CSCE 448/748 - Computational Photography

Image Morphing

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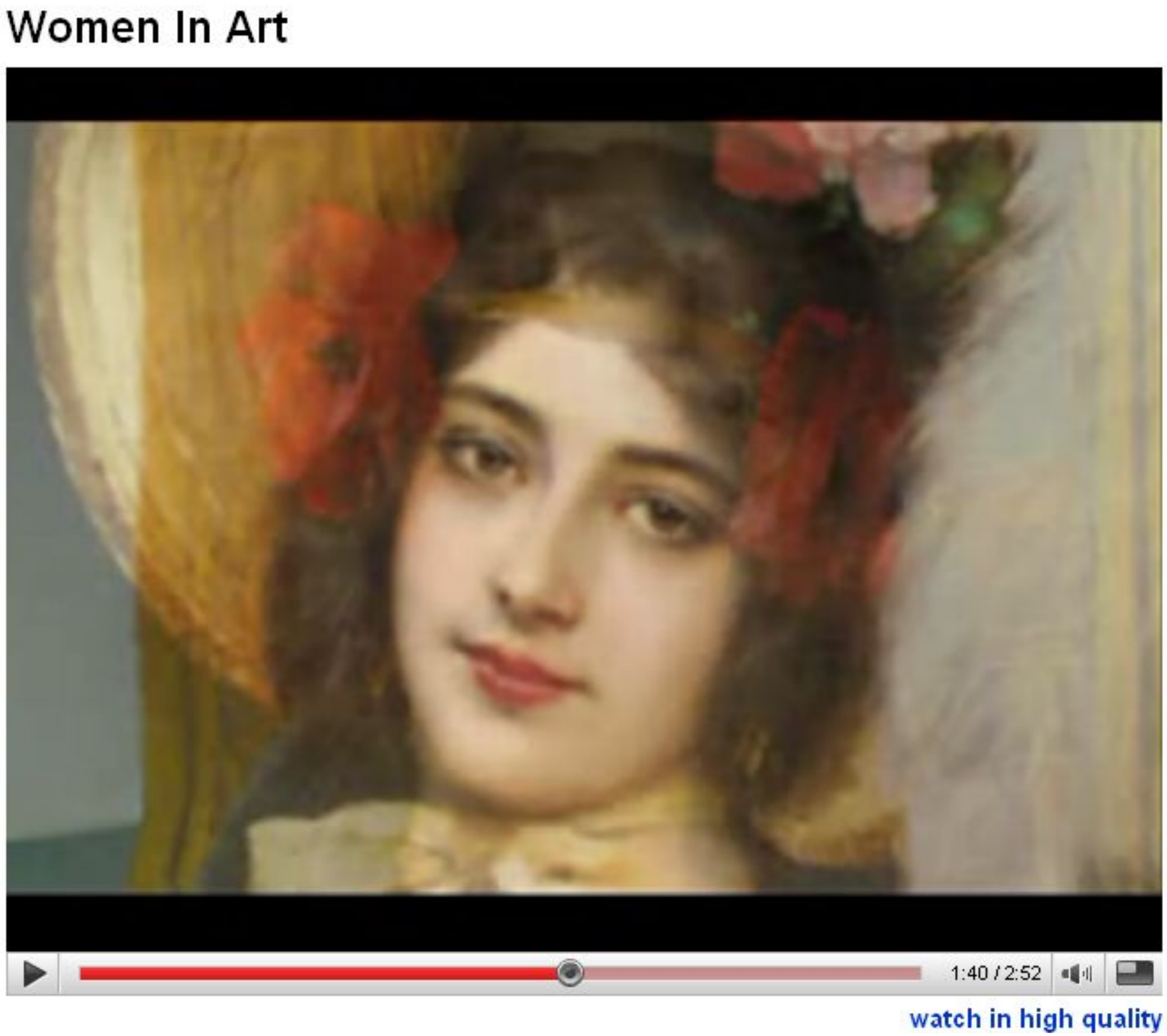
Slides from Alexei A. Efros

Amuse-bouche



http://youtube.com/watch?v=nUDIoN-_Hxs

Morphing = Object Averaging

The aim is to find "an average" between two objects

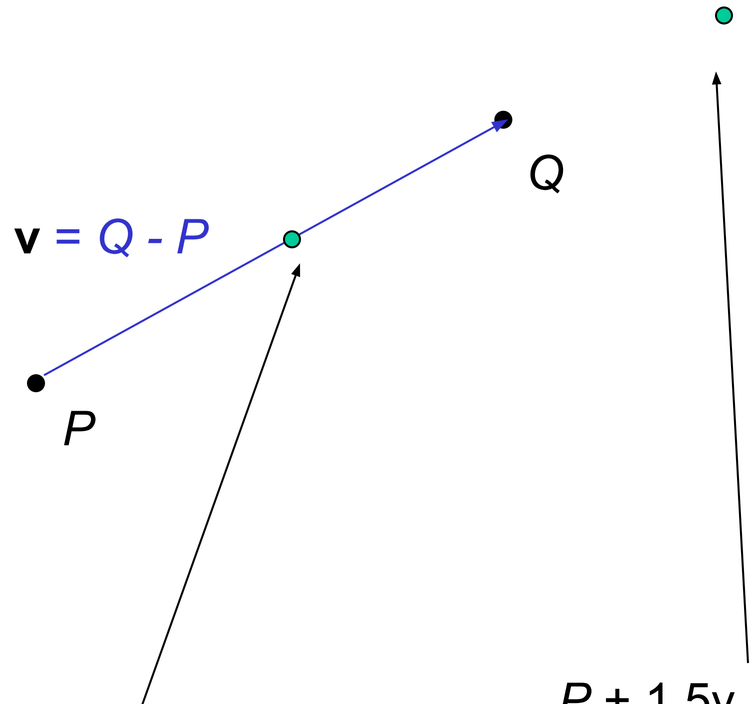
- Not an average of two images of objects…
- …but an image of the average object!
- How can we make a smooth transition in time?
  - Do a "weighted average" over time t

How do we know what the average object looks like?

