Face Morphing using 3D-Aware Appearance Optimization

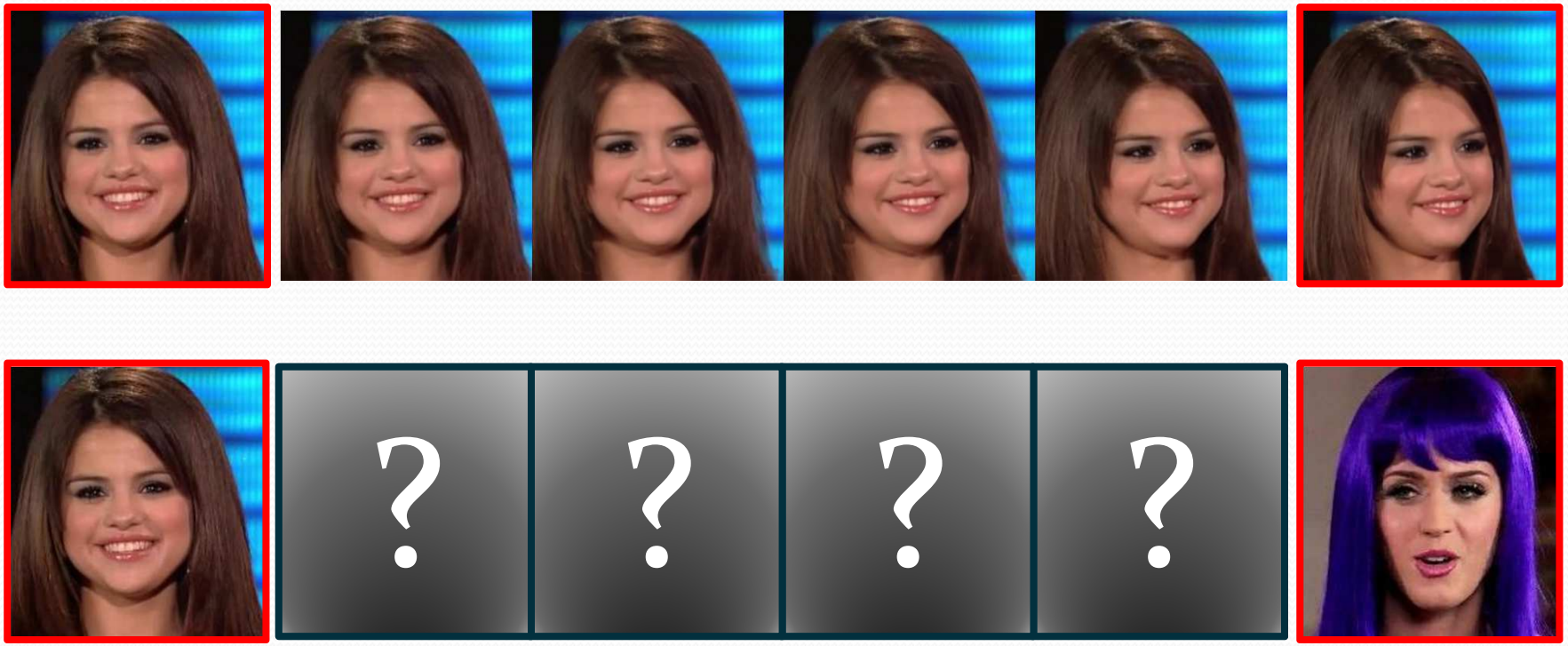
Fei Yang[1] Eli Shechtman[2] Jue Wang[2]
Lubomir Bourdev[2] Dimitris Metaxas[1]

[1.] Rutgers – the State University of New Jersey
[2.] Advanced Technology Labs, Adobe Systems

Face Morphing



Face Morphing



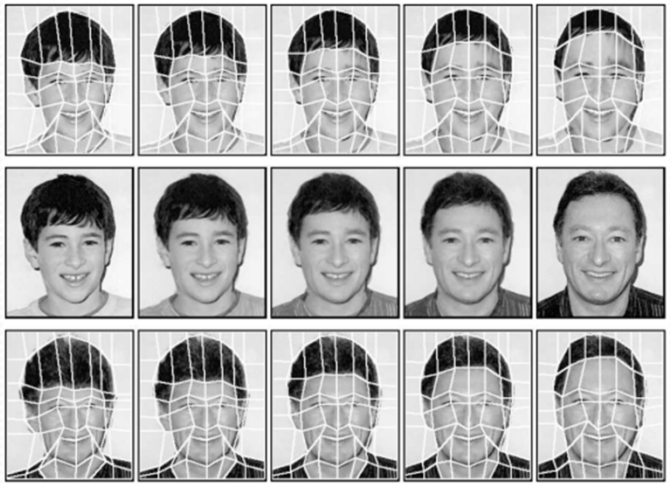
Face Morphing

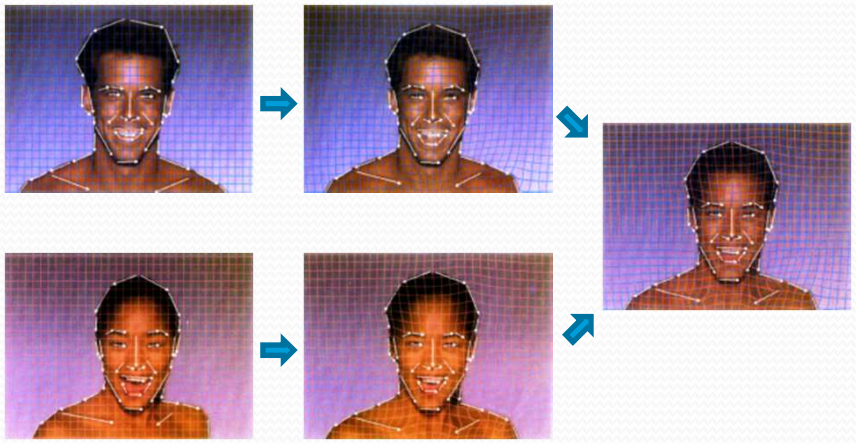
Face Morphing

- Challenges
  - Large variations from identities, poses, expressions, …
  - Human eyes are very sensitive
- Traditional image morphing
  - Manual labeling
  - Automatic correspondences
- Our method
  - Fully automatic
  - Roughly recover and interpolate 3D geometry
  - Optimize for a smooth face appearance change

Previous Work

- User-assisted morphing
  - Mesh morphing [Lee ’96]
  - Field morphing [Beier ’92]





