Face morphing generation and detection

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Outline

Introduction of image/face morphing

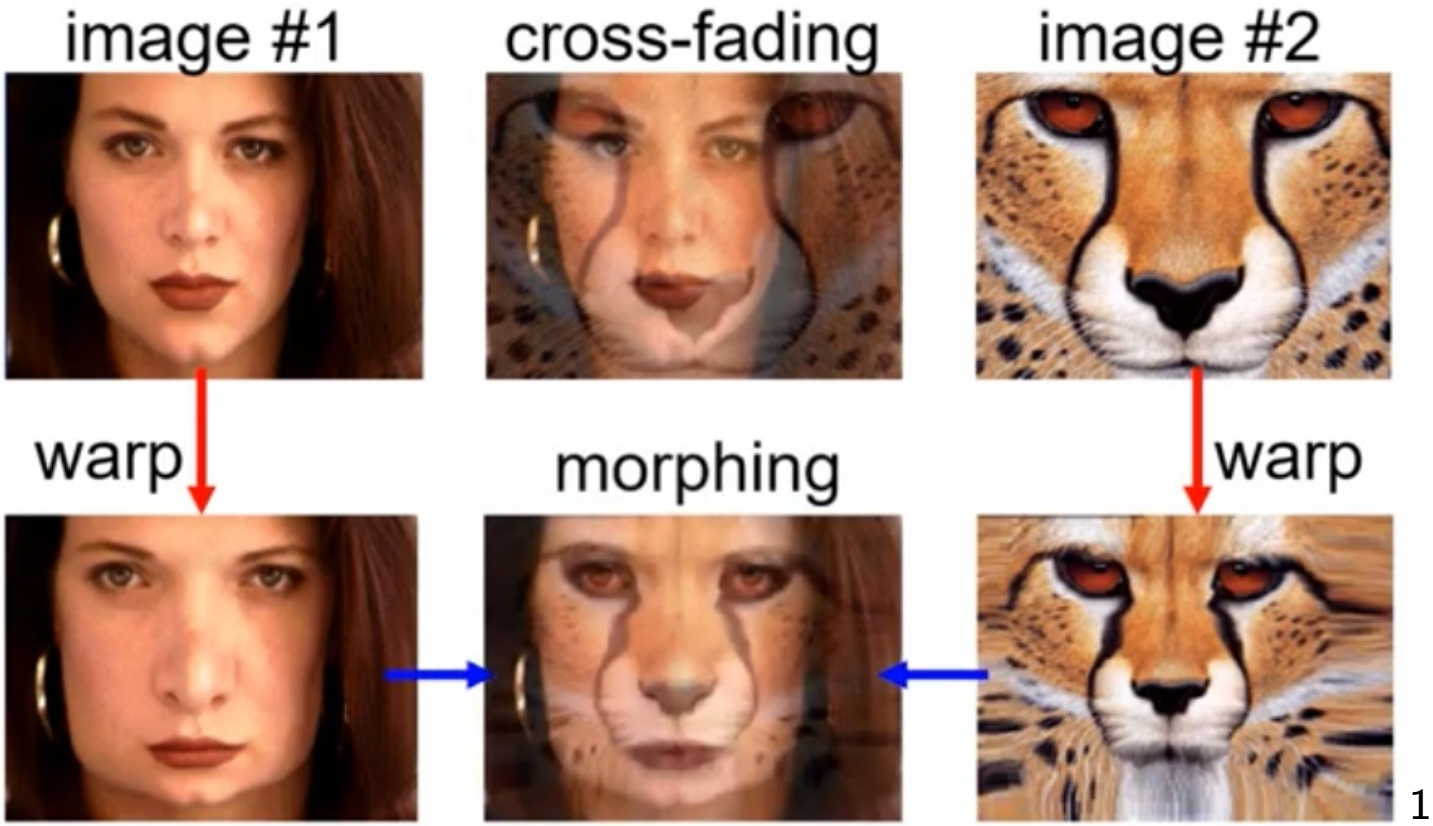
- Image morphing is one of the seminal problems in Computer Graphics
- Numerous artistic applications

Figure: Image taken from: `https://www.cartoonbrew.com/vfx/oral-history-morphing-michael-jacksons-black-white-144015.html`

Problems of image/face morphing

- Cross-fades work only on previously aligned images
- If not aligned, we need to **warp** them for feature alignment
- And **blend** their colors for a smooth transition between images

Problems of image/face morphing



[1]

[1] Image taken from: Gomes, J, Warping and Morphing of Graphical Objects, 1998, Morgan Kaufmann.

