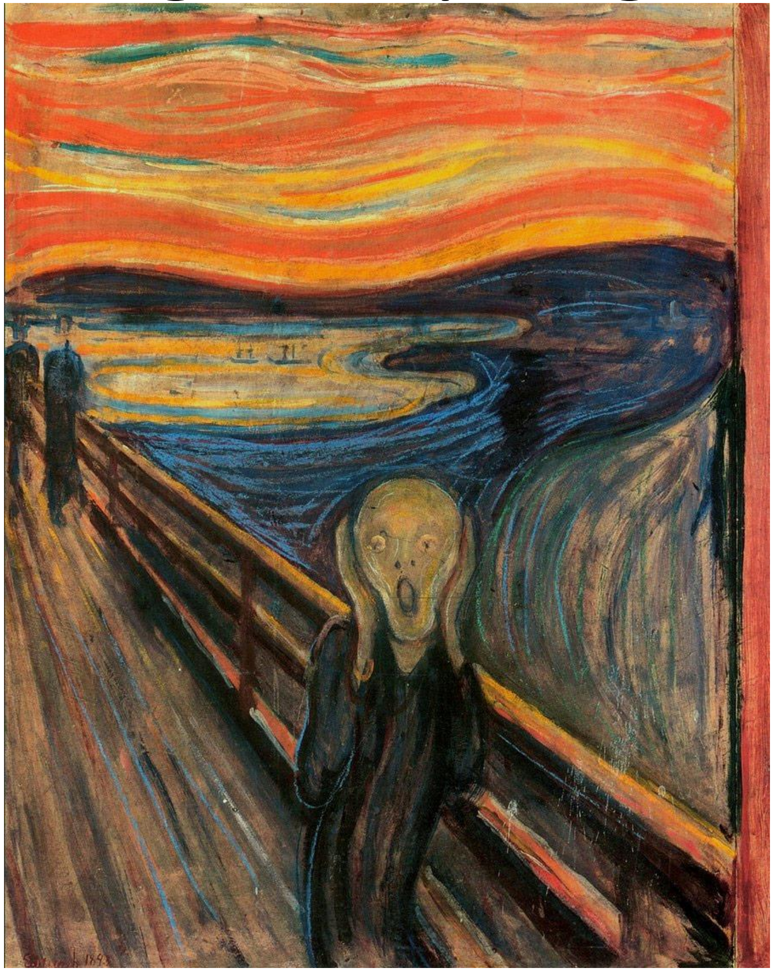
Image Morphing



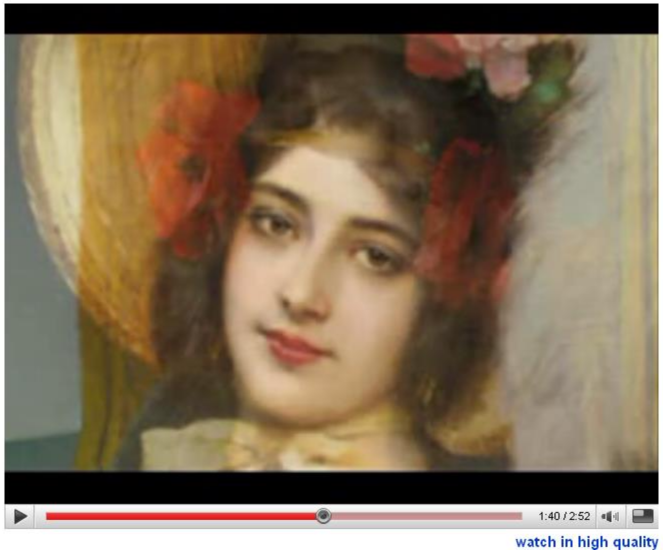
Edvard Munch, “The Scream”