- We don't have a clue!
- But we can often fake something reasonable
  - Usually required user/artist input

Averaging Points

What's the average of P and Q?



$P + 0.5\mathrm{v}$
$= P + 0.5(Q - P)$
$= 0.5P + 0.5\,Q$

$P + 1.5\mathrm{v}$
$= P + 1.5(Q - P)$
$= -0.5P + 1.5\,Q$
(extrapolation)

P and Q can be anything:

- points on a plane (2D) or in space (3D)
- Colors in RGB or HSV (3D)
- Whole images (m-by-n D)… etc.

Idea #1: Cross-Dissolve

Interpolate whole images:

$$\text{Image}_{\text{halfway}} = (1-t)^{*}\text{Image}_1 + t^{*}\text{image}_2$$

This is called **cross-dissolve** in film industry

But what is the images are not aligned?

Align, then cross-disolve

Align first, then cross-dissolve

- Alignment using global warp – picture still valid

Global warp not always enough!

What to do?

- Cross-dissolve doesn’t work
- Global alignment doesn’t work
  - Cannot be done with a global transformation (e.g. affine)

Feature matching!

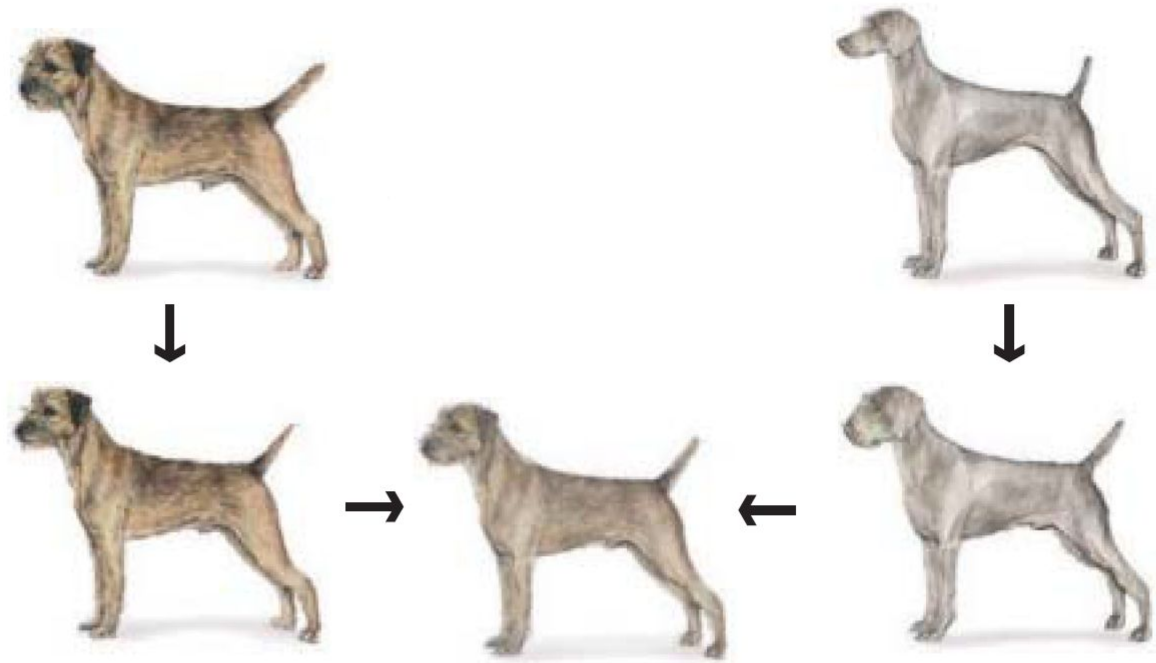
- Nose to nose, tail to tail, etc.
- This is a local (non-parametric) warp

Local (non-parametric) Image Warping

Need to specify a more detailed warp function

- Global warps were functions of a few (2,4,8) parameters
- Non-parametric warps u(x,y) and v(x,y) can be defined independently for every single location x,y!
- Once we know vector field u,v we can easily warp each pixel (use backward warping with interpolation)

Local warp, then cross-dissolve



Morphing procedure:

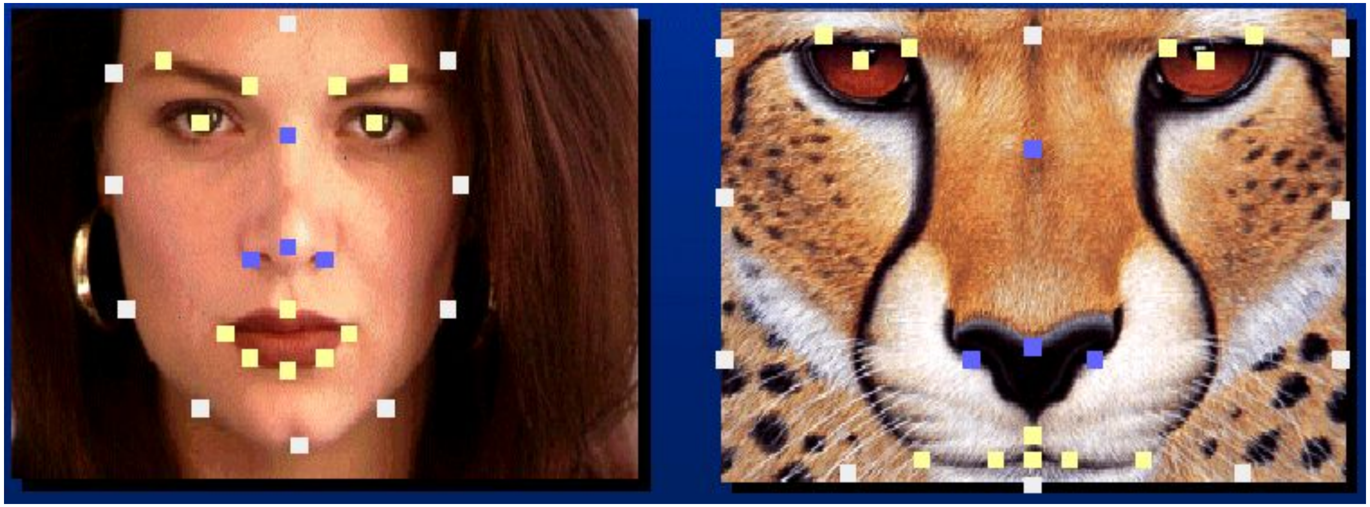
for every t,

1. Find the average shape (the “mean dog”☺)
   - local warping
2. Find the average color
   - Cross-dissolve the warped images

Slide credit: Alyosha Efros

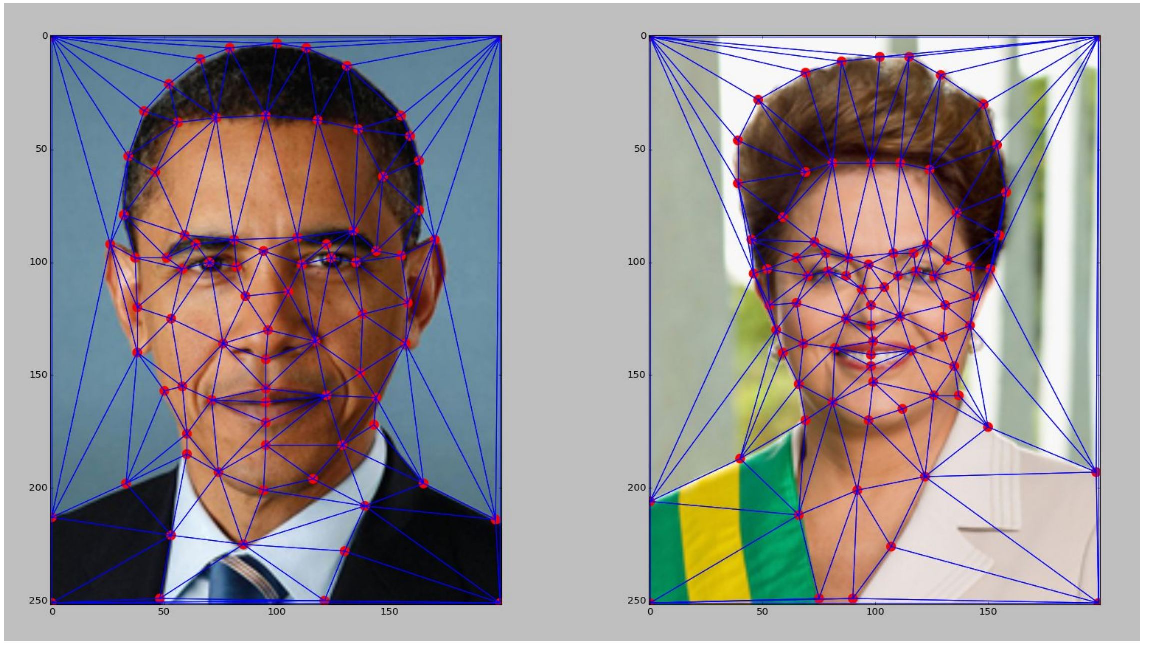
Warp specification - sparse

How can we specify a sparse warp?



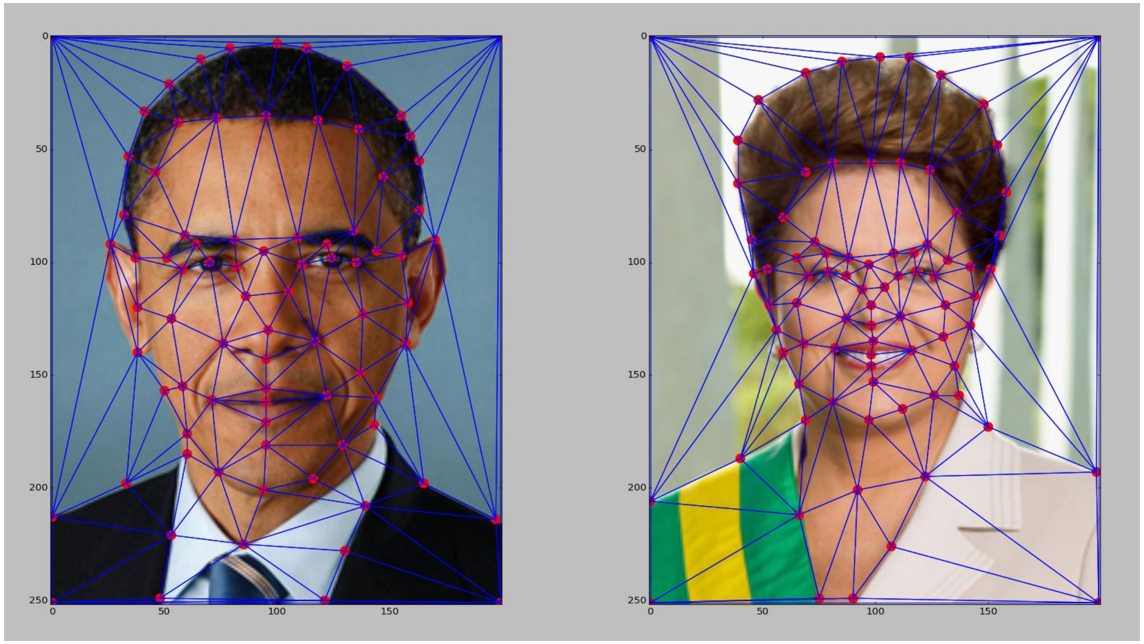
How do we go from feature points to pixels?