Motivation

- The transformations up to this point are not **continuous**, or **smooth**
- Why is this important or useful?
- If the transformation is smooth, we can leverage its **differential properties** during the warping/blending
- Also, the transformation is a continuum between the images, instead of a finite number of states

Problem statement

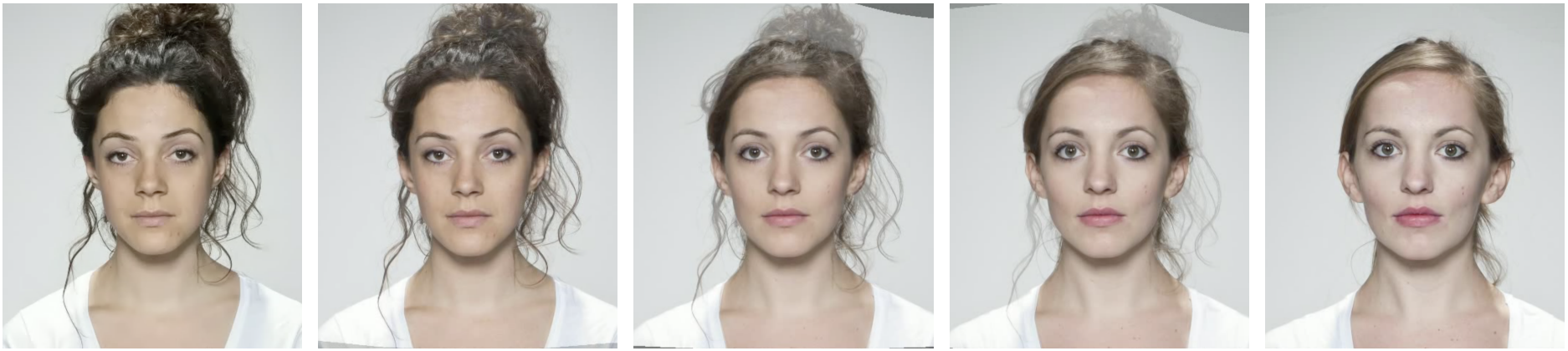
- Coordinate-based neural networks were proposed as representations for signed distance functions in 3D
- They build a continuous and smooth representation of 2D and 3D objects[2,3]

[2] Schirmer L, et al. Neural Networks for Implicit Representations of 3D Scenes. In: Proceedings of the 34th SIBGRAPI.

[3] Novello T, et al., Exploring differential geometry in neural implicits. In: Computers & Graphics, Volume 108, 2022.

Problem statement

- Can we leverage them to model warpings/blendings of (face) images?



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Assumptions and background

- We assume the images to be *neural images*, i.e., represented by sinusoidal multilayer perceptrons
  - $\mathsf{I}_0, \mathsf{I}_1 : \mathbb{R}^2 \to \mathcal{C}$, where $\mathcal{C}$ is the color space
  - With this, we can calculate its derivatives using automatic differentiation
- We define a *neural warping* $\mathbf{T} : \mathbb{R}^2 \times \mathbb{R} \to \mathbb{R}^2$ to align the key-points $\{p_i, q_i\}$
  - The key-points may be extracted using face landmark detection (such as DLib 68 landmarks model[4])
  - $\mathbf{T}(\mathbf{x})$ receives a pair of coordinates and outputs the warped coordinates
- We propose a *neural blending* $\mathscr{M}(\theta)$ to combine the warped images

[4] Kazemi, V. and Sullivan J., One millisecond face alignment with an ensemble of regression trees. In Proceedings of the IEEE CVPR 2014

Warping Loss

$$\mathscr{L}(\theta) = \mathscr{W}(\theta) + \mathscr{D}(\theta) + \mathscr{T}(\theta). \tag{1}$$