Previous Work

- User-assisted morphing
  - Mesh morphing [Lee ’96]
  - Field morphing [Beier ’92]
  - View morphing [Seitz ’96]

Previous Work

- Automatic morphing
  - Bayesian [Bichsel ’96]
  - Active Shape Models [Zanella ’07]

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  - Moving Gradients [Mahajan ’09]

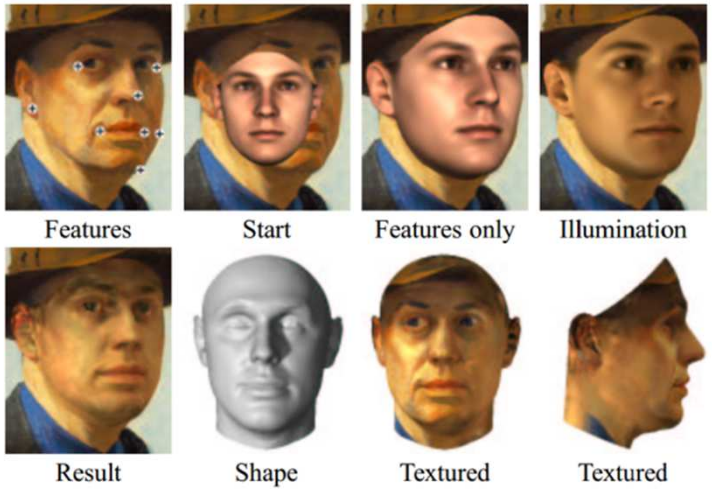
Previous Work

- Automatic morphing
  - Bayesian [Bichsel ’96]
  - Active Shape Models [Zanella ’07]
  - Moving Gradients [Mahajan ’09]
  - Regenerative Morphing [Shechtman ’10]

Previous Work

- 3D Face Animation
  - [Joshi ’03]

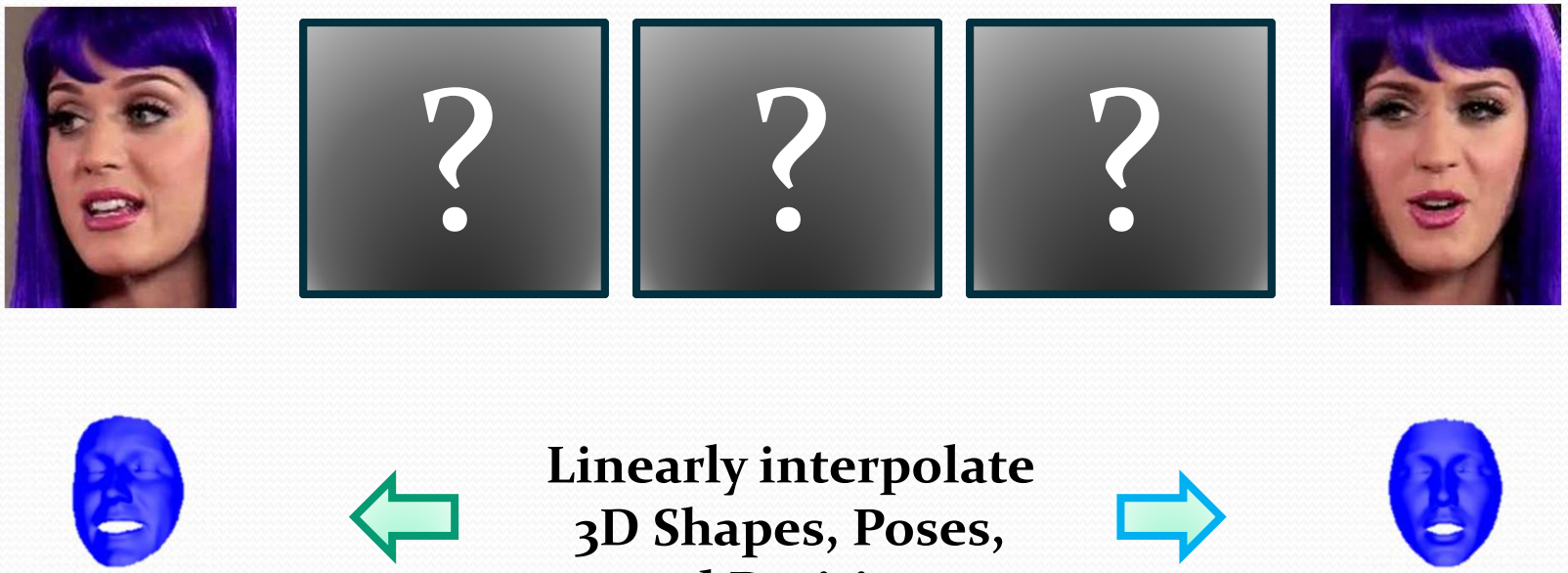
  - [Blanz ’03]



