

# Face Image Editing

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# Introduction

- ▶ A large proportion of the images people upload is face image.
- ▶ We want to develop a software that ease the process of editing facial image.

# Applications I



# Applications II



# Agenda

1. Generate a face
2. Fit a face model
3. Application: Expression Flow
4. Laplacian Surface Editing
5. Demo: Laplacian Surface Editing

# Generate a face I

Bilinear face model[?]

$$\mathbf{f} = \mathcal{M} \times \mathbf{w}_{\text{id}}^T \times \mathbf{w}_{\text{expr}}^T$$



## Generate a face II

Basel face model[?]

$$\mathbf{f} = \bar{\mathbf{f}} + \mathcal{M}_{\text{id}} \times \mathbf{w}_{\text{id}}^\top + \mathcal{M}_{\text{expr}} \times \mathbf{w}_{\text{expr}}^\top$$

$$\mathbf{w}_{\text{id}} \sim \mathcal{N}(0, \text{diag}(\sigma_{\text{id}}^{(1)}, \dots, \sigma_{\text{id}}^{(N_{\text{id}})}))$$

$$\mathbf{w}_{\text{expr}} \sim \mathcal{N}(0, \text{diag}(\sigma_{\text{expr}}^{(1)}, \dots, \sigma_{\text{expr}}^{(N_{\text{expr}})}))$$

Under the assumption of weak perspective camera model, with scale  $s$ , rotation  $\mathbf{R}$  and translation  $\mathbf{t}$ , we have

$$\hat{\mathbf{f}} = s(\mathbf{R}\mathbf{f} + \mathbf{t})$$

# Fit a face model

Given an image and 2D face landmarks  $\{l_1, \dots, l_{N_{\text{lm}}}\}$  from a off-the-shelf tracker<sup>1</sup>. Solve the following optimization problem:

$$\min_{\mathbf{w}_{\text{id}}, \mathbf{w}_{\text{expr}}, s, \mathbf{R}, \mathbf{t}} \sum_{i=1}^{N_{\text{lm}}} \|l_i - h_i\|_2^2$$

where  $\{h_1, \dots, h_{N_{\text{lm}}}\}$  is the corresponding points on 3d model.

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<sup>1</sup><https://www.faceplusplus.com.cn/>

# Coordinate Descent

We alternate the optimization of  $s, \mathbf{R}, \mathbf{t}$  and  $\mathbf{w}_{\text{id}}, \mathbf{w}_{\text{expr}}$ .

$$\min_{\mathbf{w}_{\text{id}}, \mathbf{w}_{\text{expr}}, s, \mathbf{R}, \mathbf{t}} \sum_{i=1}^{N_{\text{Im}}} \|l_i - s(\mathbf{R}(\mathcal{M} \times [\mathbf{w}_{\text{id}}, \mathbf{w}_{\text{expr}}]^\top)_i + \mathbf{t})\|_2^2$$

# Algorithm: Fit a face model

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**Algorithm 1:** Fit face model to a single image

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**Input:** facial landmarks  $\{l_1, \dots, l_{N_{\text{lm}}}\}$  and PCA model

**Output:** shape coefficients  $w$  and camera parameters  $s, R, t$

Set  $w = 0$ ;

**repeat**

Set  $f = \bar{f} + M \times w^\top$ ;

Find the camera parameters  $s, R, t$  using  $f$  and  $\{l_1, \dots, l_{N_{\text{lm}}}\}$ ;

Project all vertices of  $f$  onto the image plane:  $\hat{f} = s(Rf + t)$ ;

Find the convex hull of  $\hat{f}$  as  $\text{hull}(\hat{f})$ ;

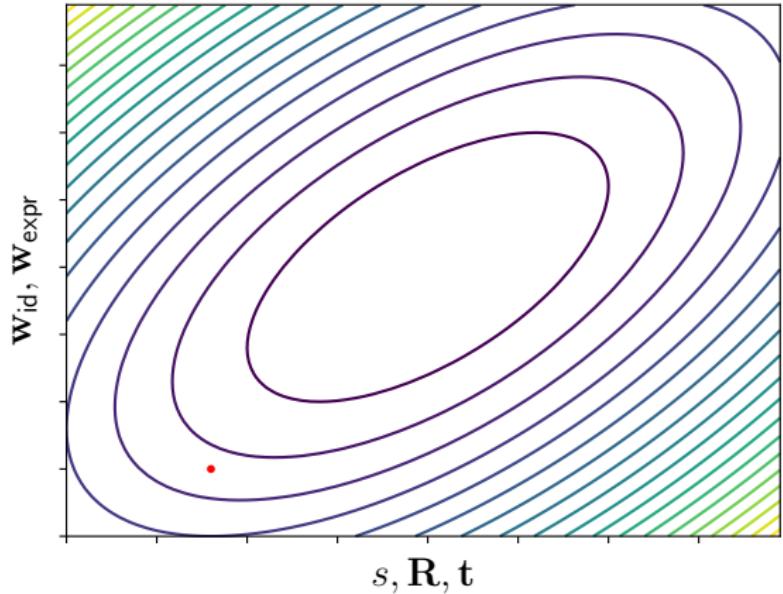
For contour landmarks  $l_i$ , find the correspondence;