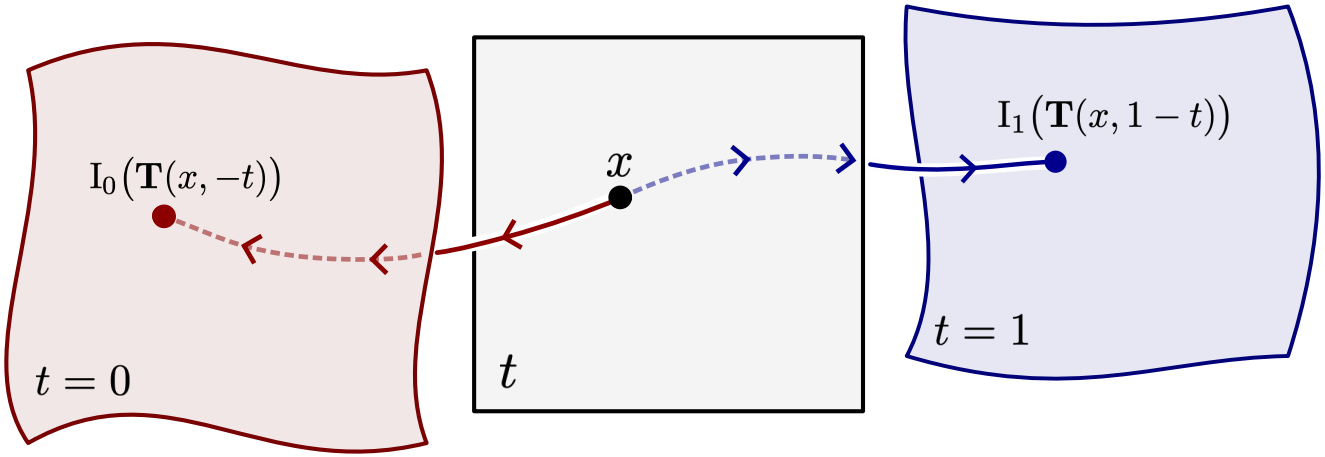
$\mathscr{W}(\theta)$, $\mathscr{D}(\theta)$, $\mathscr{T}(\theta)$ are the *warping*, *data*, *thin-plate* constraints

$$\mathscr{W}(\theta) = \underbrace{\int_{\mathbb{R}^2} \|\mathbf{T}(x,0) - x\|^2 \, dx}_{\text{Identity constraint}} + \underbrace{\int_{\mathbb{R}^2 \times \mathbb{R}} \left\|\mathbf{T}\Big(\mathbf{T}(x,t), -t\Big) - x\right\|^2 dxdt}_{\text{Inverse constraint}}. \tag{2}$$

$$\mathscr{D}(\theta) = \int_{[0,1]} \|\mathbf{T}(p_i,t) - \mathbf{T}(q_i, 1-t)\|^2 \, dt \tag{3}$$

$$\mathscr{T}(\theta) = \int_{\mathbb{R}^2 \times \mathbb{R}} \|\mathbf{Hess}\,(\mathbf{T})\,(x,t)\|_F^2 \, dxdt \tag{4}$$

An illustration of warping



Blending loss

$$\mathscr{M}(\theta) = \underbrace{\int_{\Omega} \|\mathrm{Jac}(\mathbf{I}) - U\|^2 \, dxdt}_{\mathscr{C}(\theta)} + \underbrace{\int_{S-\Omega} \left(\mathbf{I} - \mathbf{I}^*\right)^2 dxdt}_{\mathscr{B}(\theta)} . \tag{5}$$

where U is a matrix obtained by blending $\mathrm{Jac}(\mathbf{I}_i)$, $\mathscr{C}(\theta)$ fits $\mathbf{I}$ to the primitive of U in Ω, and $\mathscr{B}(\theta)$ is a *boundary constraint* to fit $\mathbf{I}$ to $\mathbf{I}^*$ in $S - \Omega$.

