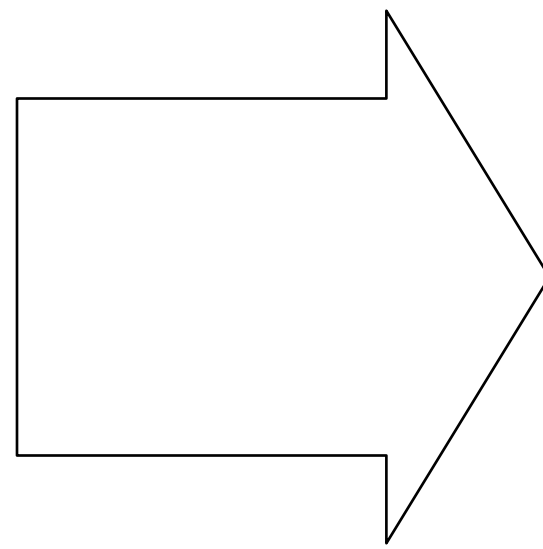


Morphing

Fredo Durand
MIT EECS
6.8370/6.8371

Challenge

- “Smoothly” transform a face into another
- Related: slow motion interpolation
interpolate between key frames



Averaging images

- **Cross-fading**

$$\text{output}[y, x] = t * \text{im1}[y, x] + (1-t) * \text{im2}[y, x]$$



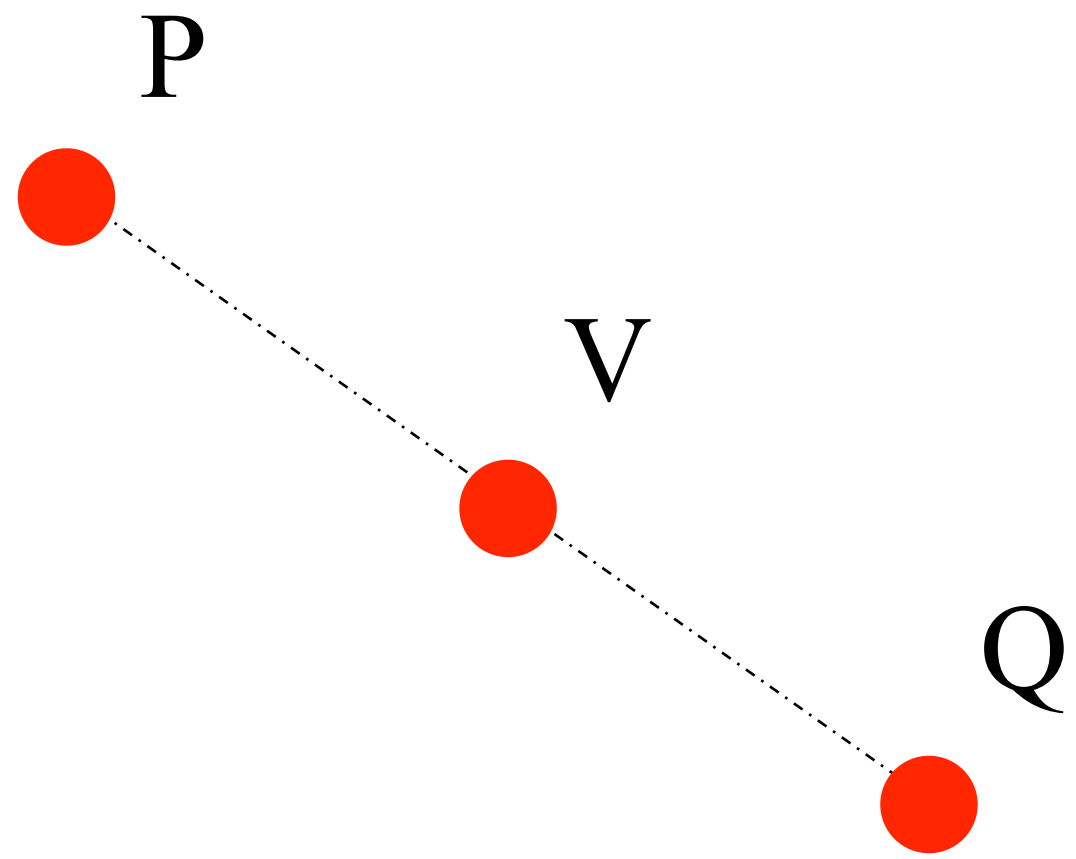
Problem with cross fading

- Features (eyes, mouth, etc) are not aligned
- It is probably not possible to get a global alignment
- We need to interpolate the **LOCATION** of features
—domain transform!