Solve  $w$ ;

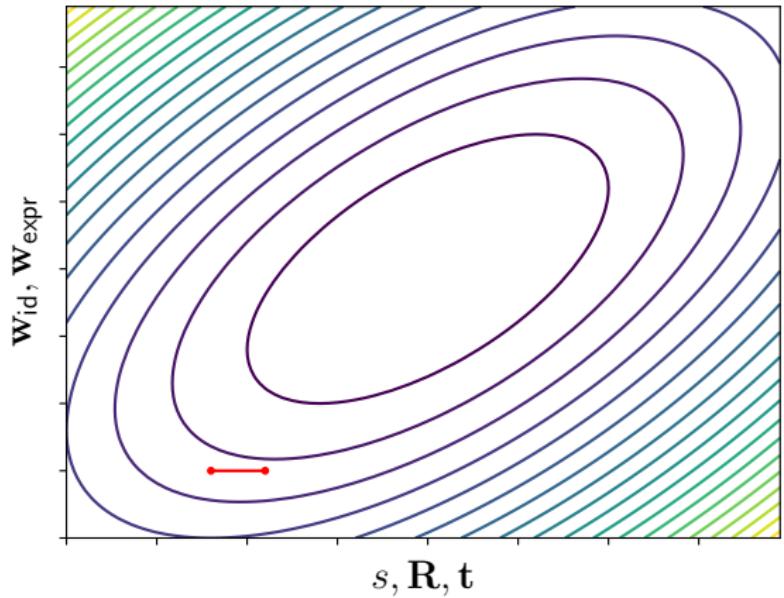
**until**  $w$  converges;

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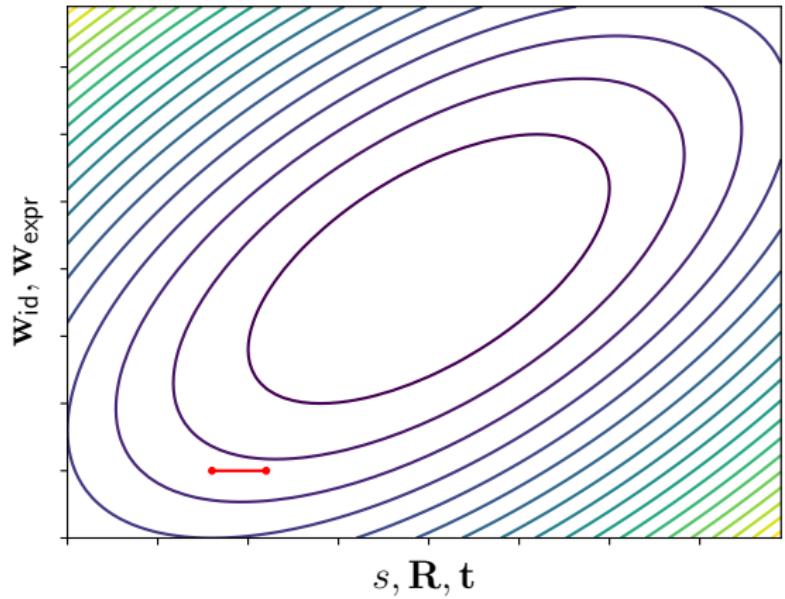
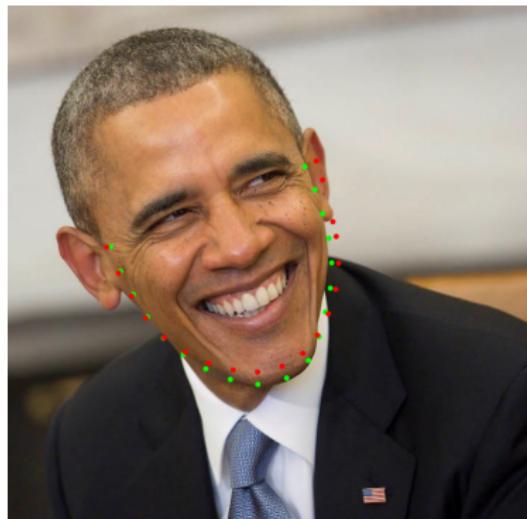
# Coordinate Descent I