CSC320: Introduction to Visual Computing
Michael Guerzhoy

Many slides borrowed
from Derek Hoeim, Alexei Efros

Morphing Examples

Women in art

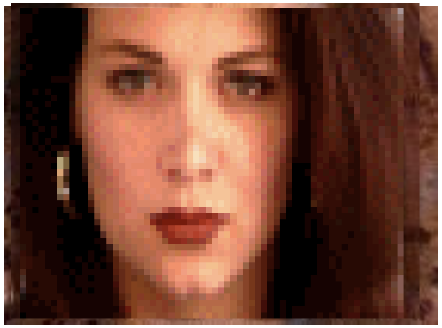


http://youtube.com/watch?v=nUDIoN-_Hxs

Aging

http://www.youtube.com/watch?v=L0GKp-uvjO0

Morphing = Object Averaging

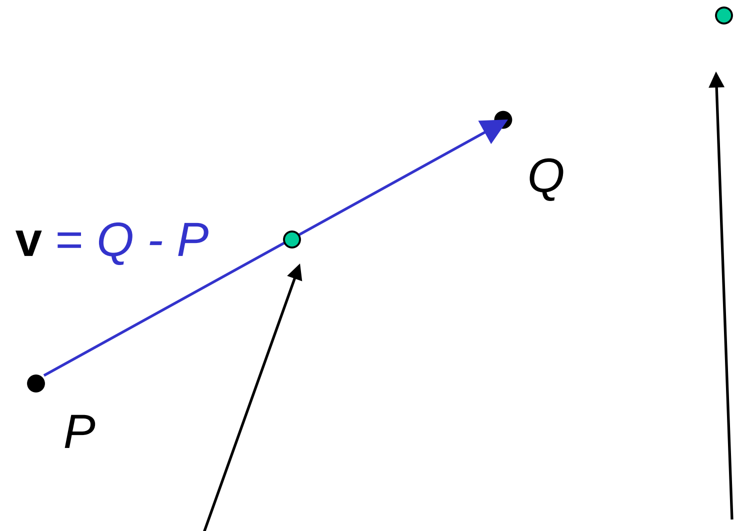


The aim is to find "an average" between two objects

- 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

Averaging Points

What's the average of P and Q?



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

Extrapolation: t<0 or t>1
$P + 1.5\mathrm{v}$
$= \; P + 1.5(Q - P)$
$= -0.5P + 1.5\,Q \; (t=1.5)$

Linear Interpolation
New point: $(1-t)P + tQ$
$0<t<1$

P and Q can be anything:

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

Idea #1: Cross-Dissolve

Interpolate whole images:

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

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

But what if the images are not aligned?

Idea #2: Align, then cross-disolve

Align first, then cross-dissolve

- Alignment using global warp – picture still valid

Dog Averaging

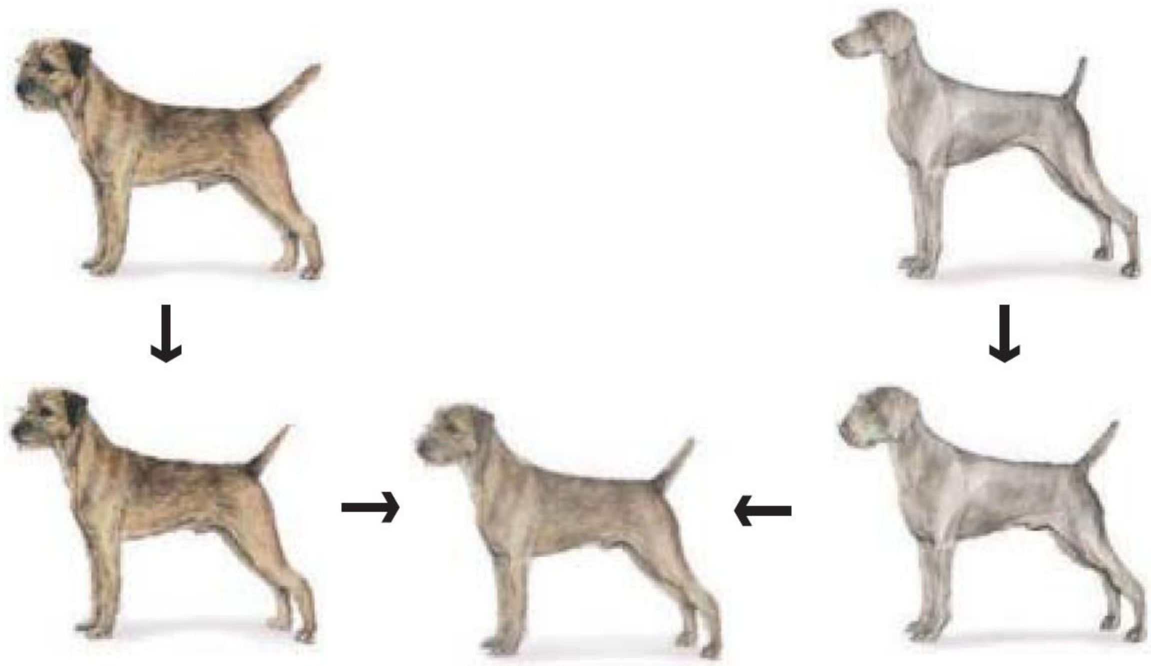
What to do?