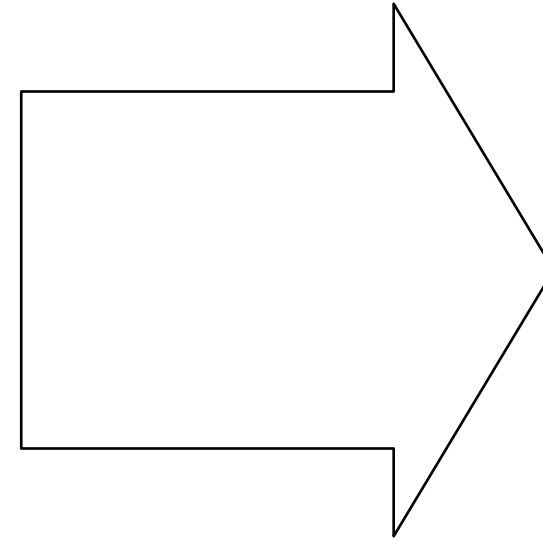
Averaging points (location)

- P & Q are two 2D points (in the “domain”)
- $V = t P + (1-t) Q$



Warping

- Move pixel spatially: $C'(x,y)=C(f(x,y))$
- Leave colors unchanged

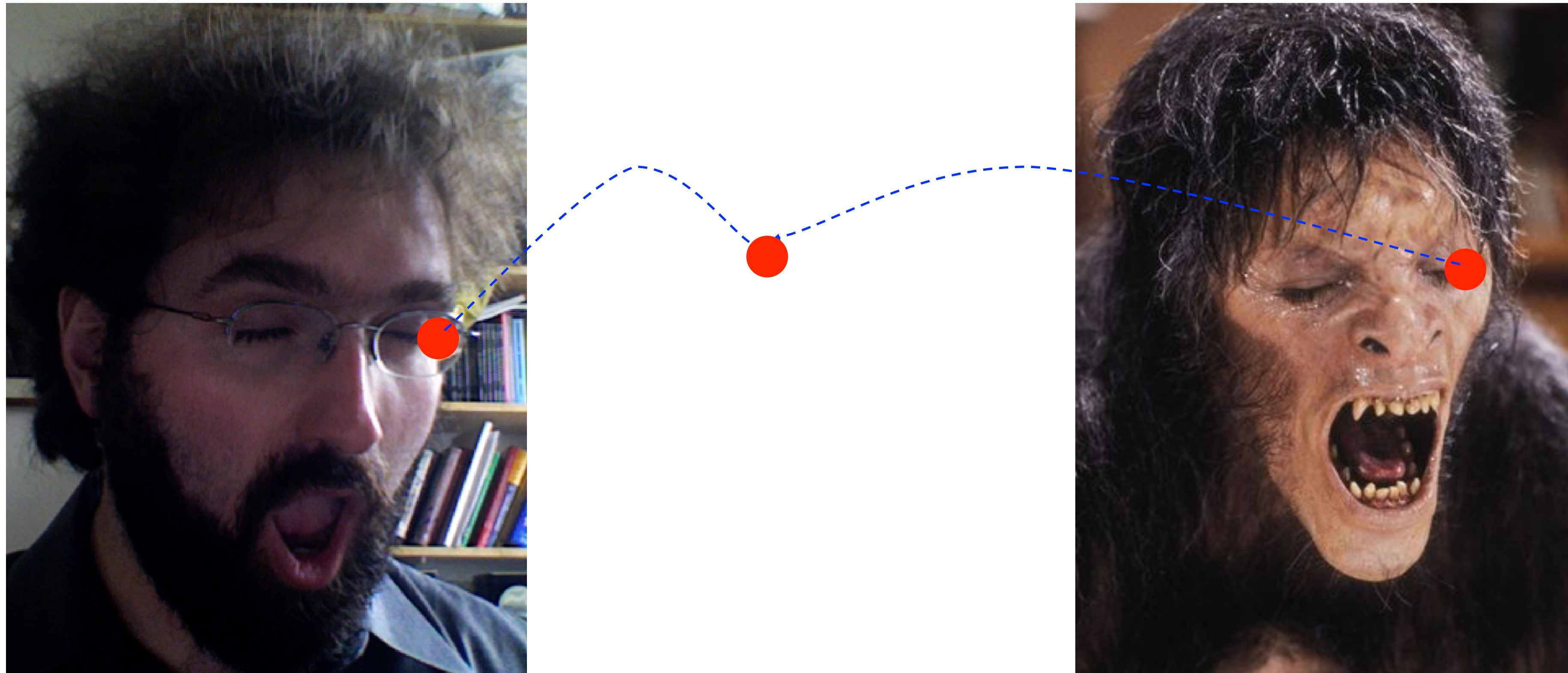


Recap & questions

- **Color (range) interpolation:**
 $\text{output}[y, x] = t * \text{im1}[y, x] + (1-t) * \text{im2}[y, x]$