Triangular Mesh



1. Input correspondences at key feature points
2. Define a triangular mesh over the points
   - Same mesh in both images!
   - Now we have triangle-to-triangle correspondences
3. Warp each triangle separately from source to destination
   - How do we warp a triangle?

Triangular Mesh



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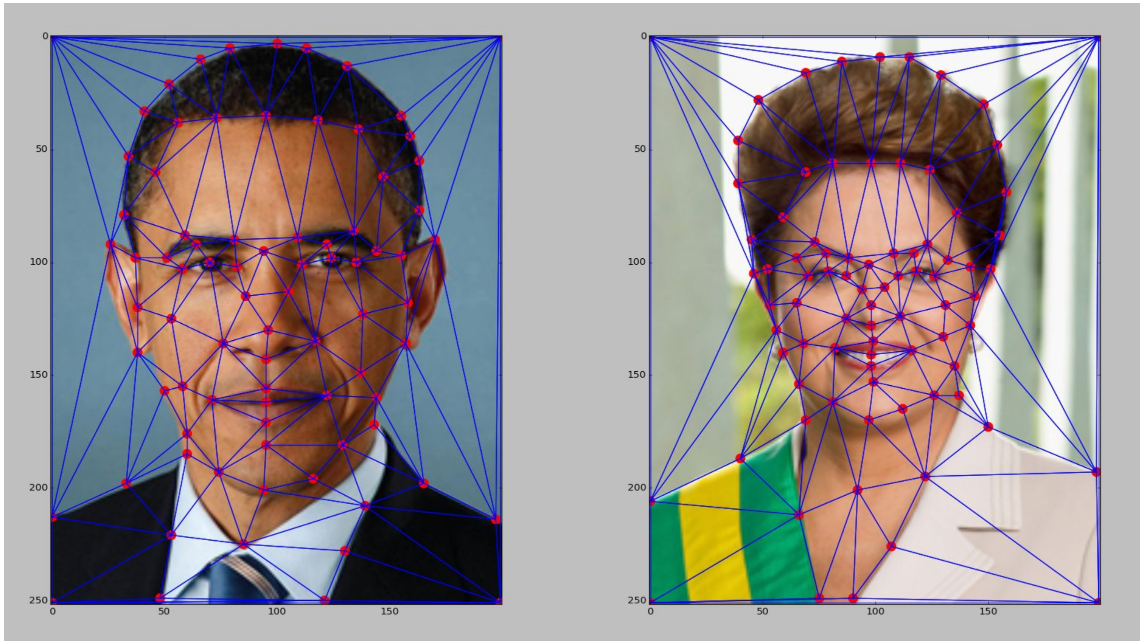

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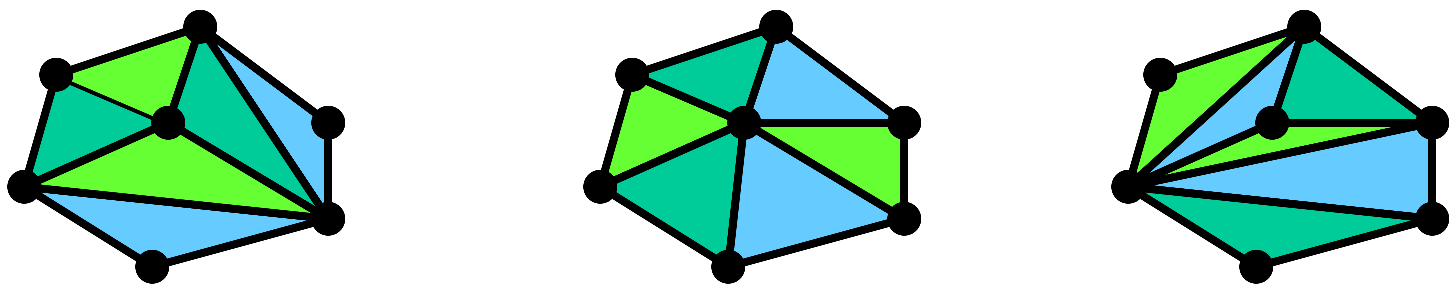
Triangulations

A *triangulation* of set of points in the plane is a *partition* of the convex hull to triangles whose vertices are the points, and do not cross edges.

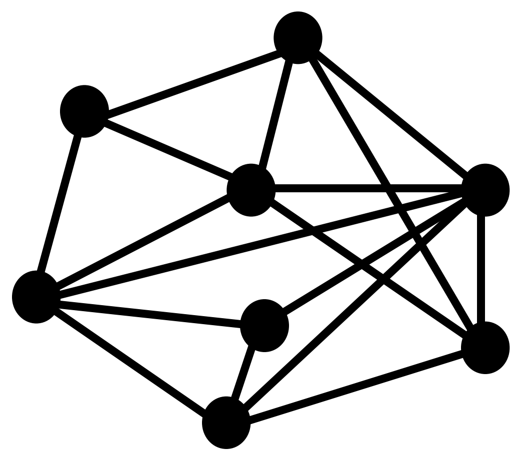
There are an exponential number of triangulations of a point set.