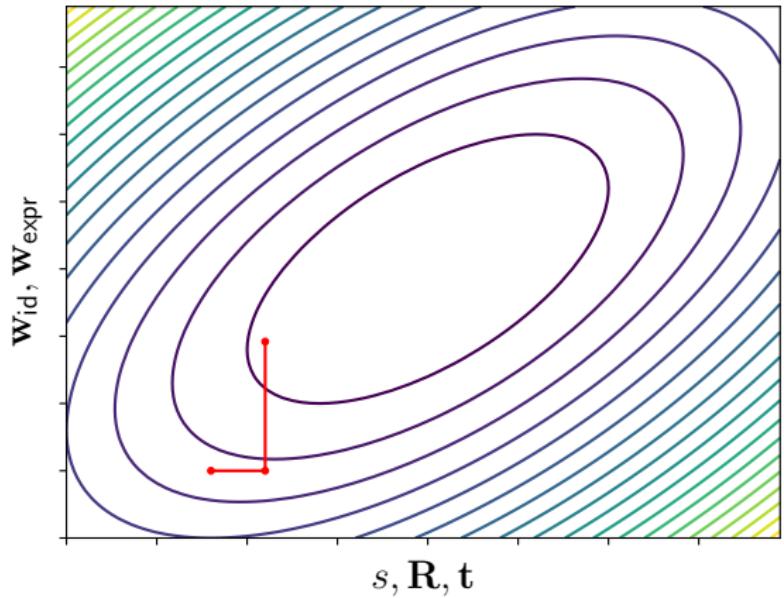
# Coordinate Descent II



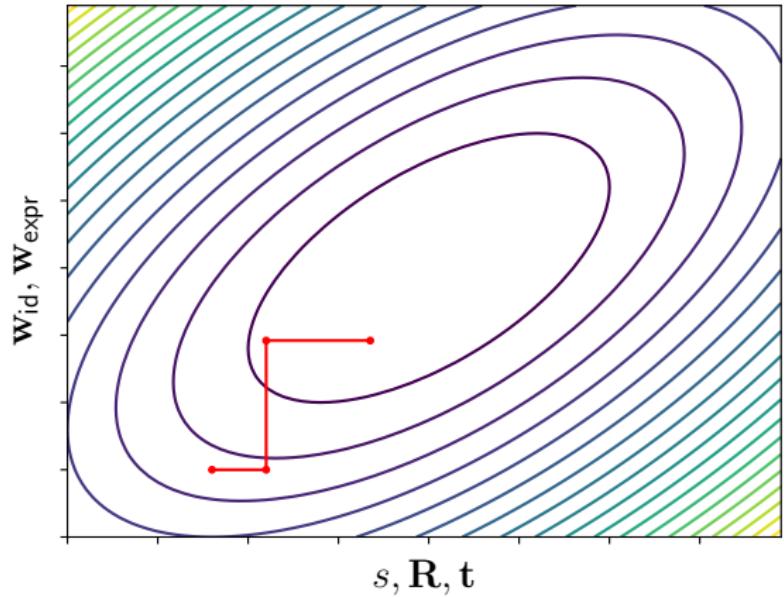
# Coordinate Descent III



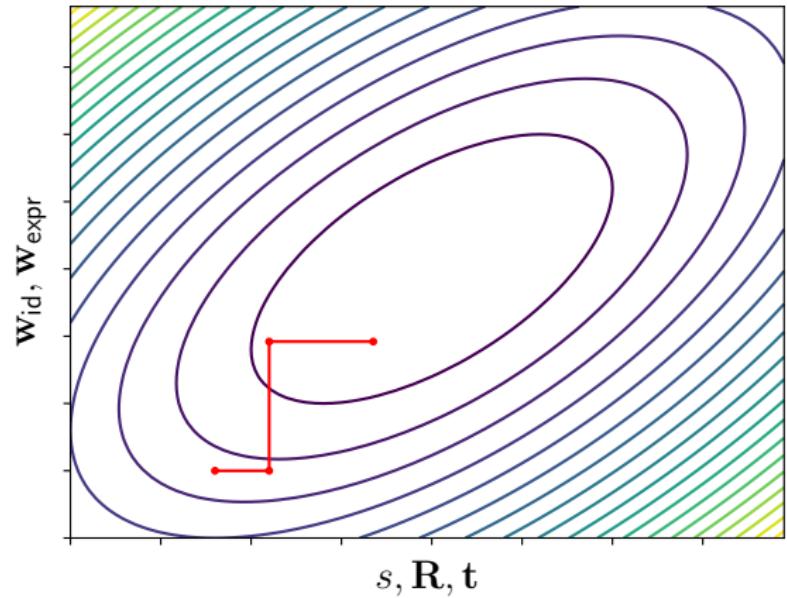
# Coordinate Descent IV



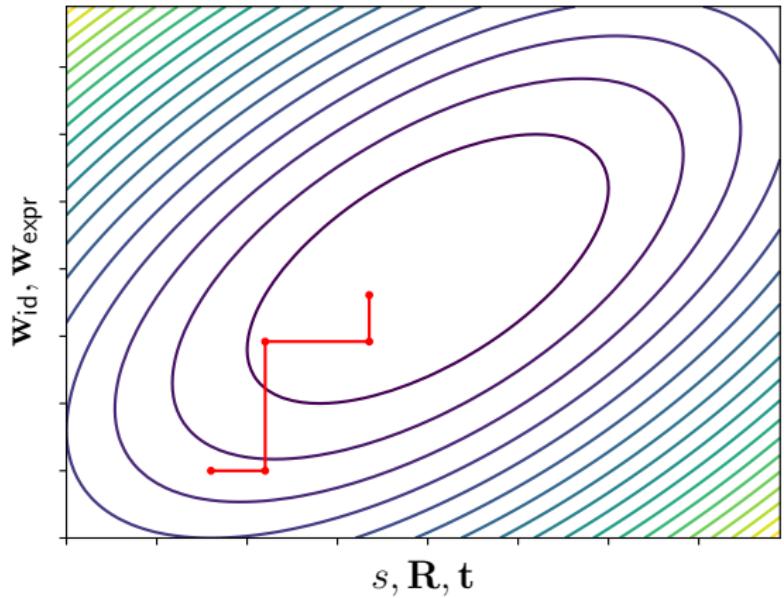