Our Approach

Our Approach

- 3D-assisted 2D method



1. Fit 3D Face Models

Input

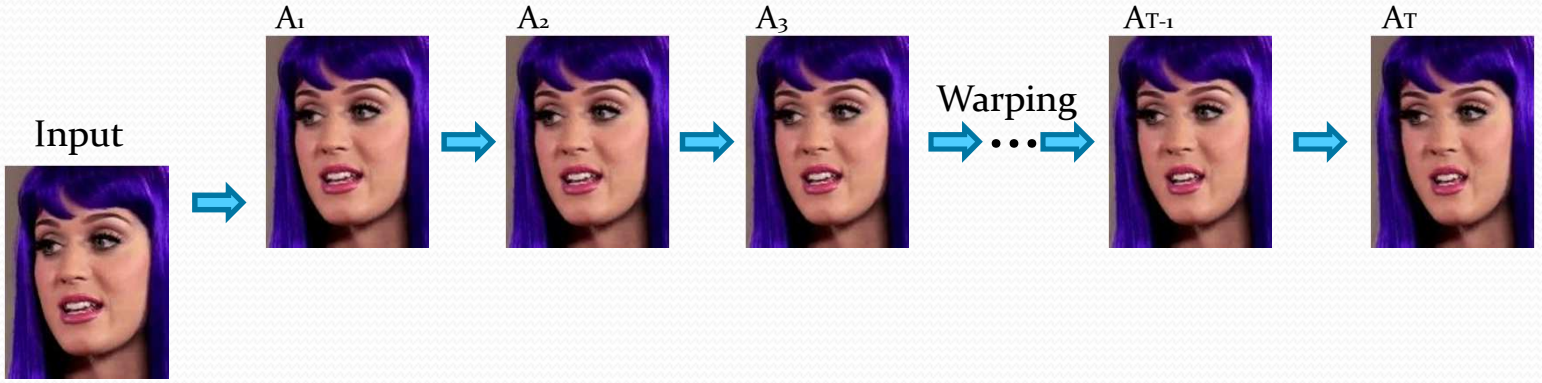
Input

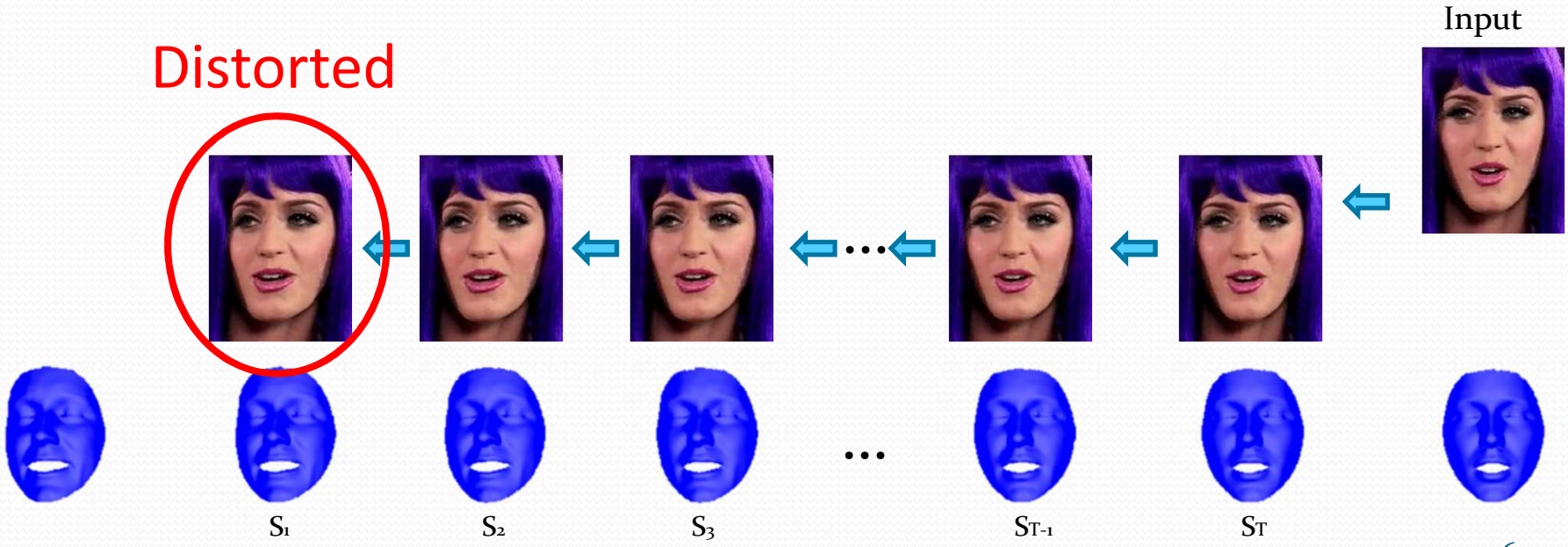
2. Interpolate 3D Shapes

Input

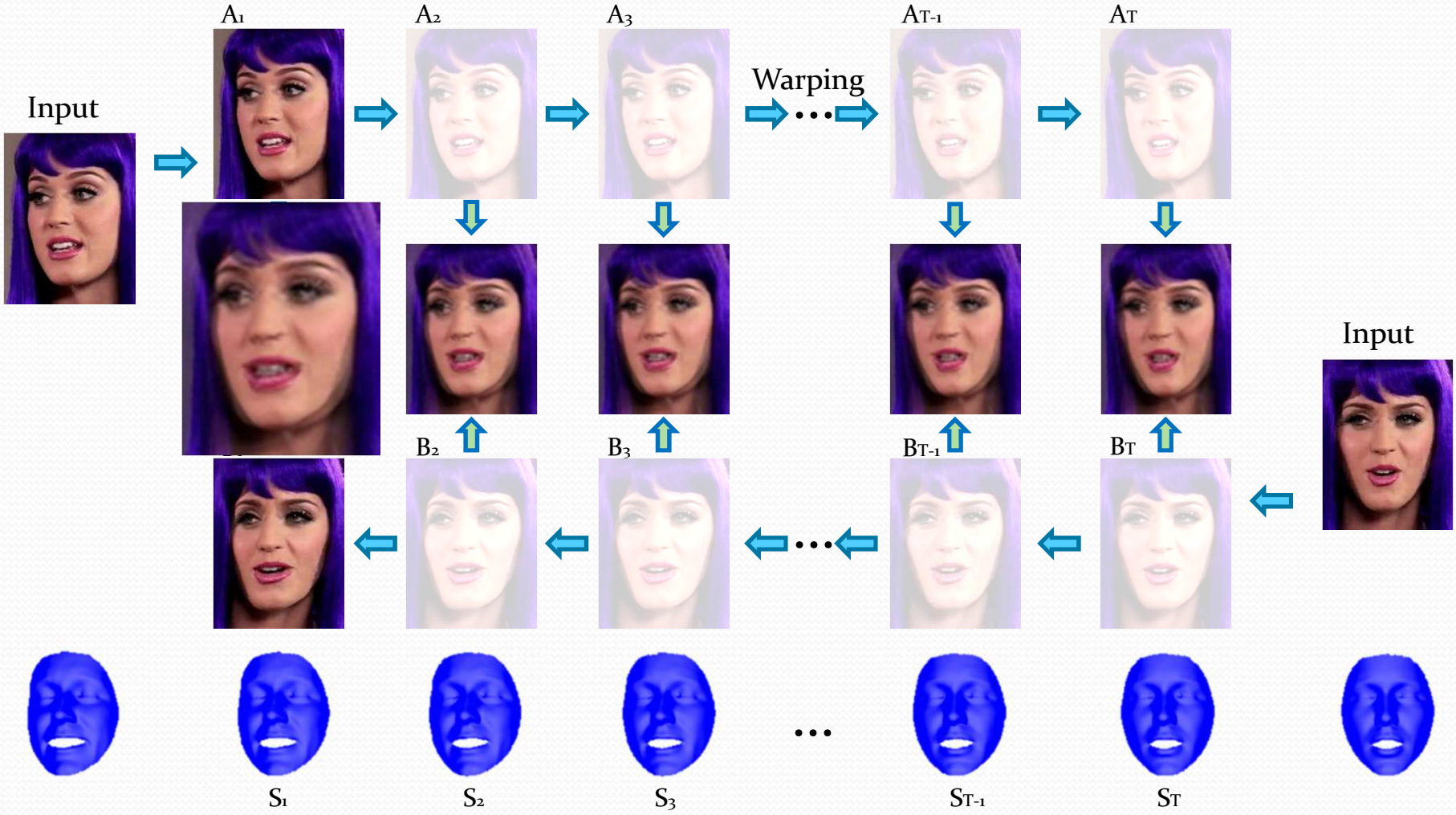
Input

3. Pre-Warp Faces

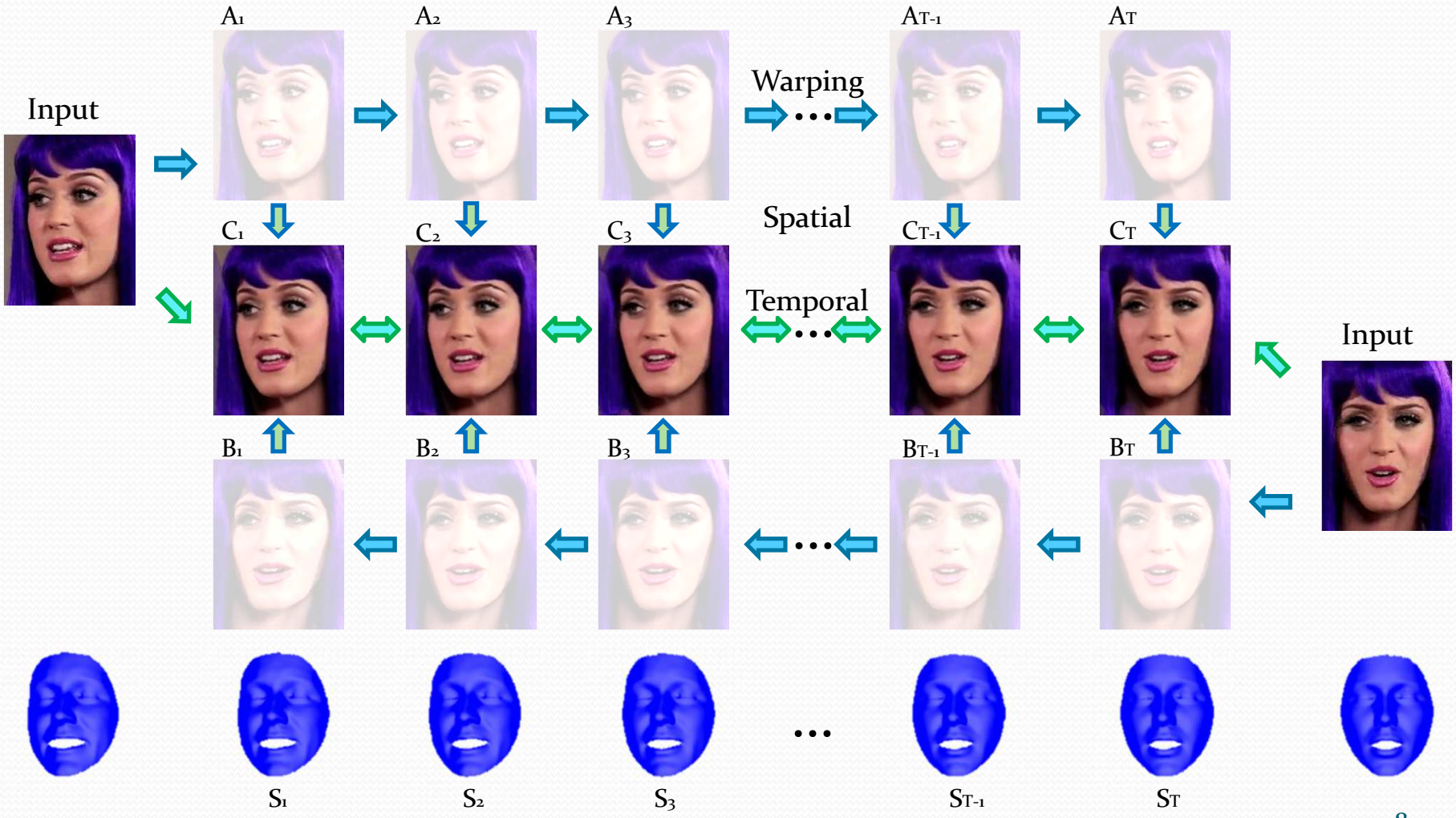




4. Appearance Optimization



4. Appearance Optimization



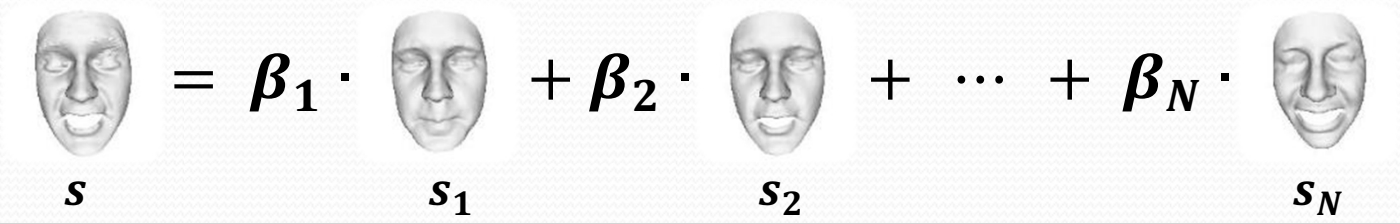
1. Fit 3D Face Models

Input

Input

1. Fit 3D Face Models

- Linear span



- PCA subspace
  - Mean shape $\bar{s}$
  - Eigen shapes $\mathbf{V} = [v_1, v_1, \ldots, v_n]$
  - New shape $s = \bar{s} + V \cdot \beta$

Training data from [Vlasic et al. 2005]

1. Fit 3D Face Models

- Optimization
  - Total energy function

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

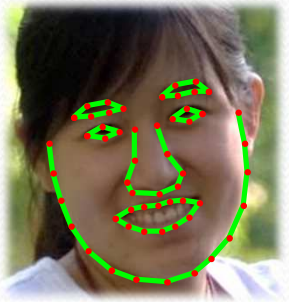
  - Fidelity term

$$\boldsymbol{E_{fid}} = \frac{\mathbf{1}}{\mathbf{2}} ||\boldsymbol{W}^{\mathbf{1/2}}(\boldsymbol{P}(\bar{\boldsymbol{s}} + \boldsymbol{V\beta}) - \boldsymbol{X})||^{\mathbf{2}}$$