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

Feature matching!

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

Idea #3: Local warp, then cross-dissolve



Morphing procedure

For every frame t,

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

Local (non-parametric) Image Warping

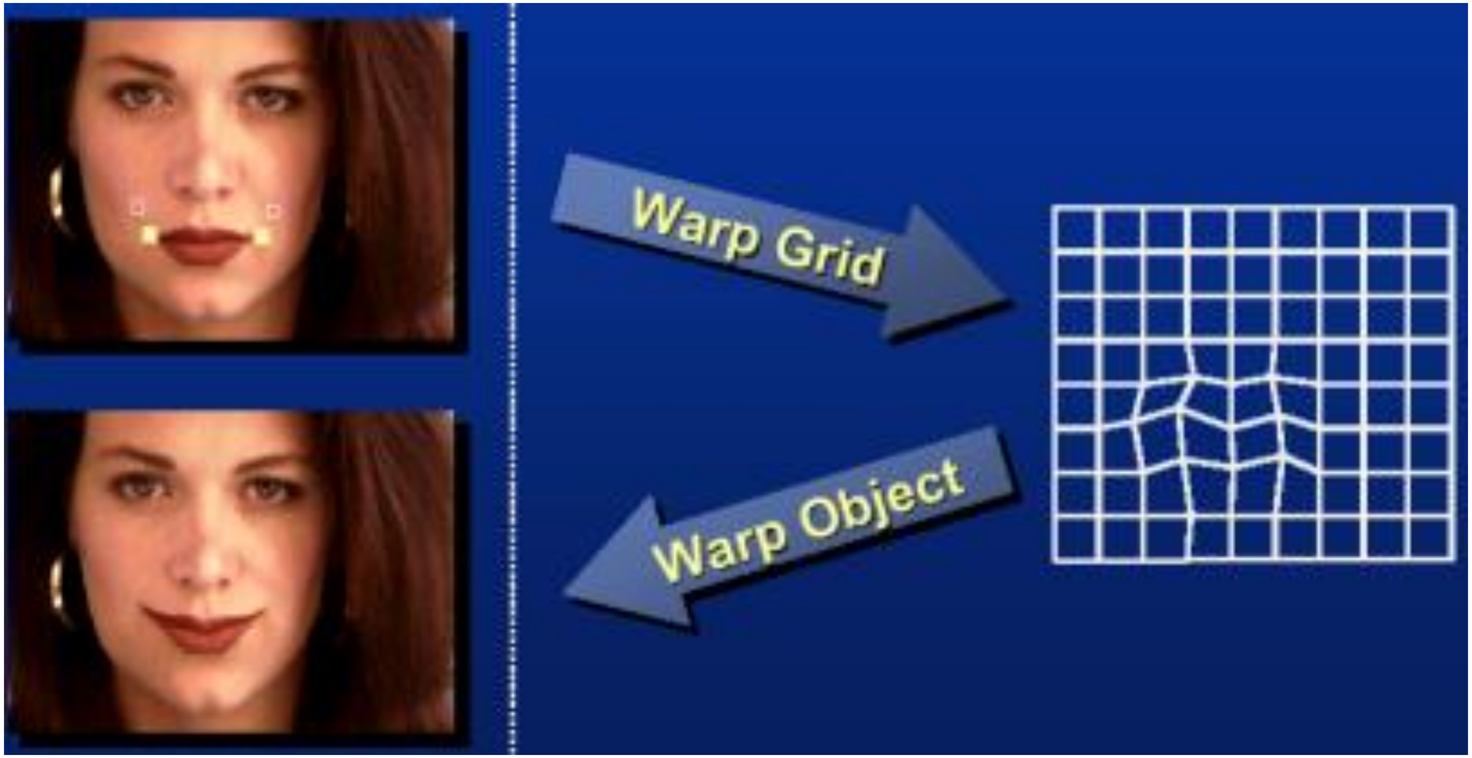
Need to specify a more detailed warp function

- 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)