- **Location (domain) interpolation:** $V = t P + (1-t) Q$
- **Warping:** domain transform $\text{out}(x, y) = \text{im}(f^{-1}(x, y))$

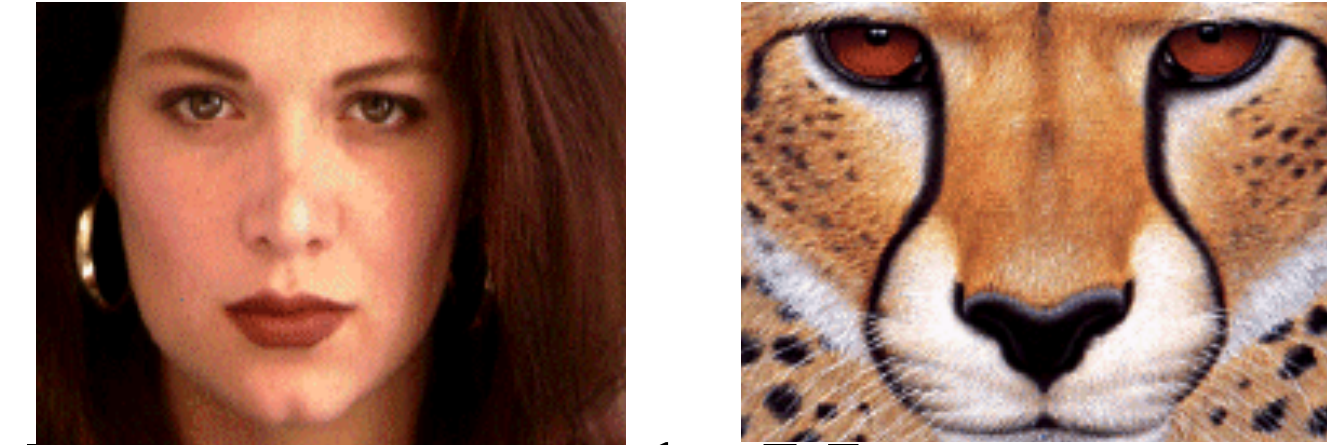
Morphing: combine both

- **For each pixel**
 - Transform its location like a vector (domain)
 - Then linearly interpolate colors (range)