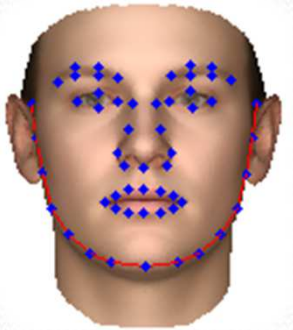
Weights

Projection matrix

2D features



$\boldsymbol{X}$: Facial features



$\boldsymbol{s}$: 3D landmarks

1. Fit 3D Face Models

- Optimization
  - Total energy function

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

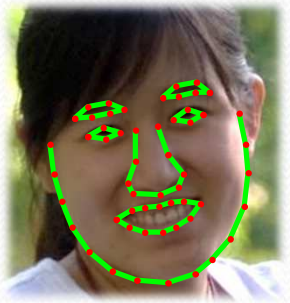
  - Fidelity term

$$\boldsymbol{E_{fid} = \frac{1}{2}||W^{1/2}(P(\bar{s} + V\beta) - X)||^2}$$

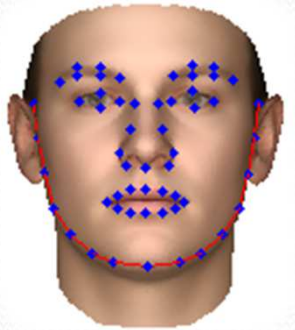
  - Subspace energy term

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

- Solution
  - $\boldsymbol{E}$ is quadratic function of β
  - Solve β in a linear system



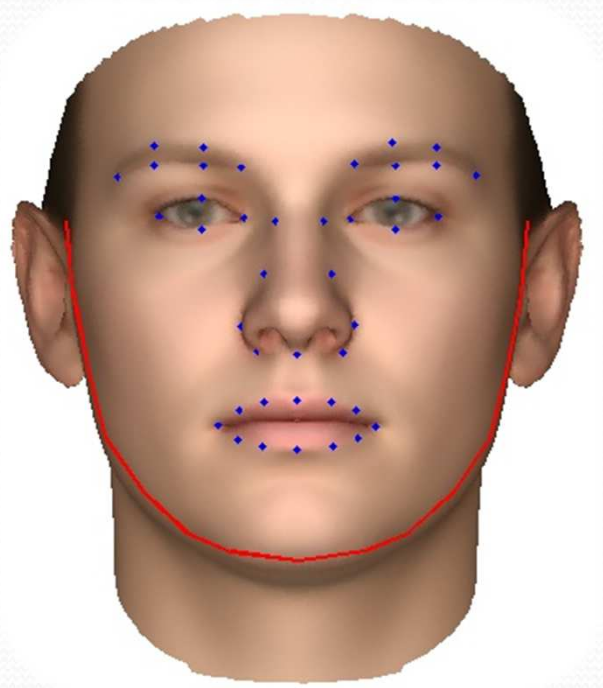
$\boldsymbol{X}$: Facial features



$\boldsymbol{s}$: 3D landmarks

1. Fit 3D Face Models

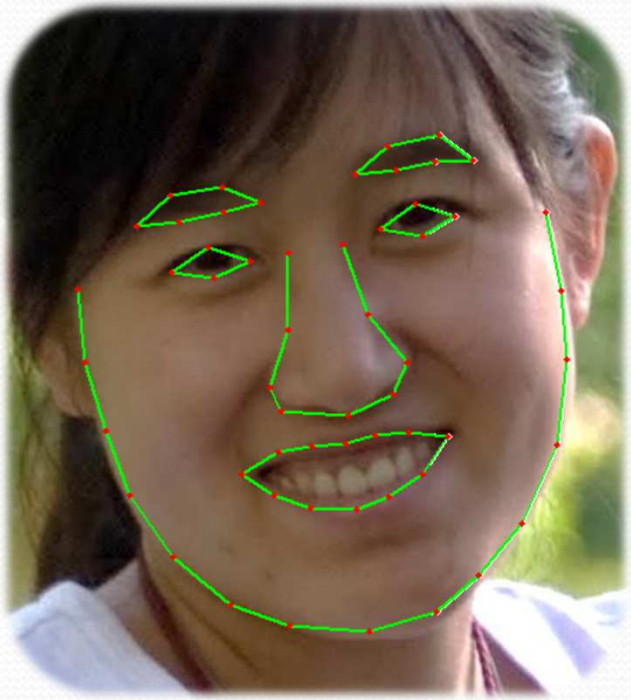
- Matching features
  - Internal landmarks
  - Face boundary