Image Warping – non-parametric

Move control points to specify a spline warp

Spline produces a smooth vector field

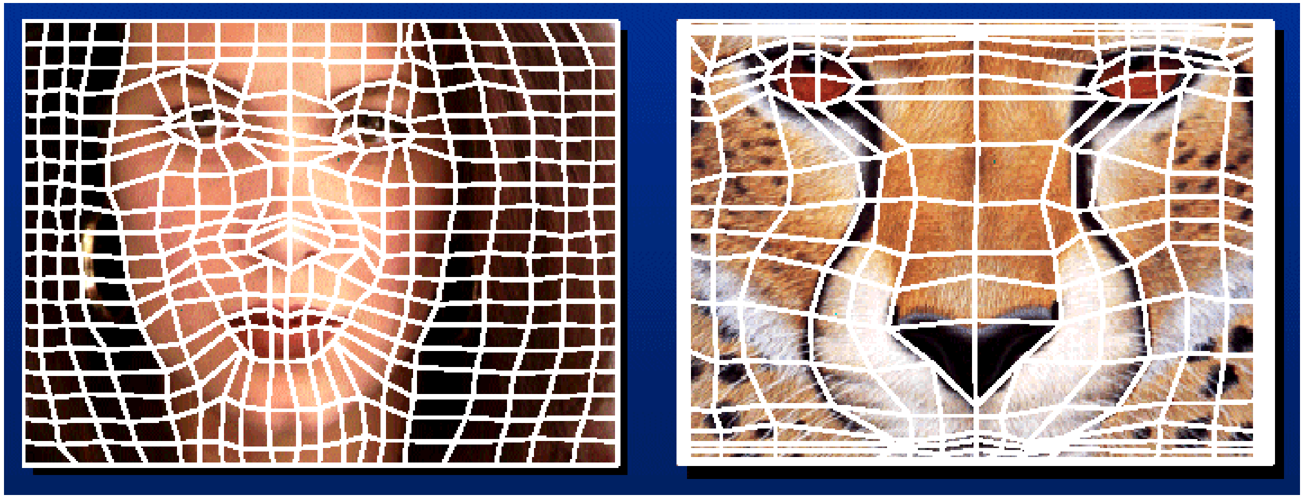


Warp specification - dense

How can we specify the warp?

Specify corresponding *spline control points*

- *interpolate* to a complete warping function



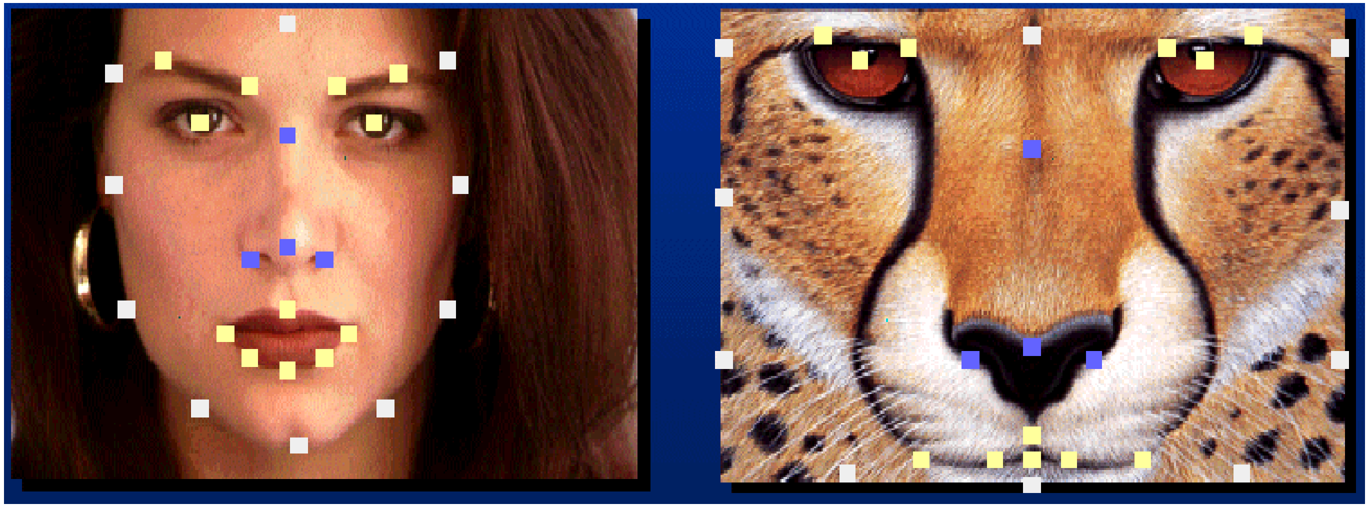
But we want to specify only a few points, not a grid

Warp specification - sparse

How can we specify the warp?

