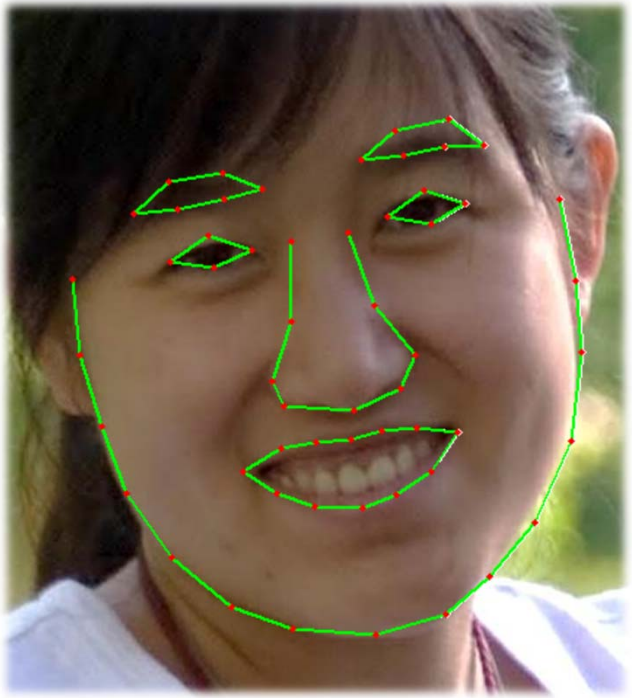
Shape to image fitting

- Matching features
  - Internal landmarks
  - Face boundary landmarks



Shape to image fitting

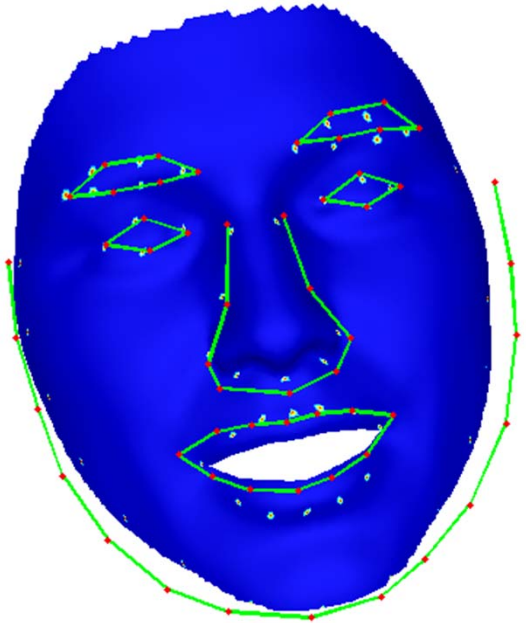
- Algorithm
  1. Detect landmarks



Milborrow and Nicolls [ECCV 2008]