1. Fit 3D Face Models

- Algorithm

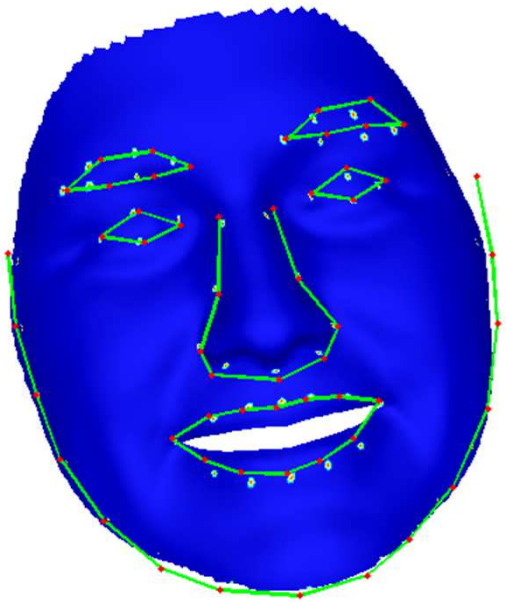
1. Detect landmarks



1. Fit 3D Face Models

- Algorithm

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



After 3 iterations

2. Interpolate 3D Shapes

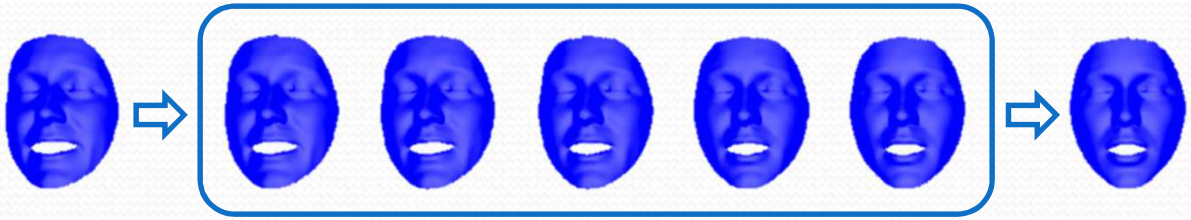
Input

Input

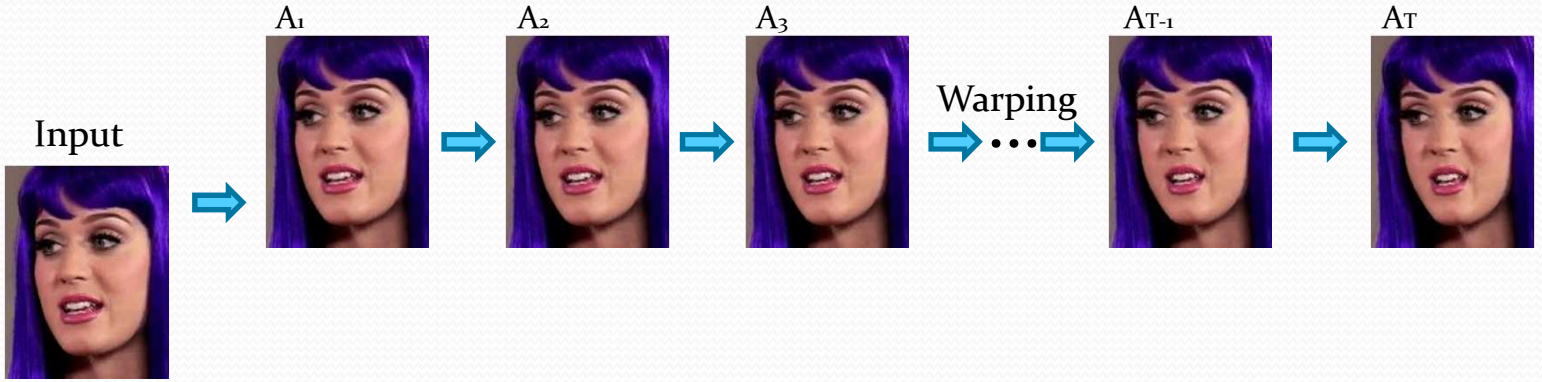
S_1 S_2 S_3 ... S_{T-1} S_T

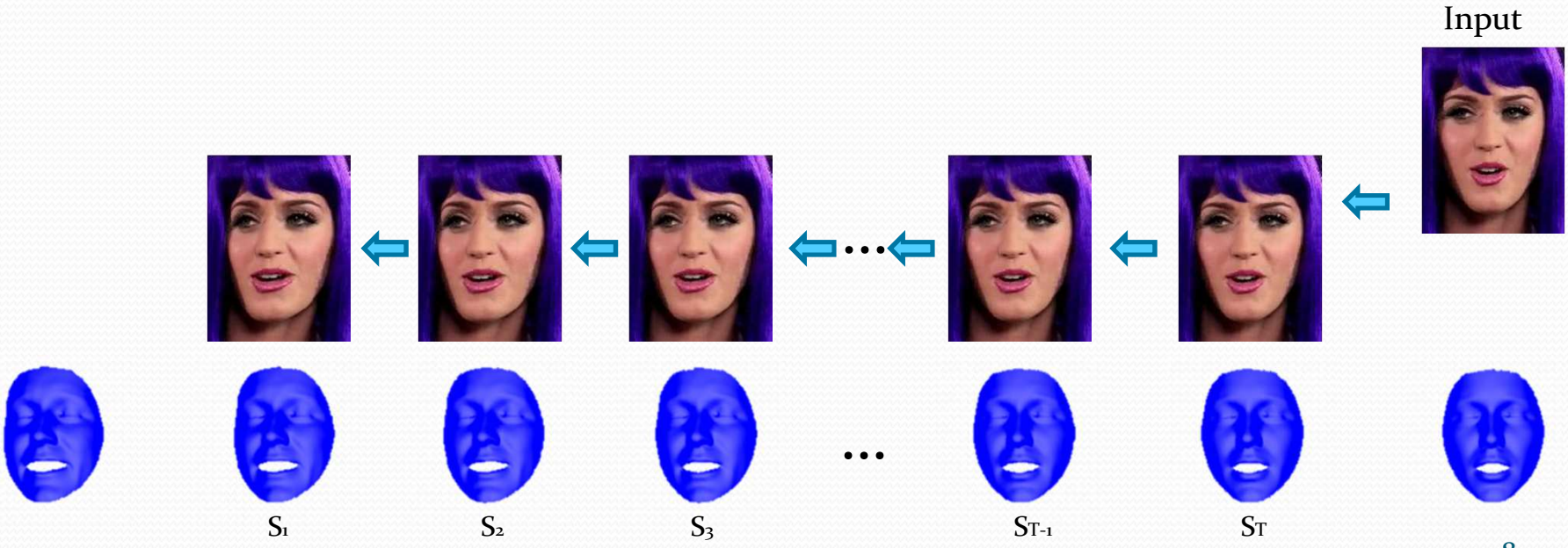
2. Interpolate 3D Shapes

- Parameters of 3D shapes
  - Intrinsic parameters
    - shape coefficients $\boldsymbol{\beta}$
  - External parameters
    - Rotation angles $\boldsymbol{\theta_x}, \boldsymbol{\theta_y}, \boldsymbol{\theta_z}$
    - Translations $\boldsymbol{d_x}, \boldsymbol{d_y}$
    - Scale $\boldsymbol{s}$
  - Linearly interpolate all parameters