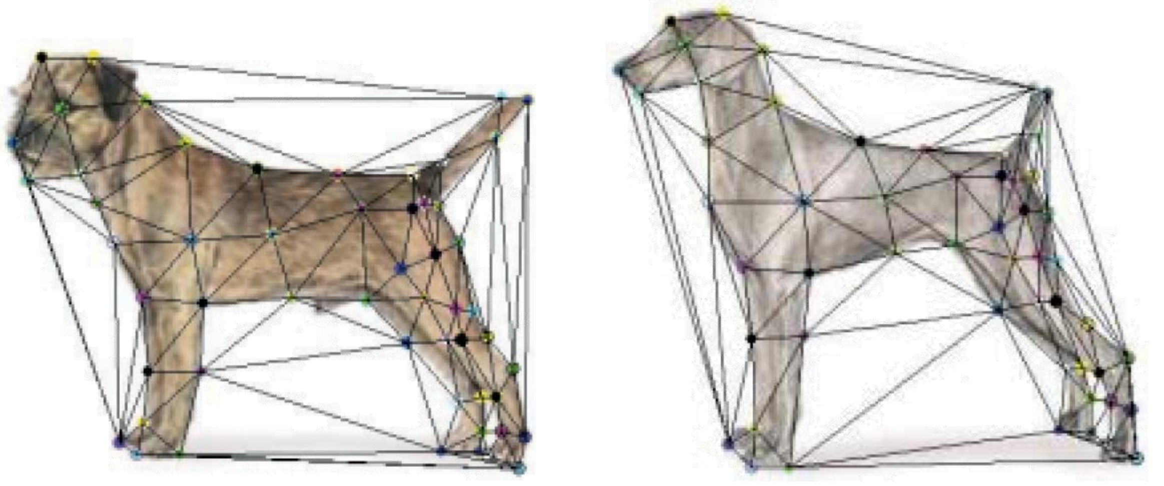
Specify corresponding *points*

- *interpolate* to a complete warping function
- How do we do it?



How do we go from feature points to pixels?

Triangular Mesh

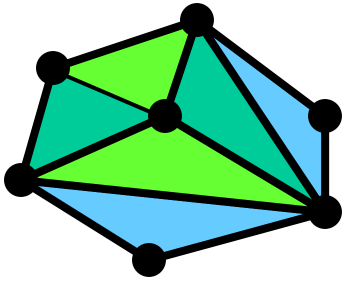


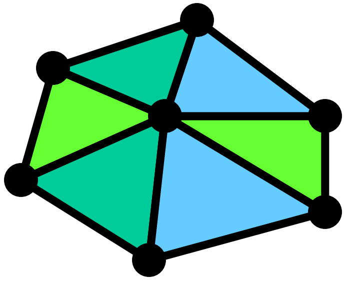
1. Input correspondences at key feature points
2. Define a triangular mesh over the points
   - Same mesh (triangulation) in both images!
   - Now we have triangle-to-triangle correspondences
3. Warp each triangle separately from source to destination
   - Affine warp with three corresponding points

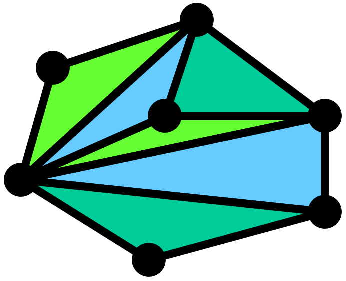
Triangulations

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 contain other points.