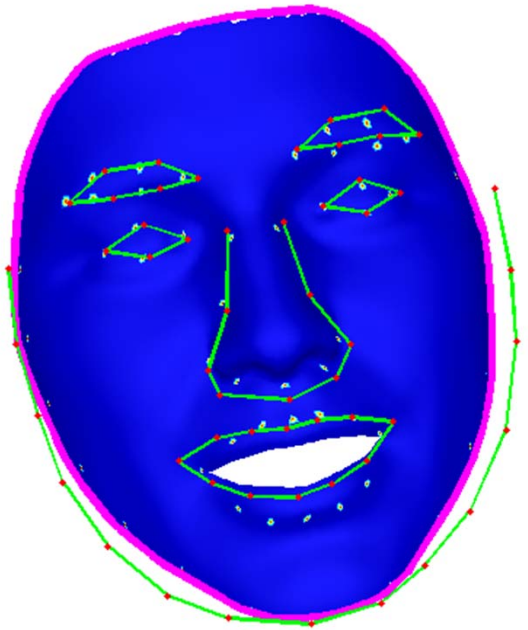
Shape to image fitting

- Algorithm
  1. Detect landmarks
  2. Place 3D mean shape



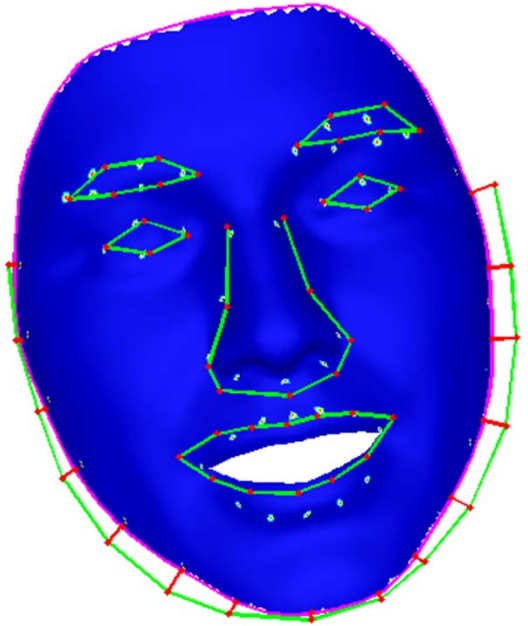
Shape to image fitting

- Algorithm
  1. Detect landmarks
  2. Place 3D mean shape
  3. Find face boundary



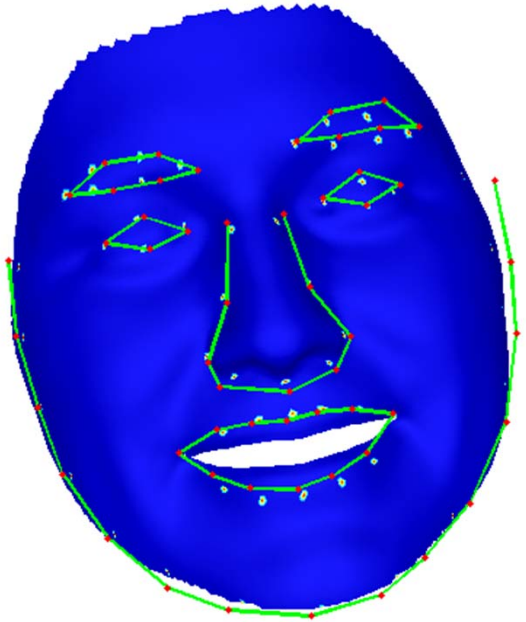
Shape to image fitting

- Algorithm
  1. Detect landmarks
  2. Place 3D mean shape
  3. Find face boundary
  4. Find corresponding vertex



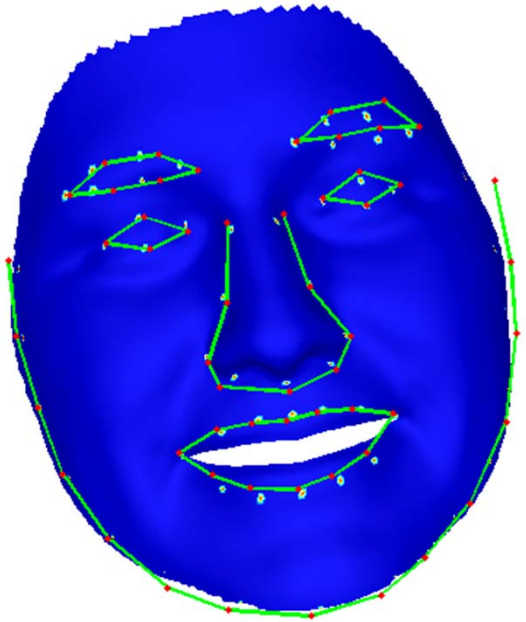
Shape to image fitting

- Algorithm
  1. Detect landmarks
  2. Place 3D mean shape
  3. Find face boundary
  4. Find corresponding vertex
  5. Update 3D shape



Shape to image fitting

- Algorithm
  1. Detect landmarks
  2. Place 3D mean shape
  3. Find face boundary
  4. Find corresponding vertex
  5. Update 3D shape



After 3 iterations

Fitting shapes jointly

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Expression

a

$$= \gamma^{a}_{1,1} \cdot \quad + \gamma^{a}_{1,2} \cdot \quad + \cdots + \gamma^{a}_{1,k} \cdot \quad + \cdots + \gamma^{a}_{1,M} \cdot$$
$$+ \cdots \quad \cdots \quad \cdots \quad \cdots$$
$$+ \gamma^{a}_{i,1} \cdot \quad + \gamma^{a}_{i,2} \cdot \quad + \cdots + \gamma^{a}_{i,k} \cdot \quad + \cdots + \gamma^{a}_{i,M} \cdot$$
$$+ \cdots \quad \cdots \quad \cdots \quad \cdots$$
$$+ \gamma^{a}_{N,1} \cdot \quad + \gamma^{a}_{N,2} \cdot \quad + \cdots + \gamma^{a}_{N,k} \cdot \quad + \cdots + \gamma^{a}_{N,M} \cdot$$