# Coordinate Descent V



# Coordinate Descent VI



# Coordinate Descent VII



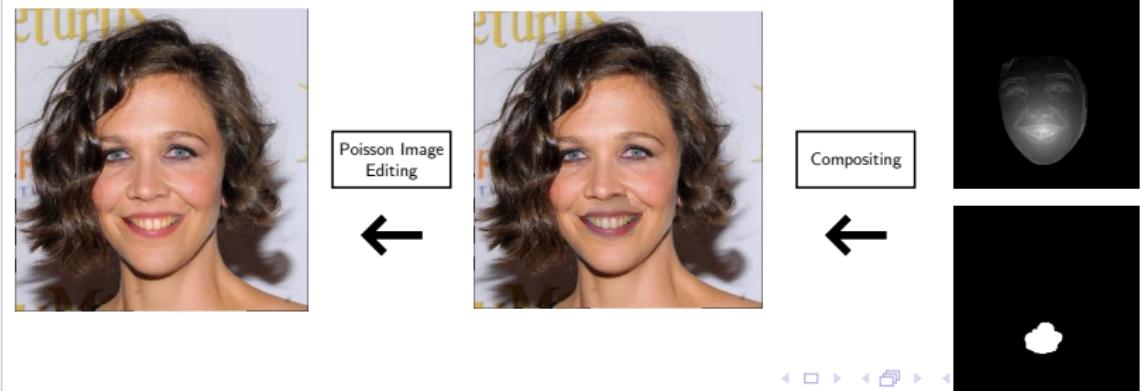
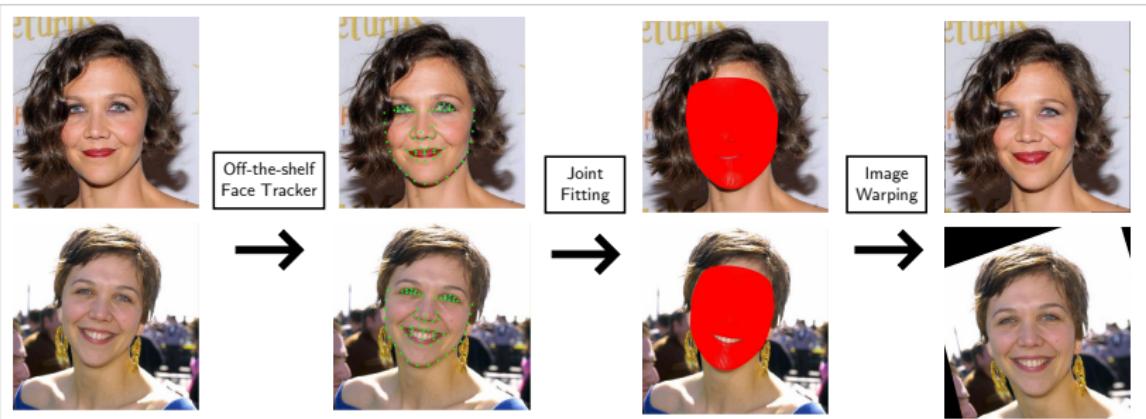
# Estimation of Parameters