An $O(n^3)$ Triangulation Algorithm

Repeat until impossible:

- Select two sites.
- If the edge connecting them does not intersect previous edges, keep it.



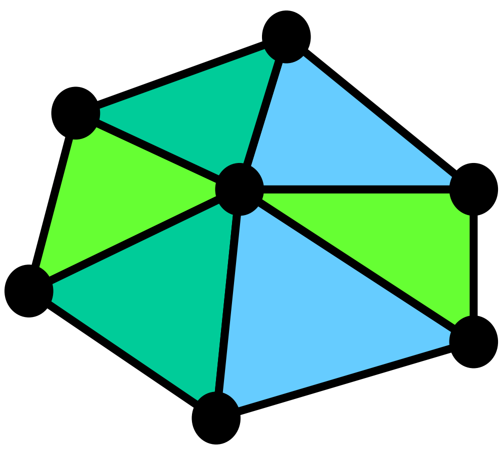
“Quality” Triangulations

Let $\alpha(T) = (\alpha_1, \alpha_2, \ldots, \alpha_{3t})$ be the vector of angles in the triangulation T in increasing order.

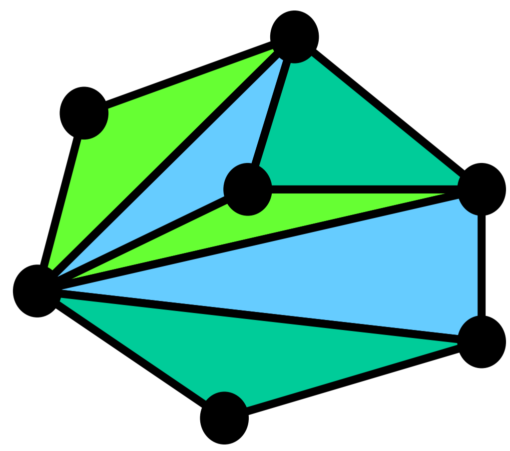
A triangulation T_1 will be “better” than T_2 if $\alpha(T_1) > \alpha(T_2)$ lexicographically.

The Delaunay triangulation is the “best”

- Maximizes smallest angles



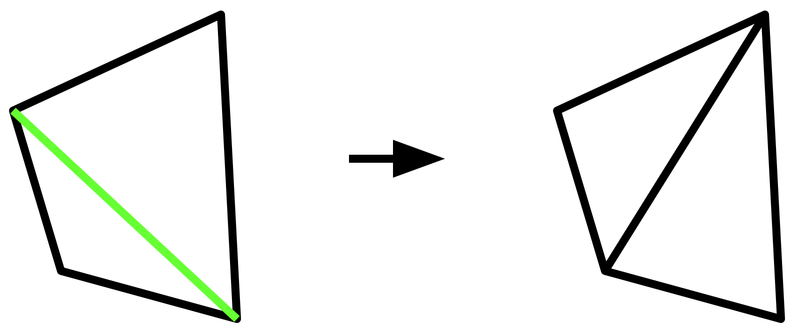
good



bad

Improving a Triangulation

In any convex quadrangle, an *edge flip* is possible. If this flip *improves* the triangulation locally, it also improves the global triangulation.