Identity

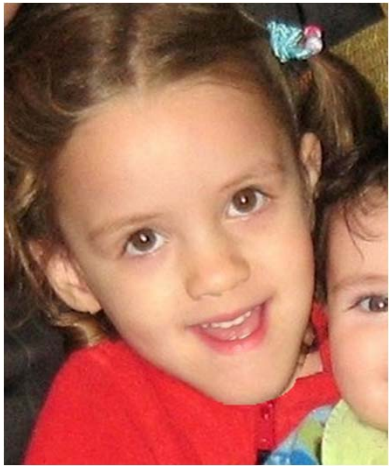
b

$$= \gamma^{b}_{1,1} \cdot \quad + \gamma^{b}_{1,2} \cdot \quad + \cdots + \gamma^{b}_{1,k} \cdot \quad + \cdots + \gamma^{b}_{1,M} \cdot$$
$$+ \cdots \quad \cdots \quad \cdots \quad \cdots$$
$$+ \gamma^{b}_{i,1} \cdot \quad + \gamma^{b}_{i,2} \cdot \quad + \cdots + \gamma^{b}_{i,k} \cdot \quad + \cdots + \gamma^{b}_{i,M} \cdot$$
$$+ \cdots \quad \cdots \quad \cdots \quad \cdots$$
$$+ \gamma^{b}_{N,1} \cdot \quad + \gamma^{b}_{N,2} \cdot \quad + \cdots + \gamma^{b}_{N,k} \cdot \quad + \cdots + \gamma^{b}_{N,M} \cdot$$

Identity

Fitting shapes jointly

Target



Fitting independently

Fitting shapes jointly

SIGGRAPH2011

a

b

Expression

Identity

Identity

Problem: best fit comes from different identities

Fitting shapes jointly

a

$$= \gamma^{a}_{1,1} \cdot \quad + \gamma^{a}_{1,2} \cdot \quad + \cdots + \gamma^{a}_{1,k} \cdot \quad + \cdots + \gamma^{a}_{1,M} \cdot$$
$$+ \quad \cdots \quad + \quad \cdots \quad + \quad \cdots \quad + \quad \cdots$$
$$+ \gamma^{a}_{i,1} \cdot \quad + \gamma^{a}_{i,2} \cdot \quad + \cdots + \gamma^{a}_{i,k} \cdot \quad + \cdots + \gamma^{a}_{i,M} \cdot$$
$$+ \quad \cdots \quad + \quad \cdots \quad + \quad \cdots \quad + \quad \cdots$$
$$+ \gamma^{a}_{N,1} \cdot \quad + \gamma^{a}_{N,2} \cdot \quad + \cdots + \gamma^{a}_{N,k} \cdot \quad + \cdots + \gamma^{a}_{N,M} \cdot$$

Expression

Identity

b

$$= \gamma^{b}_{1,1} \cdot \quad + \gamma^{b}_{1,2} \cdot \quad + \cdots + \gamma^{b}_{1,k} \cdot \quad + \cdots + \gamma^{b}_{1,M} \cdot$$
$$+ \quad \cdots \quad + \quad \cdots \quad + \quad \cdots \quad + \quad \cdots$$
$$+ \gamma^{b}_{i,1} \cdot \quad + \gamma^{b}_{i,2} \cdot \quad + \cdots + \gamma^{b}_{i,k} \cdot \quad + \cdots + \gamma^{b}_{i,M} \cdot$$
$$+ \quad \cdots \quad + \quad \cdots \quad + \quad \cdots \quad + \quad \cdots$$
$$+ \gamma^{b}_{N,1} \cdot \quad + \gamma^{b}_{N,2} \cdot \quad + \cdots + \gamma^{b}_{N,k} \cdot \quad + \cdots + \gamma^{b}_{N,M} \cdot$$

Identity

Fitting shapes jointly

a

$$= \gamma^a{}_{1,1} \cdot \ldots + \gamma^a{}_{i,1} \cdot \ldots + \gamma^a{}_{N,1} \cdot$$

γ^a

b

$=$

$$\min E_a + E_b$$

$$s.t.\ \gamma^a = \gamma^b$$

γ^b

$$+ \gamma^b{}_{1,k} \cdot \ldots + \gamma^b{}_{i,k} \cdot \ldots + \gamma^b{}_{N,k} \cdot$$