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



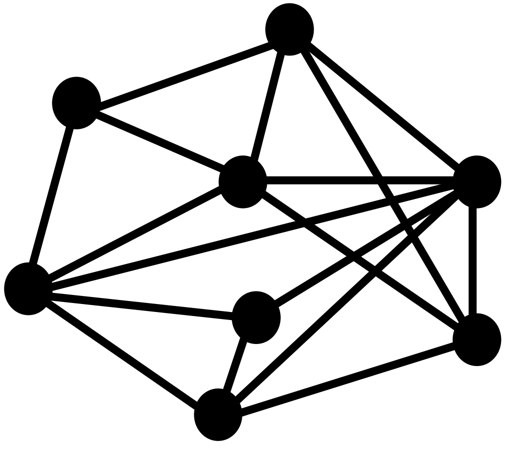




An O(n^3) Triangulation Algorithm

Repeat until impossible:

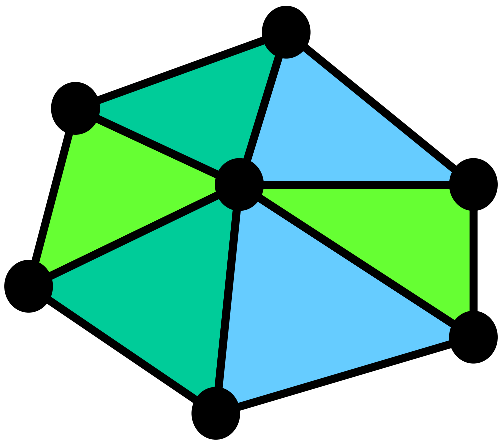
- Select two sites.
- If the edge connecting them does not intersect previous edges, keep it.



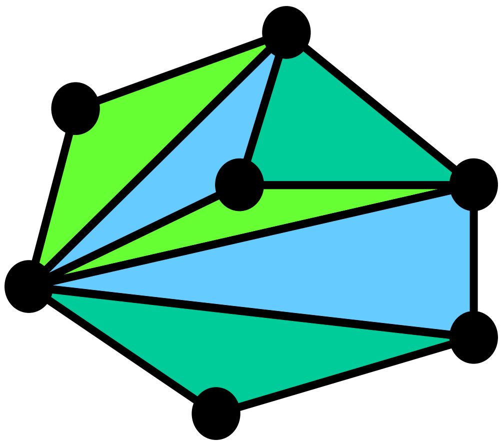
"Quality" Triangulations

Let $\alpha(T_i) = (\alpha_{i1}, \alpha_{i2}, \ldots, \alpha_{i3})$ be the vector of angles in the triangulation T in increasing order:

- A triangulation T_1 is "better" than T_2 if the smallest angle of T_1 is larger than the smallest angle of T_2
- Delaunay triangulation is the "best" (maximizes the smallest angles)



good

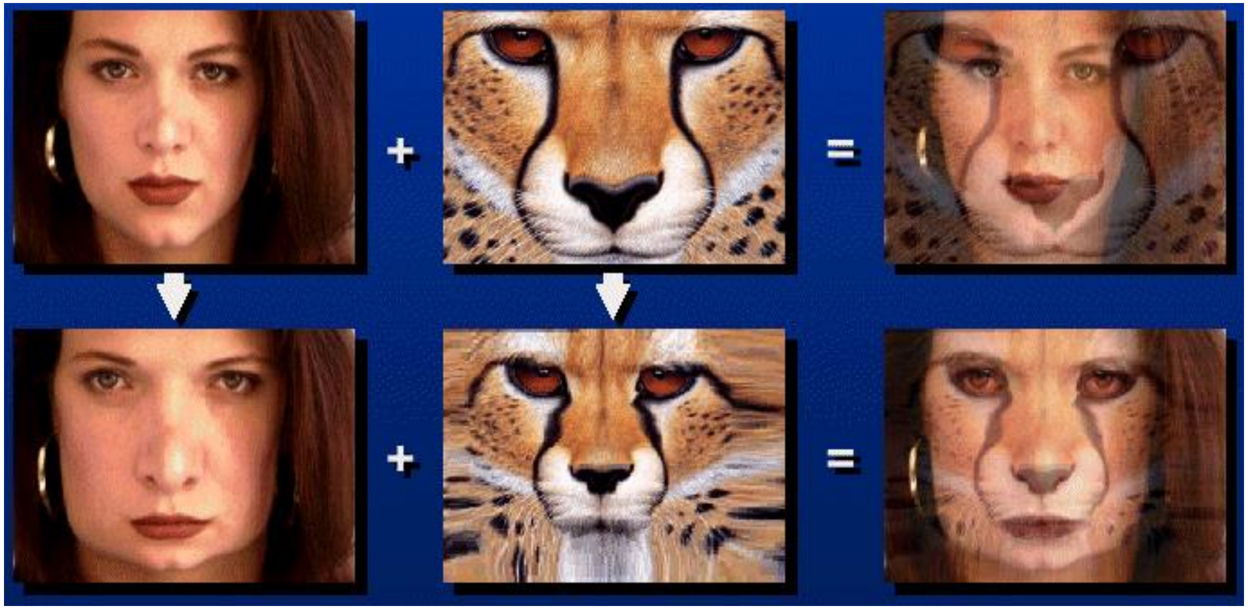


bad

Image Morphing

How do we create a morphing sequence?