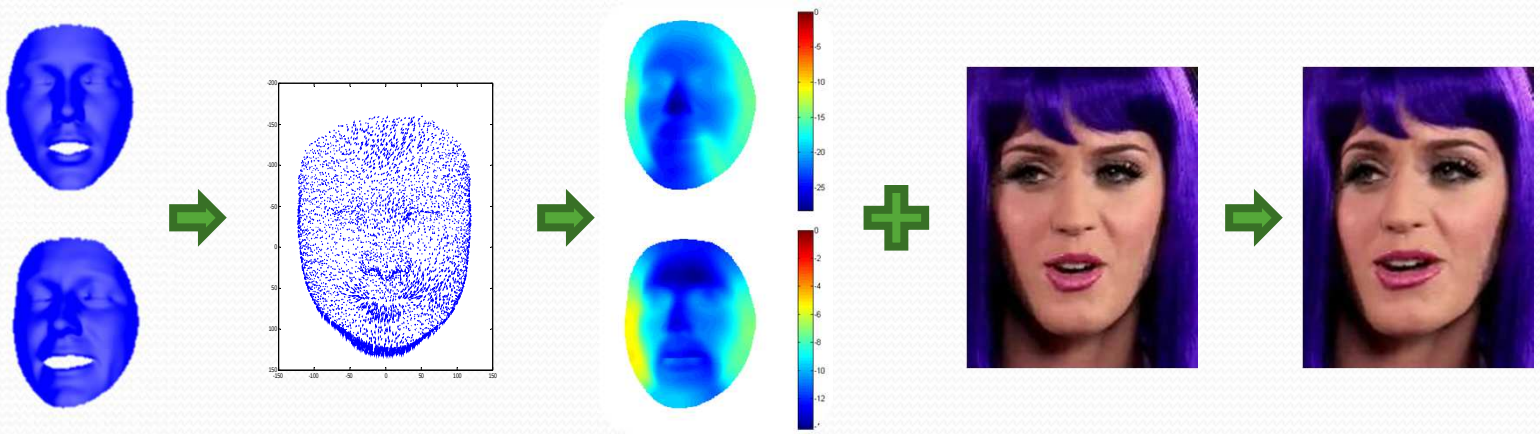
3. Pre-Warp Faces





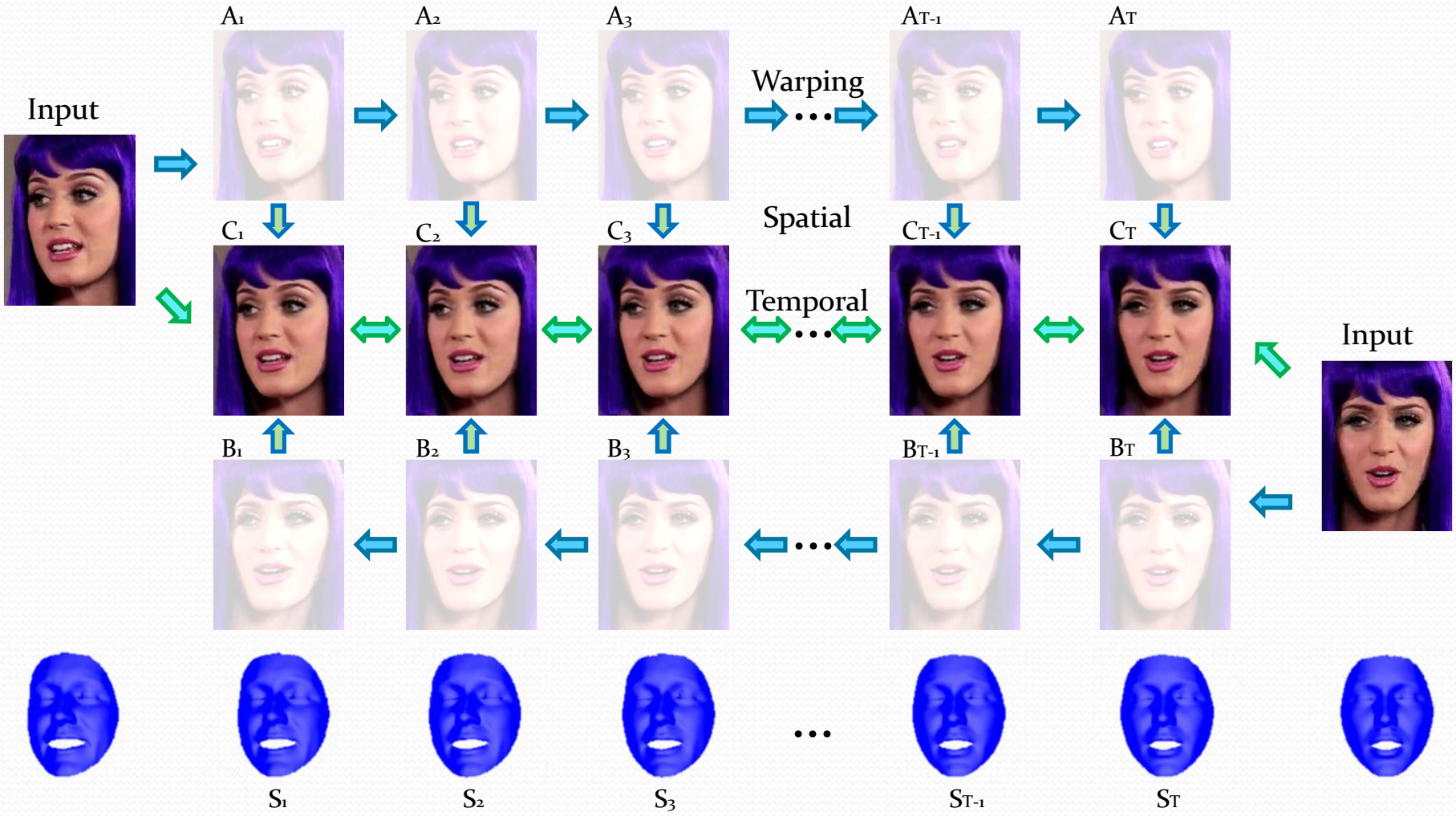
3. Pre-Warp Faces

- Expression Flow
  - Difference between two 3D Shapes
  - Apply to the original image