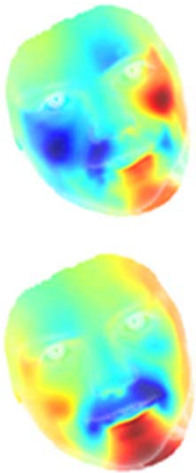
Outline of our approach

- Overview
- 3D Model Fitting
- 2D Compositing
- Results and Evaluation

2D compositing

- Warping with expression flow

Target



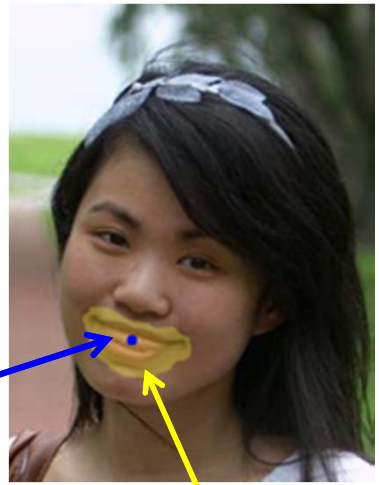
Flow

Warped Target

Difference

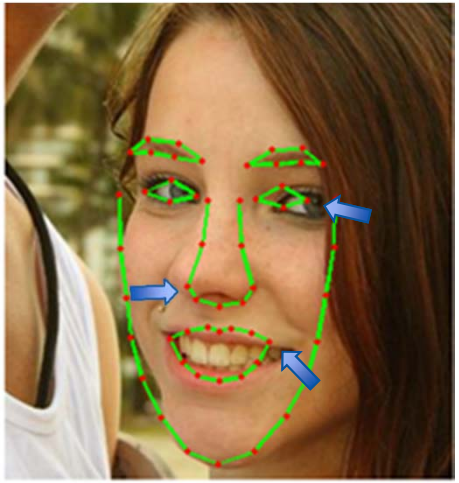
2D compositing

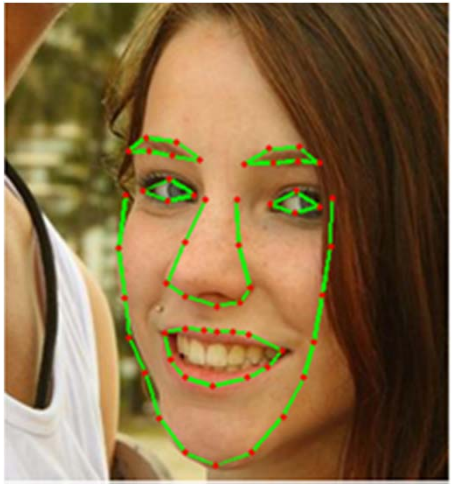
- Automatic crop region generation
  - “Graph Cuts” image segmentation [Agarwala et al. 2004]