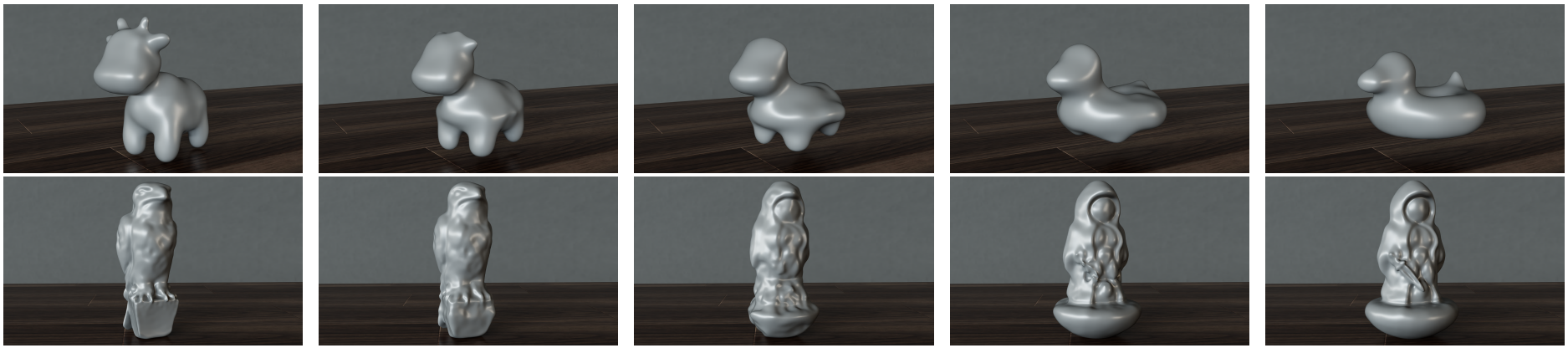
Reference images

Blending comparisons

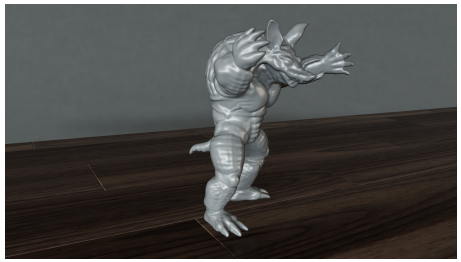
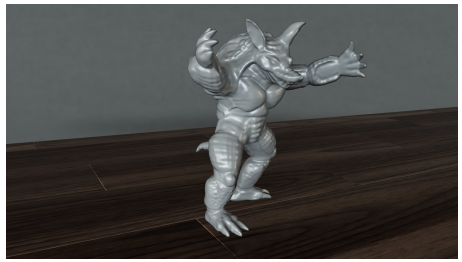
No warping | seamless cloning | average cloning | mixed cloning