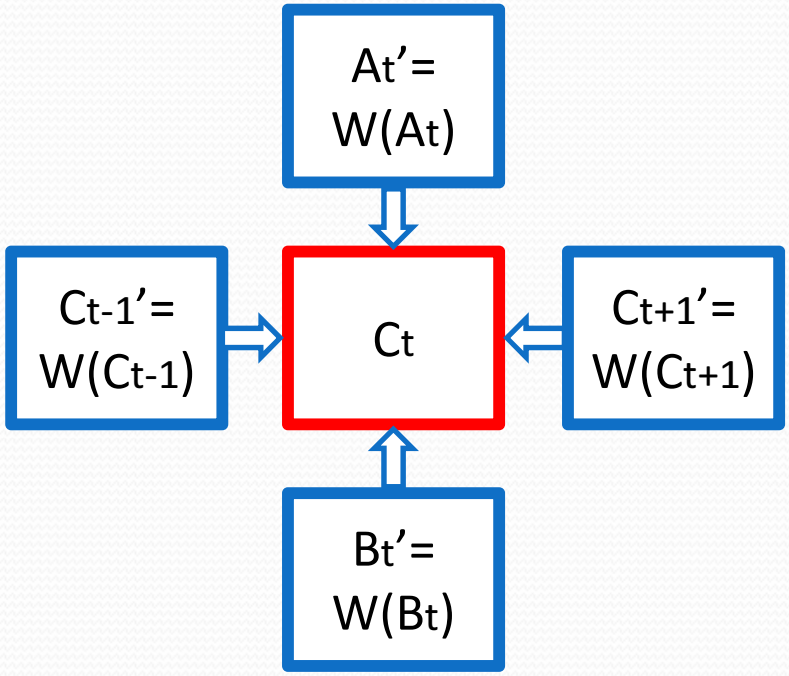
Shape flow **Expression flow**

4. Appearance Optimization



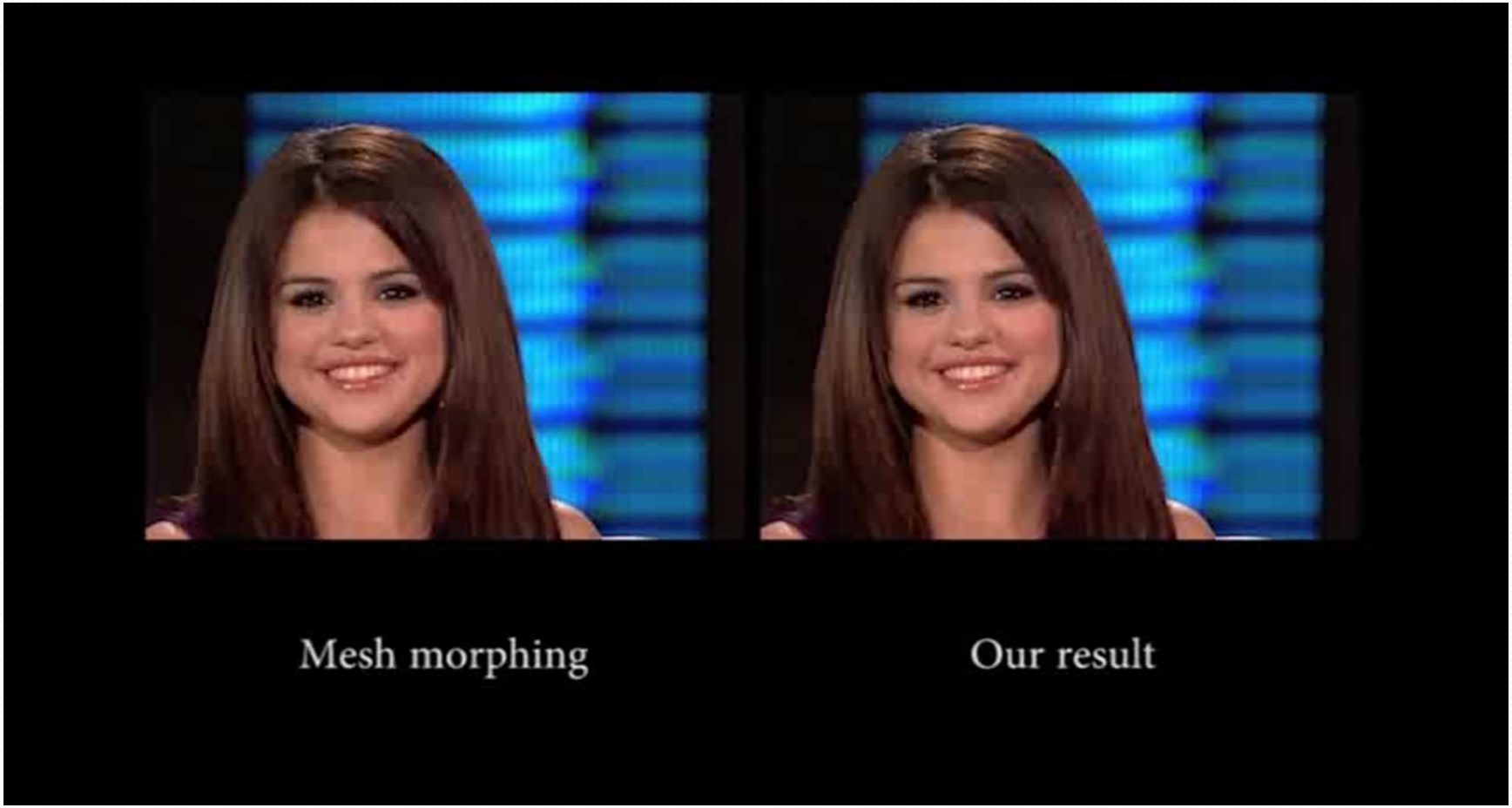
4. Appearance Optimization

- A new frame should be similar to
  - the pre-warped source frames
  - the warped adjacent frames
- Energy function
  - $E = k_A(t) \cdot ||C_t - A_t'||^2 + k_B(t) \cdot ||C_t - B_t'||^2 + k_C \cdot ||C_t - C_{t-1}'||^2 + k_C \cdot ||C_t - C_{t+1}'||^2$
- New frame
  - $C_t = k_A(t) \cdot A_t' + k_B(t) \cdot B_t' + k_C \cdot C_{t-1}' + k_C \cdot C_{t+1}'$



Examples (same subject)

Examples (diff subjects)

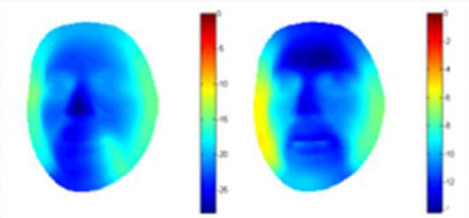


Examples (Stitching)

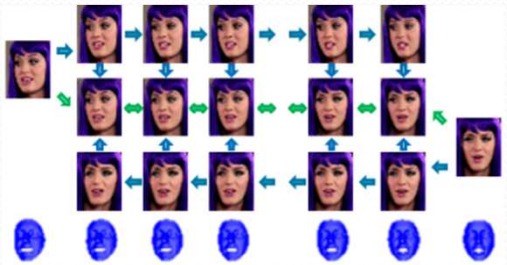
Conclusion

- Face morphing from two faces of difference poses and expressions.

- Warping the two faces by the face flow extracted from roughly fit 3D model s.



- Appearance optimization can recover small misalignment and other changes.



Thank you