User assistance

- Adjust landmarks





User assistance

- Adjust crop region

Mark fold region

Copy mouth only

Copy mouth and fold

Outline of our approach

- Overview
- Image Fitting
- 2D Compositing
- Results and Evaluation

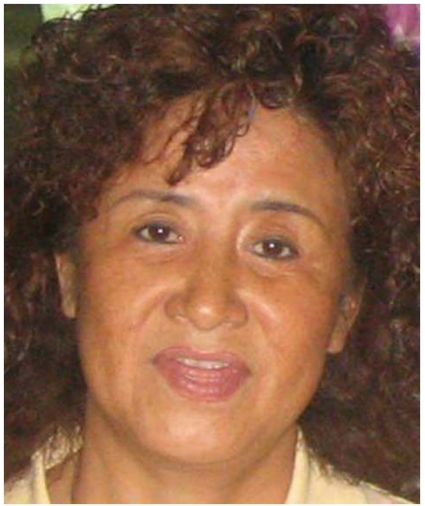
Examples

- Example 1

Reference

Warped by
3D rotation

Target



Warped by
Expression Flow

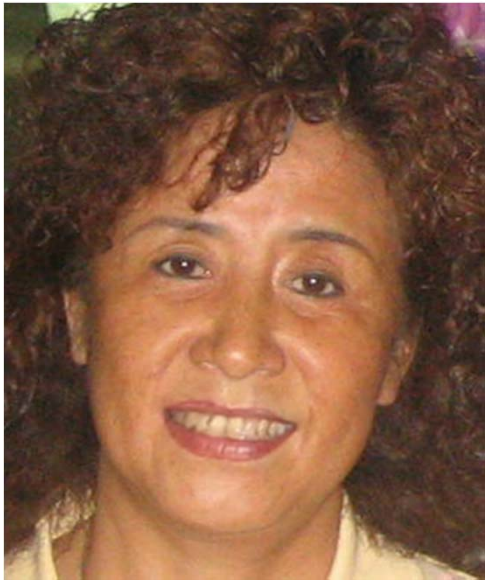
Examples

- Example 1

Mouth distorted

Mouth too close to chin

2D Method



Our Result

Examples

- Example 4

Reference

Warped by
3D rotation

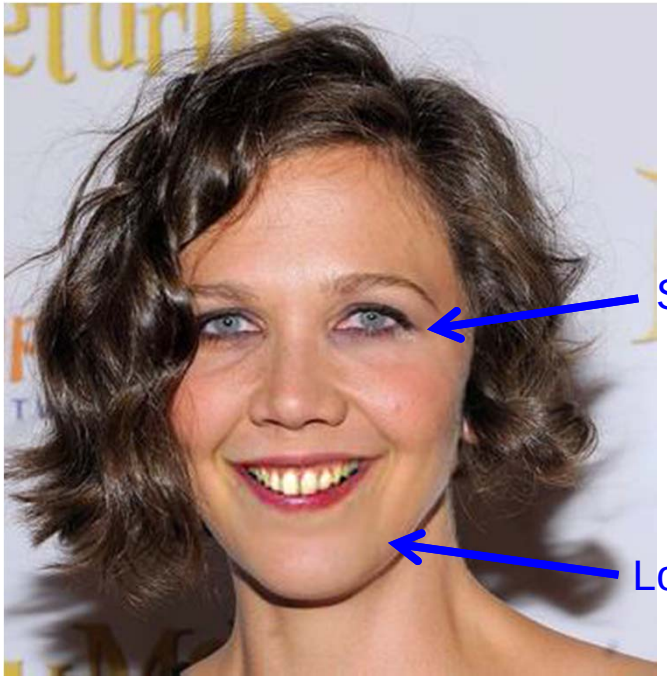
Target

Warped by
Expression Flow

Examples