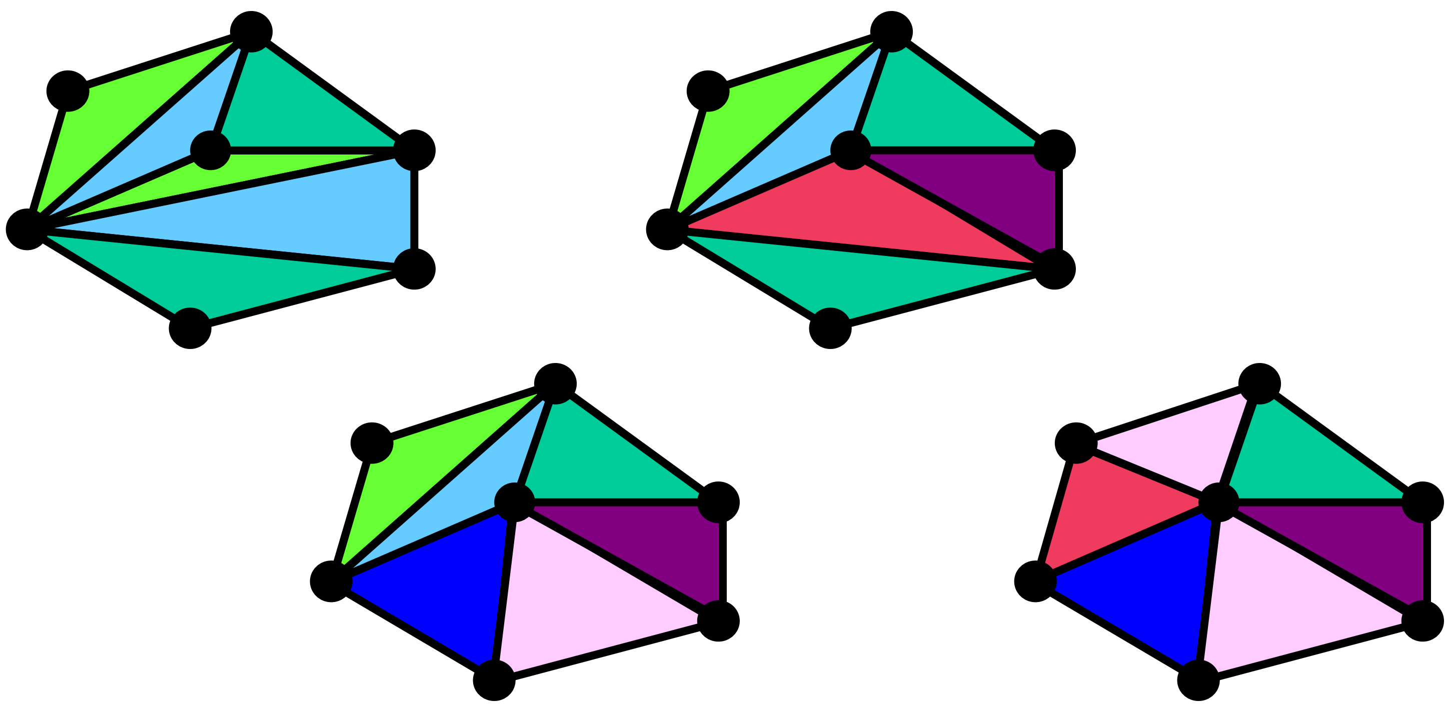


If an edge flip improves the triangulation, the first edge is called *illegal*.

Naïve Delaunay Algorithm

Start with an arbitrary triangulation. Flip any illegal edge until no more exist.

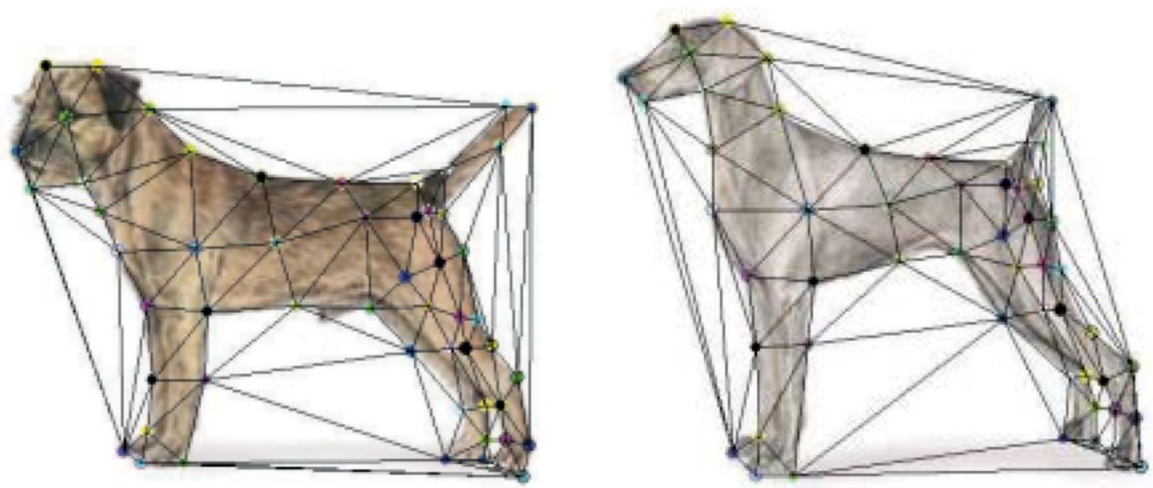
Could take a long time to terminate.



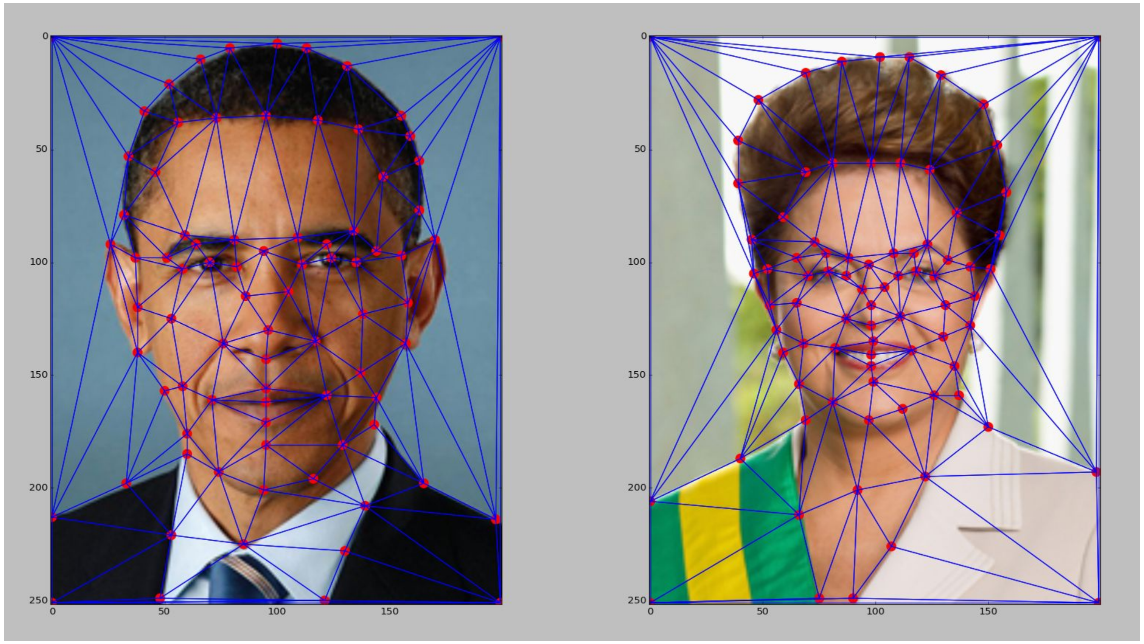
1. Create Average Shape

How do we create an intermediate warp at time t?