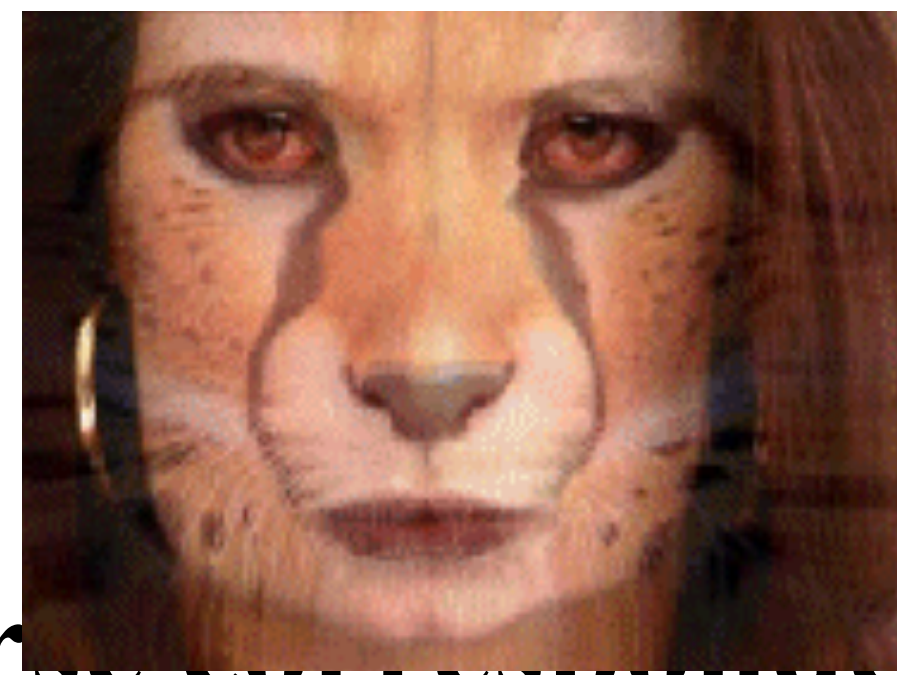


Morphing

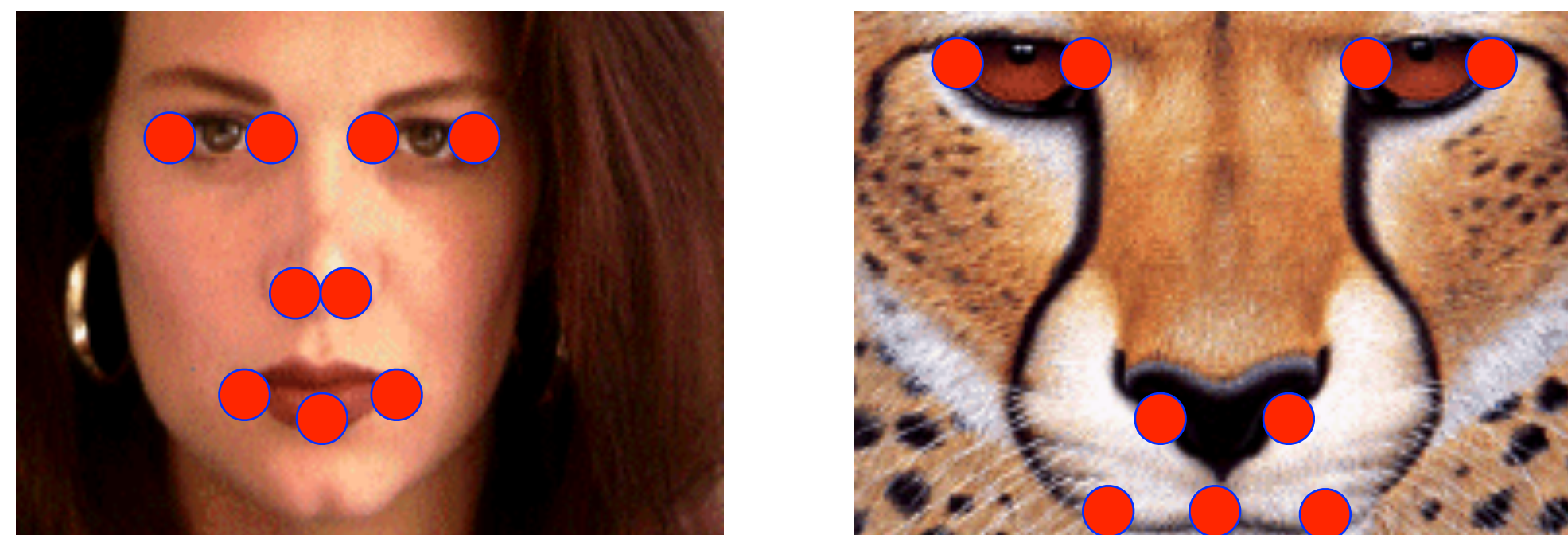
- Input: two images I_0 and I_{N+1}



- Expected output: image sequence I_i , with $i \in 1..N$

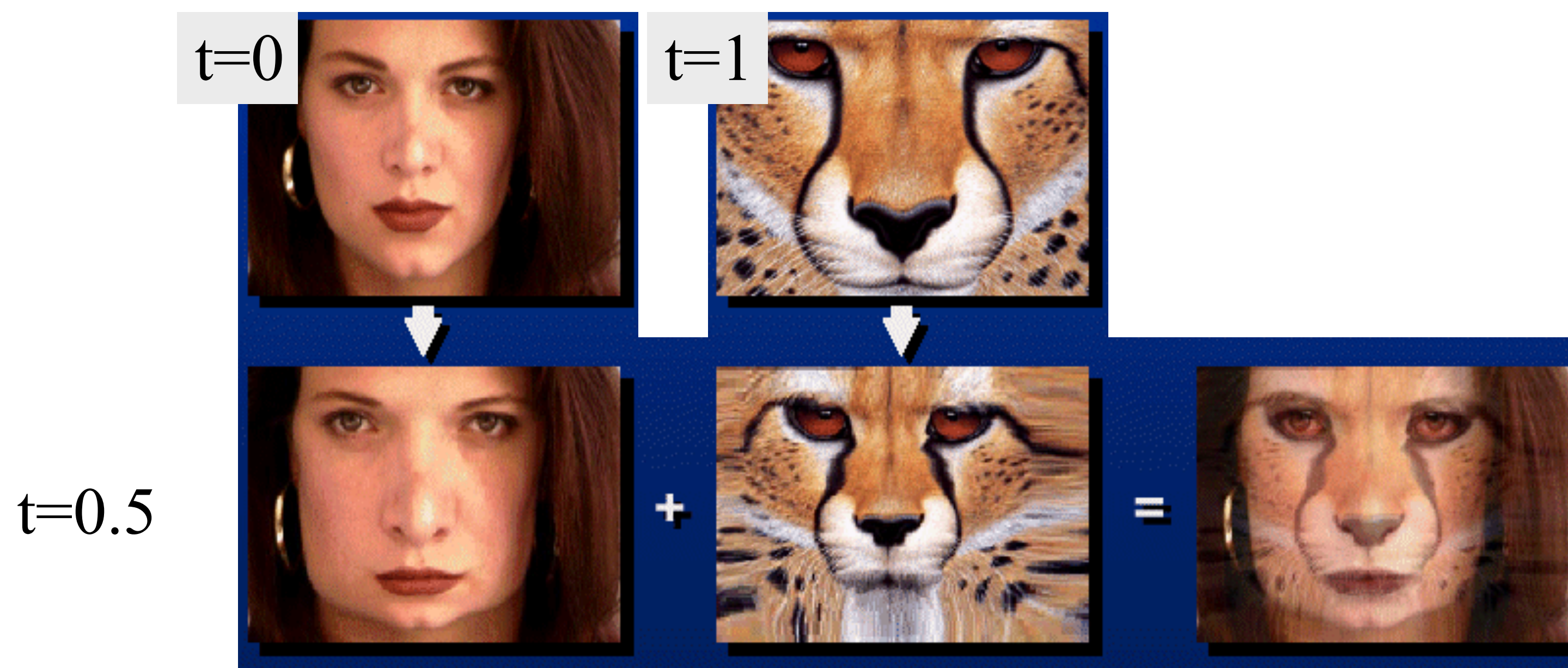


- User specifies sparse correspondences on the images



Morphing

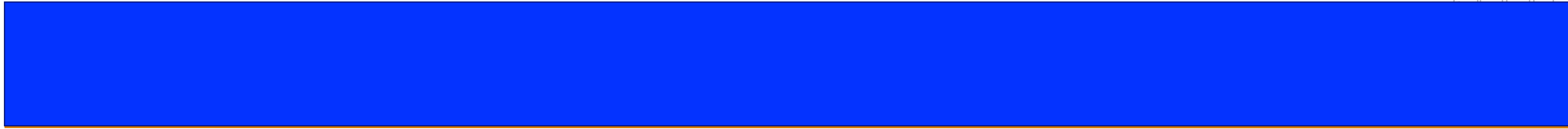
- For each intermediate frame I_t
 - Interpolate feature locations $P_i^t = (1 - t) P_i^0 + t P_i^1$
 - Perform **two** warps: one for I_0 , one for I_1
 - Deduce a dense warp field from the pairs of features
 - Warp the pixels
 - Linearly interpolate the two warped images