- Example 4

2D Method



Our Result

Examples

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- Example 2

Reference

Warped by
3D rotation

Target

Warped by
Expression Flow

Examples

- Example 2

2D Method

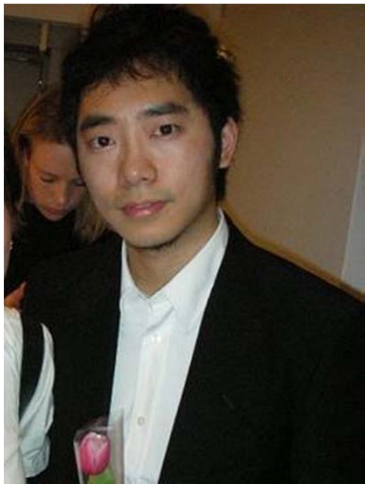
Our Result

Examples

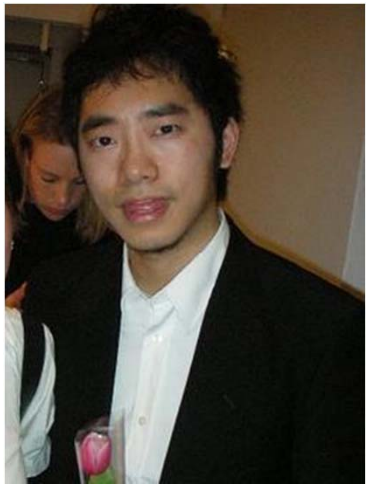
- Example 3

Reference

Warped by
3D rotation



Target

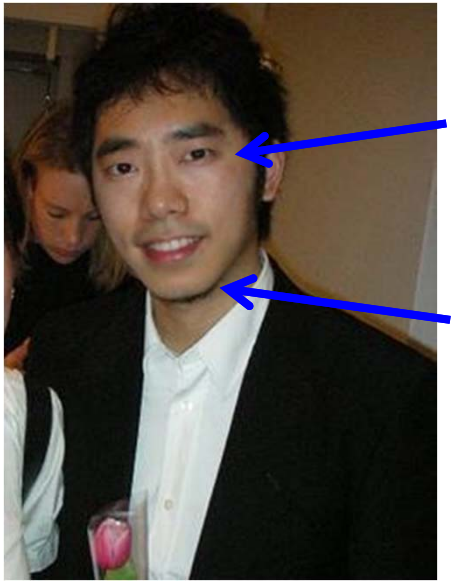


Warped by
Expression Flow

Examples

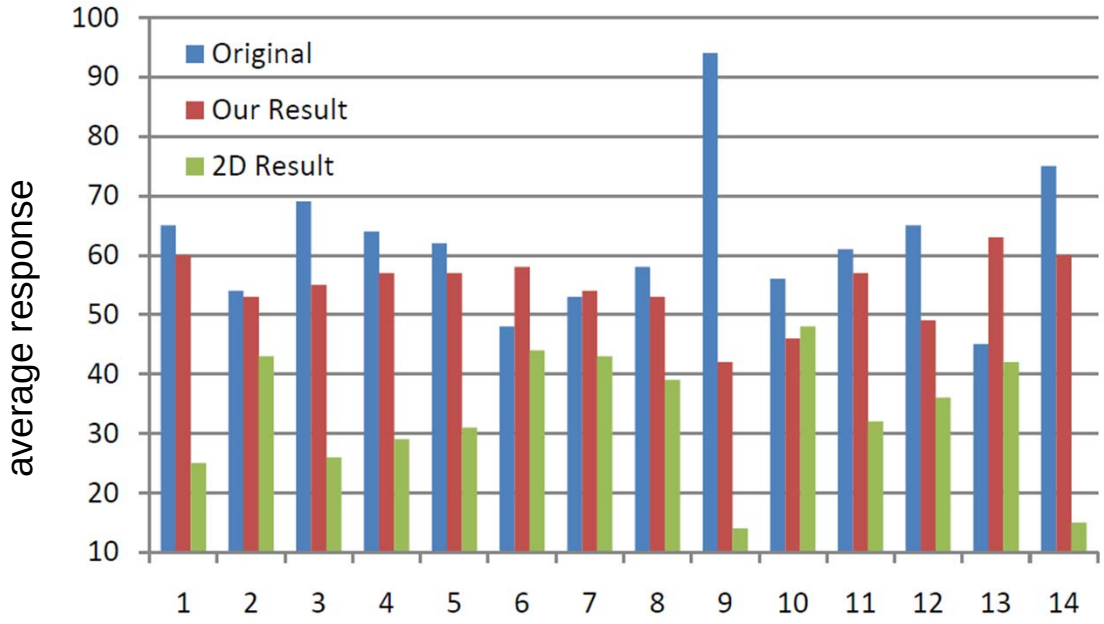
- Example 3

2D Result



Our Result

User study

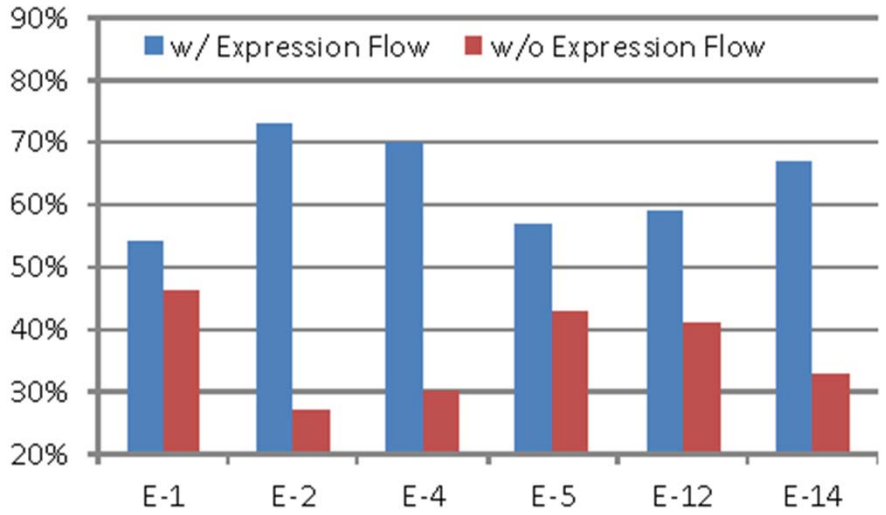


Our results

Question: Which image appears more realistic?