Varying gender and ethnicity

Interpolation 3D

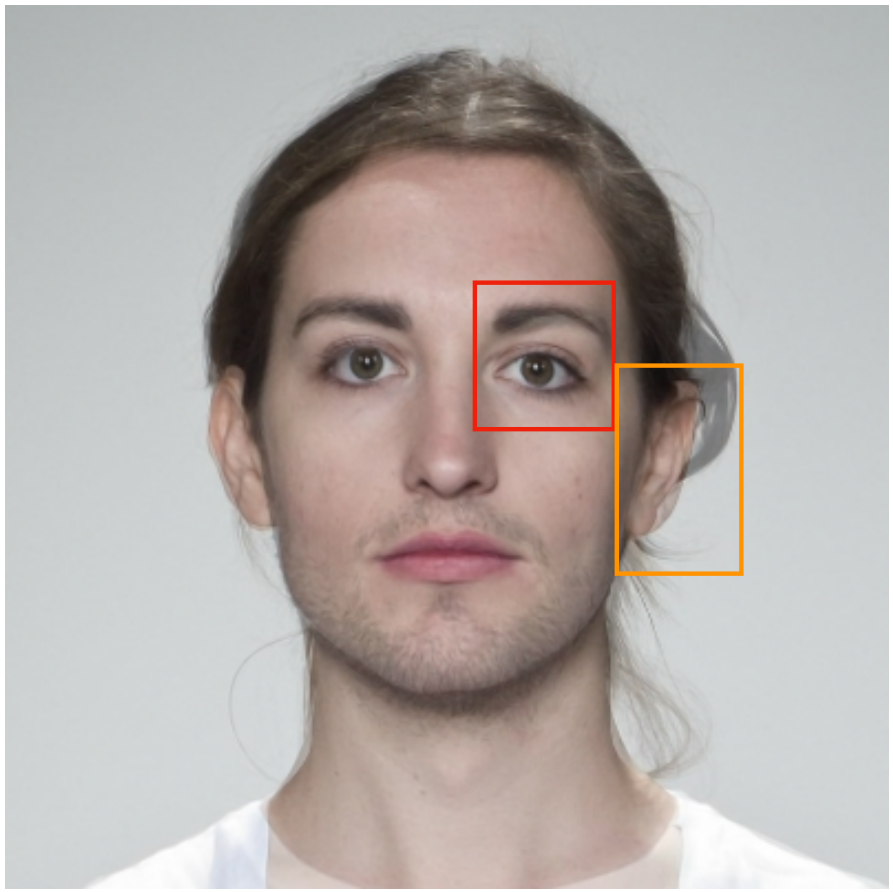


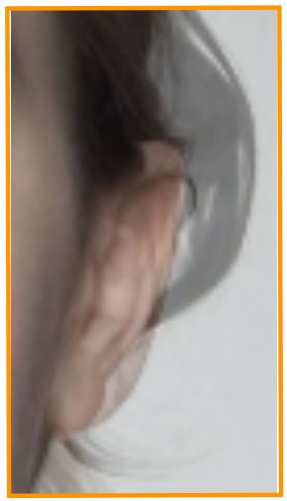
Warp 3D

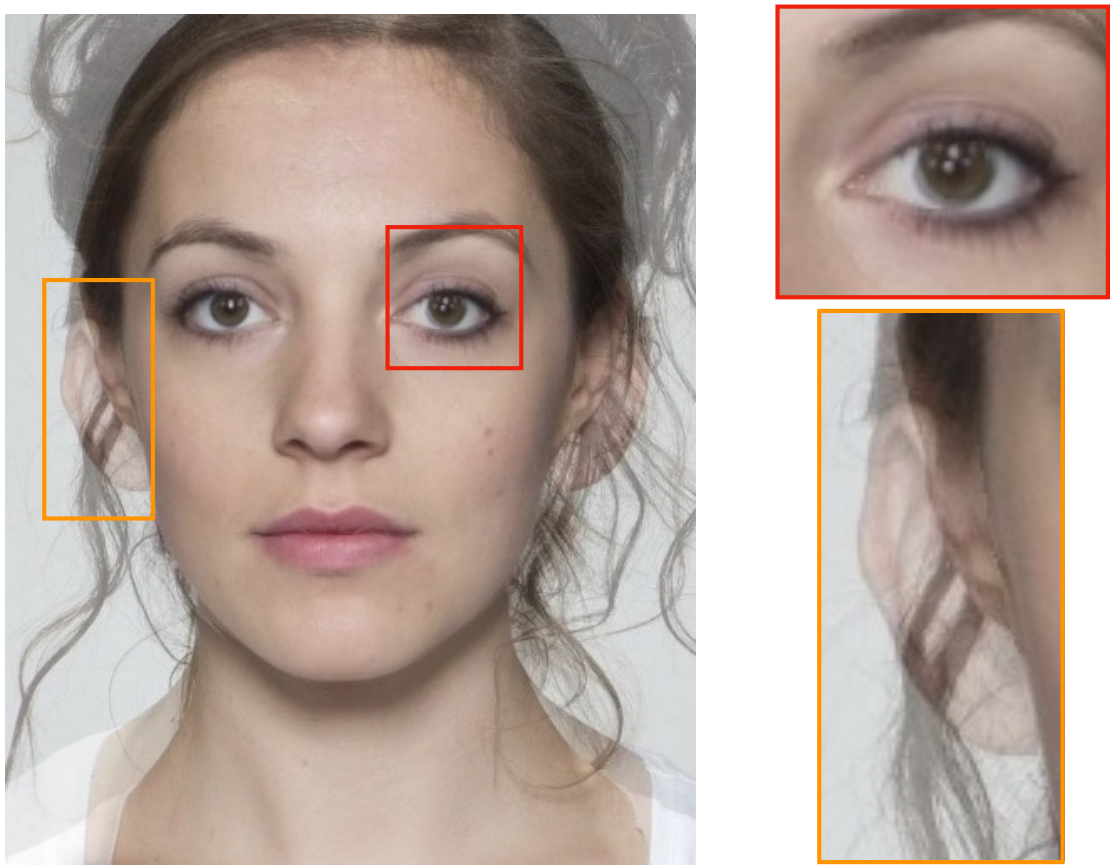





How to detect morphings?

- Subtle changes in texture
- Misaligned features
- Ghost artifacts







- (Usually) based on convolutional neural networks for feature extraction
- Modelled as a classification task (is this a true face? or is it morphed?)
- More sophisticated networks were propesed (fused classification)[5]

[5] See: Medvedev, I., Shadmand, F., Gonçalves, N. MorDeephy: Face Morphing Detection Via Fused Classification. International Conference on Pattern Recognition Applications and Methods

Questions?

- Novello T, da Silva V, Schardong G, Schirmer L, Lopes H, Velho L. Neural Implicit Surface Evolution using Differential Equations. Published online 2022. doi:10.48550/ARXIV.2201.09636, `https://arxiv.org/abs/2201.09636`
- Medvedev, I., Shadmand, F., Gonçalves, N. MorDeephy: Face Morphing Detection Via Fused Classification. International Conference on Pattern Recognition Applications and Methods. Published online 2022. doi:10.48550/arXiv.2208.03110, `https://arxiv.org/abs/2208.03110`