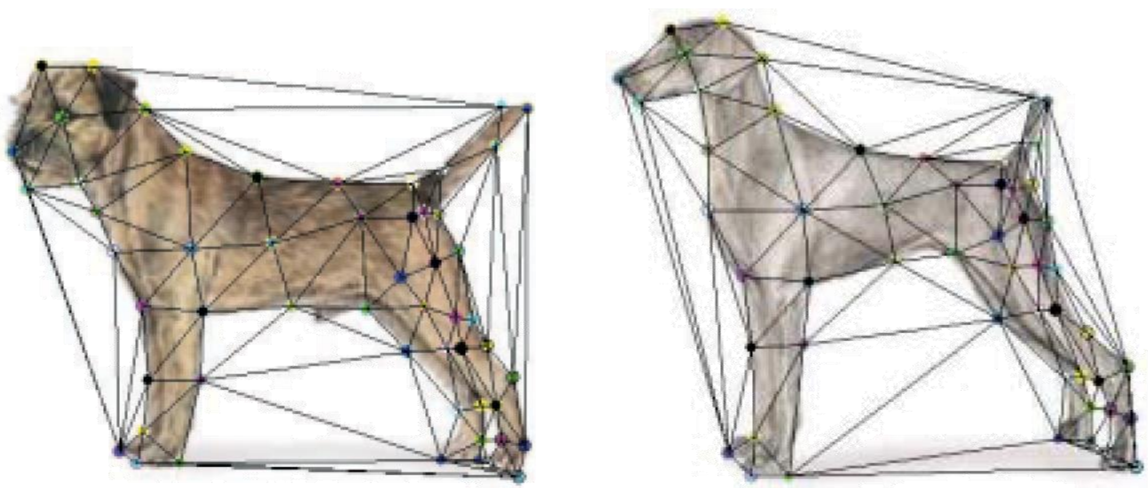
1. Create an intermediate shape (by interpolation)
2. Warp both images towards it
3. Cross-dissolve the colors in the newly warped images



Warp interpolation

How do we create an intermediate shape at time t?

- Assume t = [0,1]
- Simple linear interpolation of each feature pair
  - (1-t)*p1+t*p0 for corresponding features p0 and p1



Morphing & matting

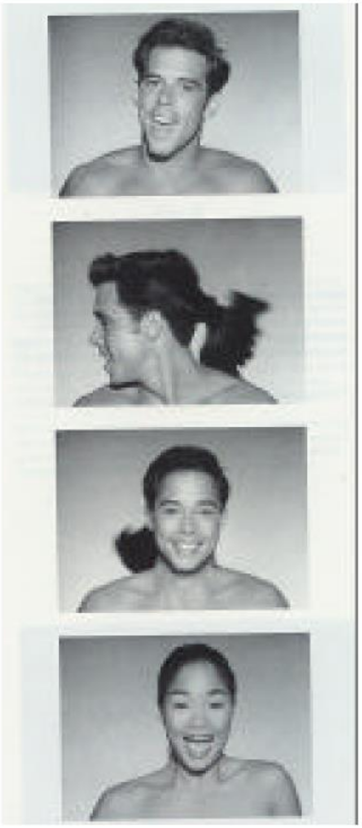
Extract foreground first to avoid artifacts in the background

(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

Dynamic Scene



Black or White (MJ): http://www.youtube.com/watch?v=R4kLKv5gtxc

Willow morph: http://www.youtube.com/watch?v=uLUyuWo3pG0

Summary of morphing

1. Define corresponding points
2. Define triangulation on points
   – Use same triangulation for both images
3. For each t in 0:step:1
   a. Compute the average shape (weighted average of points)
   b. For each triangle in the average shape
      - Get the affine projection to the corresponding triangles in each image
      - For each pixel in the triangle, find the corresponding points in each image and set value to weighted average (optionally use interpolation)
   c. Save the image as the next frame of the sequence