User study

- With vs. without Expression Flow

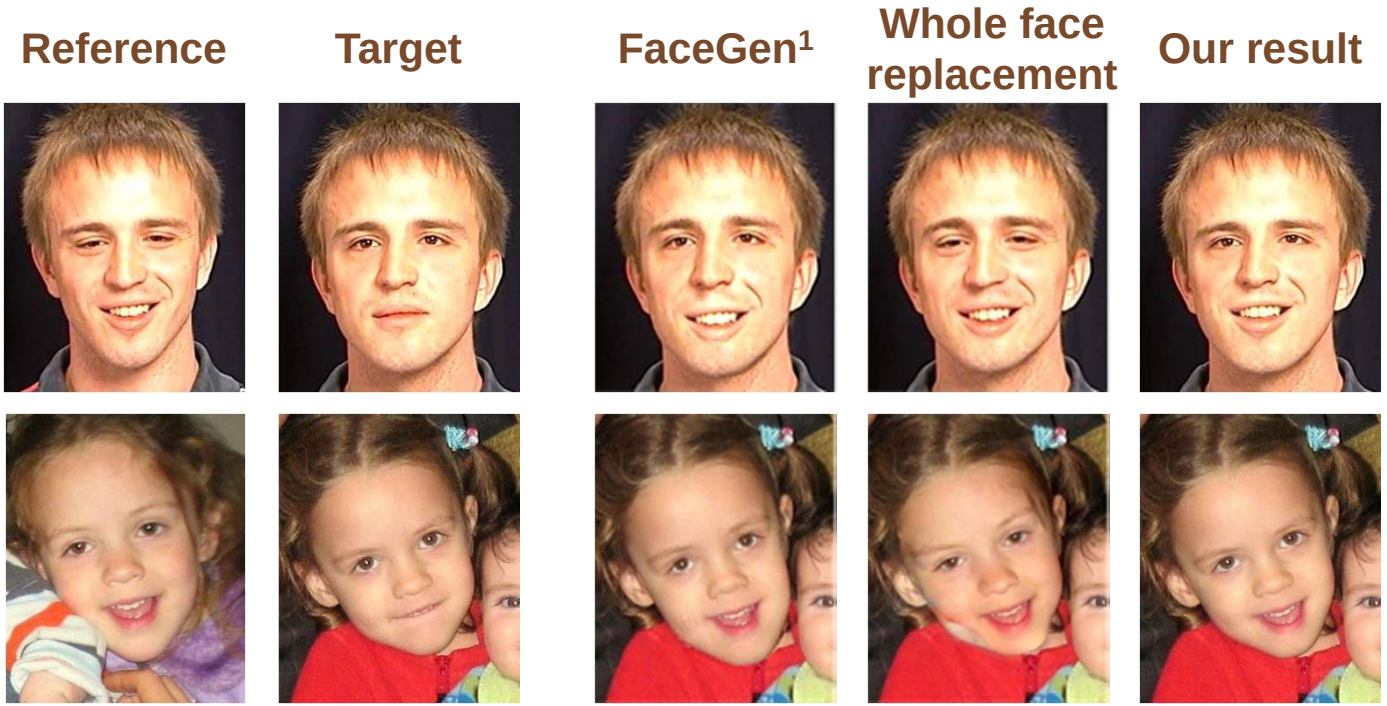


With Without

Question: Which image appears more realistic?

Comparison

- Expression flow vs. other methods



[1] FaceGen: http://www.facegen.com/

Expression flow only

Reference	Target	Our Result
		
		

From neutral to frown

Beginning

After a few years…

From neutral to frown

Reference

Target

Our Result

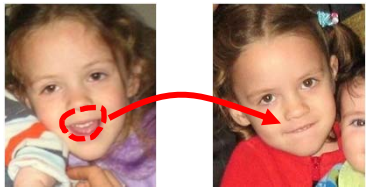
Failure cases

- Asymmetric expression

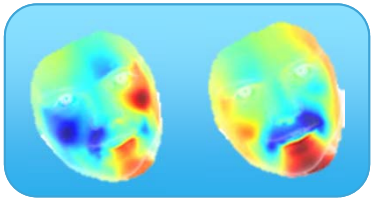
- Large pose change

Conclusion

- Local feature compositing



- Expression flow



- Joint 3D fitting

http://www.juew.org/projects/expressionflow.htm

Thank You!

Reference

Target

Our Result

Thank You!

Reference

Target

Our Result

Thank You!

Reference

Target

Our Result

Thank You!

Reference

Target

Our Result

Thank You!