- Assume t = [0,1]
- Simple linear interpolation of each feature pair
- (1-t)*p+t*p’ for corresponding features p and p’



Triangular Mesh



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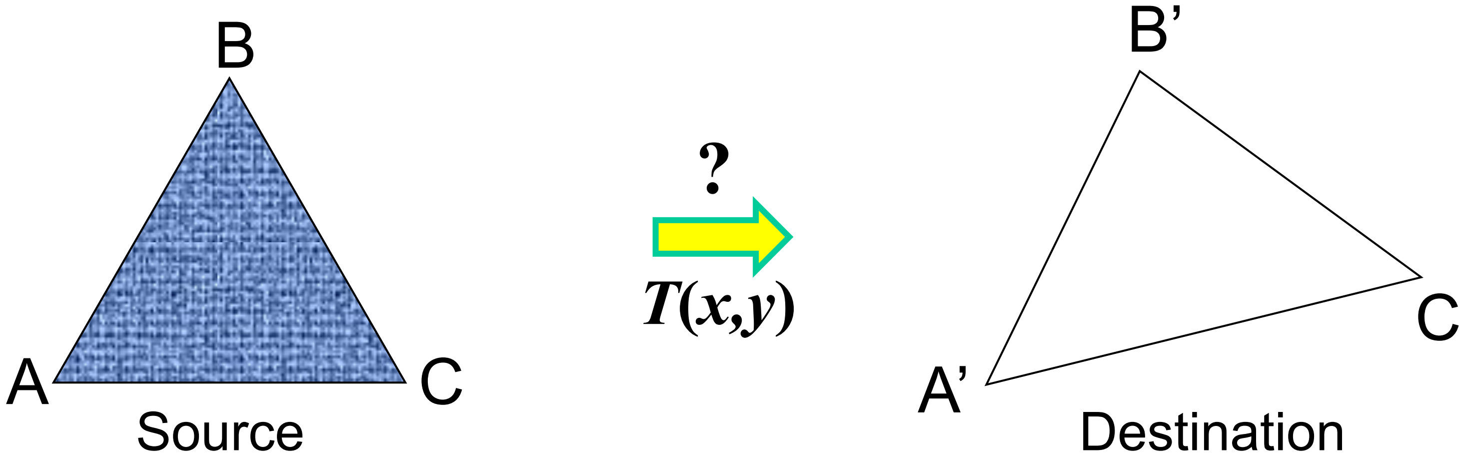
Warping triangles



Given two triangles: ABC and A'B'C' in 2D (12 numbers)

Need to find transform T to transfer all pixels from one to the other.

What kind of transformation is T?

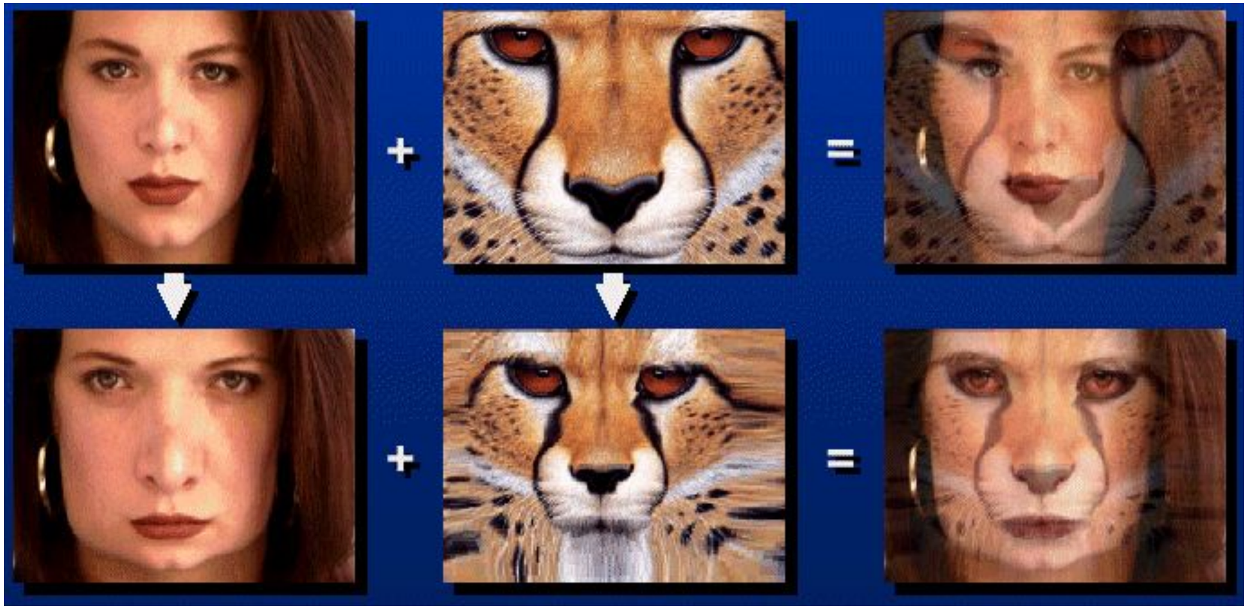
How can we compute the transformation matrix:

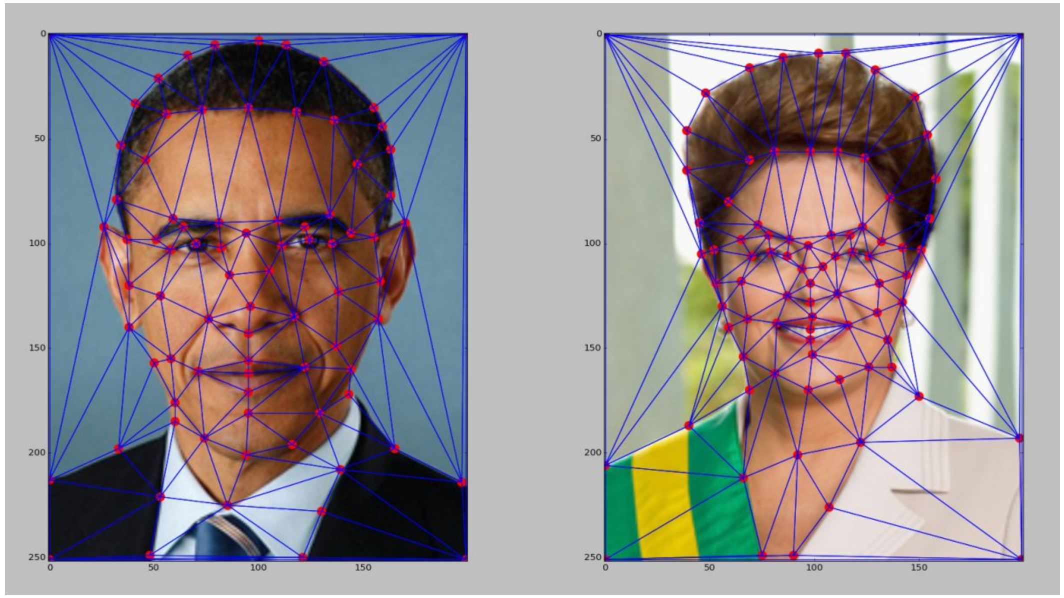
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Image Morphing Review

Creating a half-way intermediate morph (t=0.5):

1. Create an intermediate shape (by interpolation)
2. Warp both images towards it
3. Cross-dissolve the colors in the newly warped images

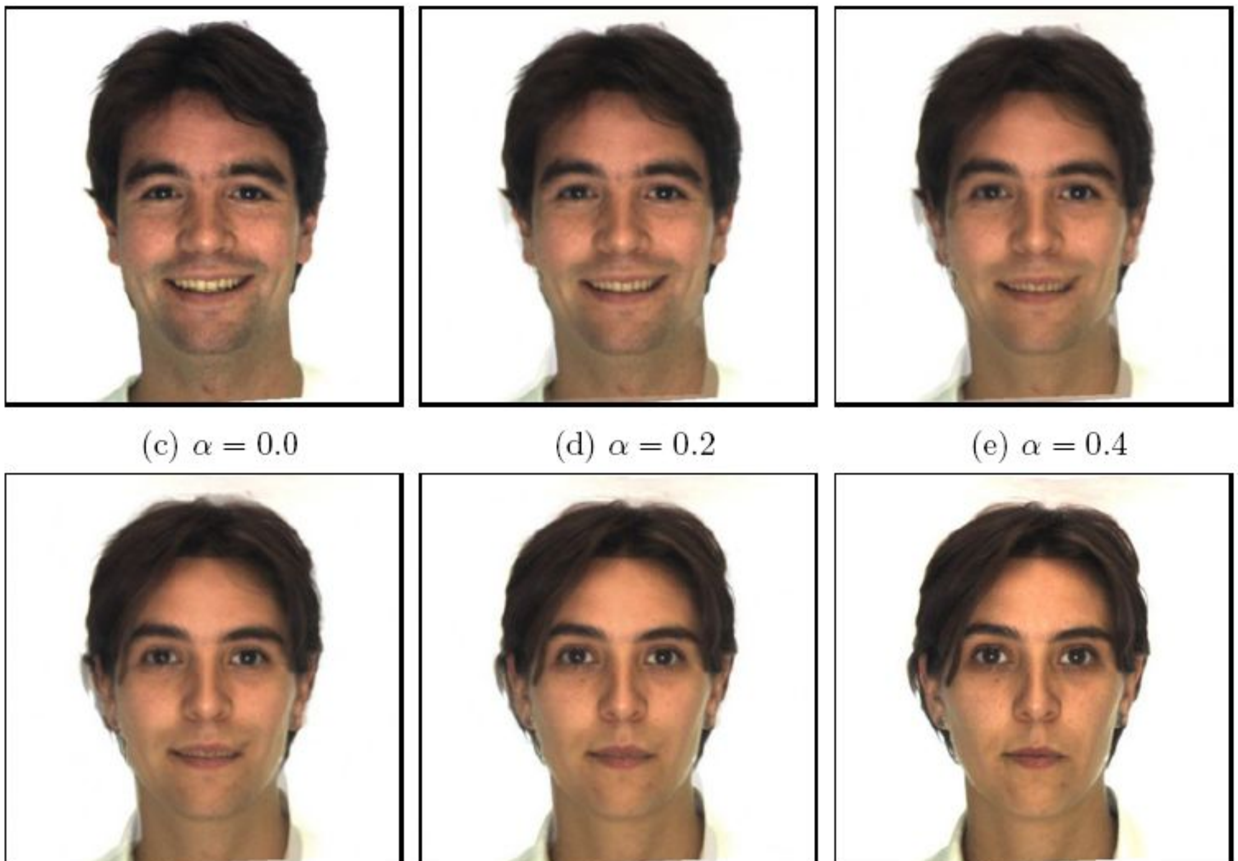




(c) Ian Albuquerque Raymundo da Silva

Morphing & matting

Extract foreground first to avoid artifacts in the background



(c) $\alpha = 0.0$ (d) $\alpha = 0.2$ (e) $\alpha = 0.4$

(f) $\alpha = 0.6$ (g) $\alpha = 0.8$ (h) $\alpha = 1.0$

Slide by Durand and Freeman

Examples