- ▶ Estimation of  $\mathbf{w}_{\text{id}}, \mathbf{w}_{\text{expr}}$  is a regularized least square.
- ▶ Estimation of  $s, \mathbf{R}, \mathbf{t}$  is achieved using POSIT algorithm.
- ▶ See more in our report!

# Application: Expression Flow for 3D-Aware Face Component Transfer[?]



# Expression Flow Pipeline



# More Results



Reference



Target



Result

# More Results



Reference



Target



Result

# Laplacian Surface Editing I

Laplacian operator measures the flatness of the mesh:

$$\Delta f(\mathbf{x}) = \lim_{|B(\mathbf{x})| \rightarrow 0} \frac{1}{|B(\mathbf{x})|} \int_{B(\mathbf{x})} f(\mathbf{z}) d\mathbf{z} - f(\mathbf{x})$$

Where  $B(\mathbf{x})$  is an infinitesimal region around  $\mathbf{x}$ . We want to the difference of mesh before and after deformation be small.

$$\begin{aligned} \int_{\Omega} ||\Delta(\mathbf{x} - \hat{\mathbf{x}})||^2 d\mathbf{A} &\approx \text{tr}(\mathbf{D}^T \mathbf{L}^T \mathbf{M}^{-T} \mathbf{M} \mathbf{M}^{-1} \mathbf{L} \mathbf{D}) \\ &= \text{tr}(\mathbf{D}^T \underbrace{\mathbf{L}^T \mathbf{M}^{-1} \mathbf{L}}_Q \mathbf{D}) \end{aligned}$$

where  $\mathbf{D}, \mathbf{L}, \mathbf{M}$  is the difference of mesh, laplacian and the mass matrix respectively.

$$\min_{\mathbf{D}_u} \text{tr} \left( (\mathbf{D}_u^T \mathbf{D}_h^T) \left( \begin{array}{cc} \mathbf{Q}_{u,u} & \mathbf{Q}_{u,h} \\ \mathbf{Q}_{h,u} & \mathbf{Q}_{h,h} \end{array} \right) \left( \begin{array}{c} \mathbf{D}_u \\ \mathbf{D}_h \end{array} \right) \right)$$

# Laplacian Surface Editing II

$$\min_{\mathbf{D}_u} \text{tr} \left( \mathbf{D}_u^\top \mathbf{Q}_{u,u} \mathbf{D}_u + 2 \mathbf{D}_u^\top \mathbf{Q}_{u,h} \mathbf{D}_h + \underbrace{\mathbf{D}_h^\top \mathbf{Q}_{h,h} \mathbf{D}_h}_{\text{constant}} \right)$$
$$\min_{\mathbf{D}_u} \text{tr} \left( \mathbf{D}_u^\top \mathbf{Q}_{u,u} \mathbf{D}_u + 2 \mathbf{D}_u^\top \mathbf{Q}_{u,h} \mathbf{D}_h \right)$$

Set the gradient to zero

$$2\mathbf{Q}_{u,u}\mathbf{D}_u + 2\mathbf{Q}_{u,h}\mathbf{D}_h = 0 \rightarrow \mathbf{D}_u = \mathbf{Q}_{u,u}^{-1}\mathbf{Q}_{u,h}\mathbf{D}_h$$

Minimization w.r.t to the unconstrained points gives us the solution.

# Demo: Laplacian Surface Editing

# Results



# Summary

What have we implemented?

- ▶ Single/Joint Face fitting [?]
- ▶ Laplacian Surface Editing [?]
- ▶ Poisson Image Editing [?]
- ▶ Formulate our problem into graph cut[?] and solve it using GCO library [?]
- ▶ ARAP shape manipulation [?]
- ▶ **Combine the above all together**

# References I

# Thanks!