Reference

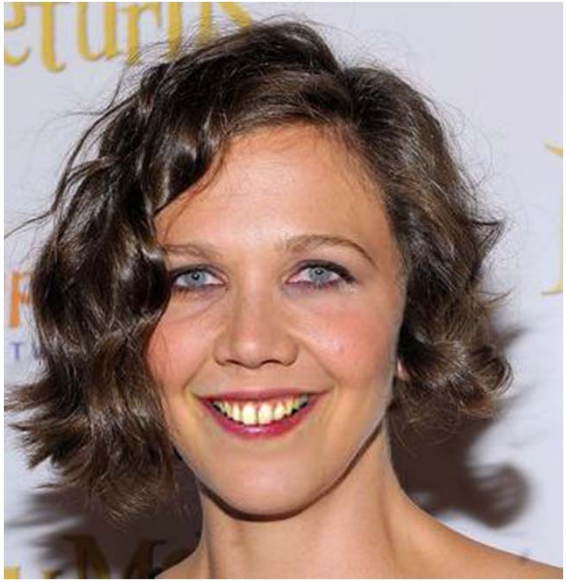
Target

Our Result

Thank You!

Reference

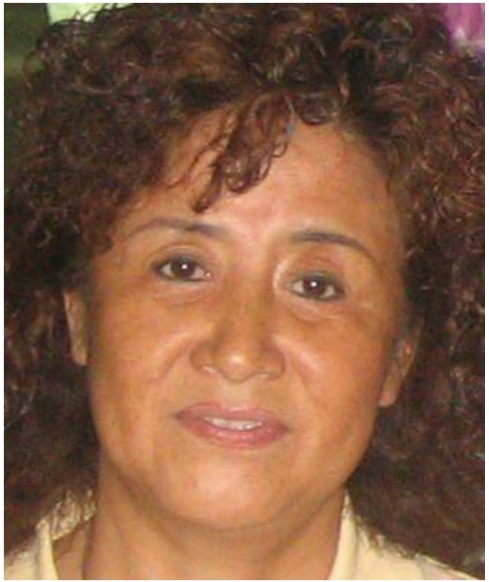
Target



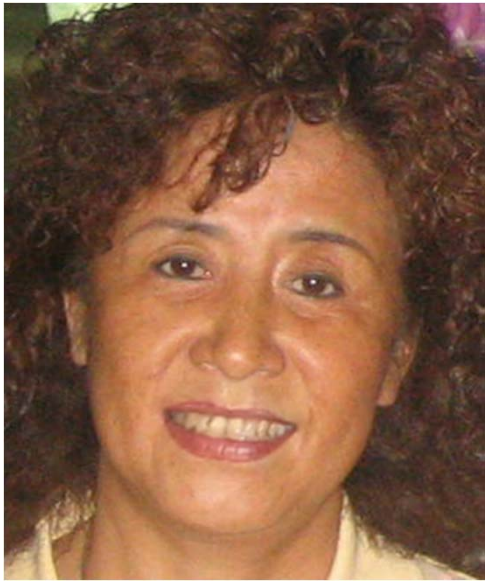
Our Result

Thank You!

Reference



Target



Our Result

Thank You!

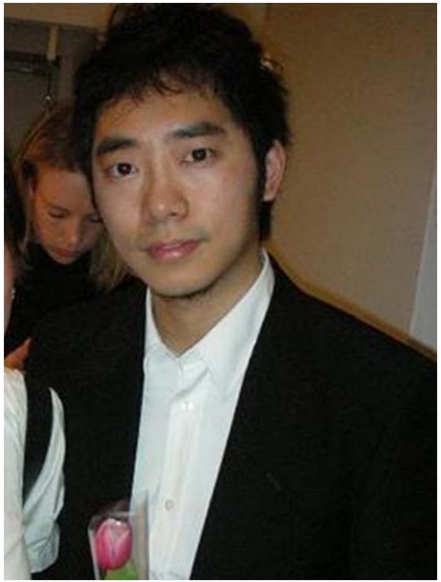
Reference

Target

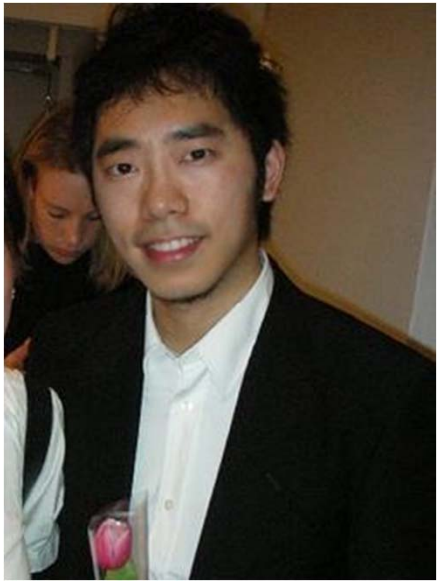
Our Result

Thank You!

Reference



Target



Our Result

Thank You!

Reference

Target

Our Result