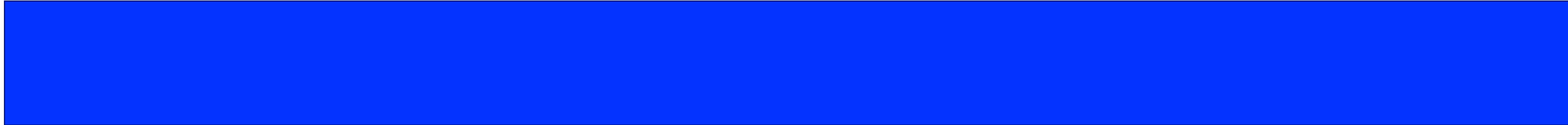
Beier and Neely

- Specify warp based on pairs of segments
 - <http://dl.acm.org/citation.cfm?id=134003>
 - Feature-Based Metamorphosis, SIGGRAPH 1992
 - Used in Michael Jackson's Black and White Music Video
 - Pset 5!!



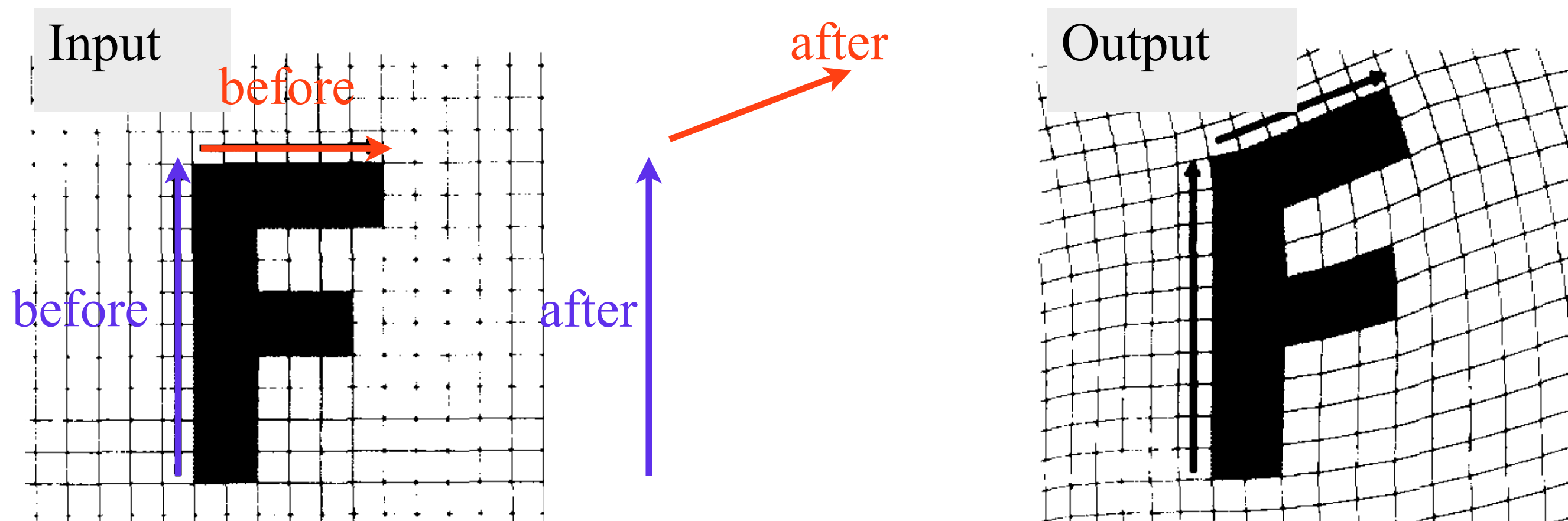


Segment-based warping



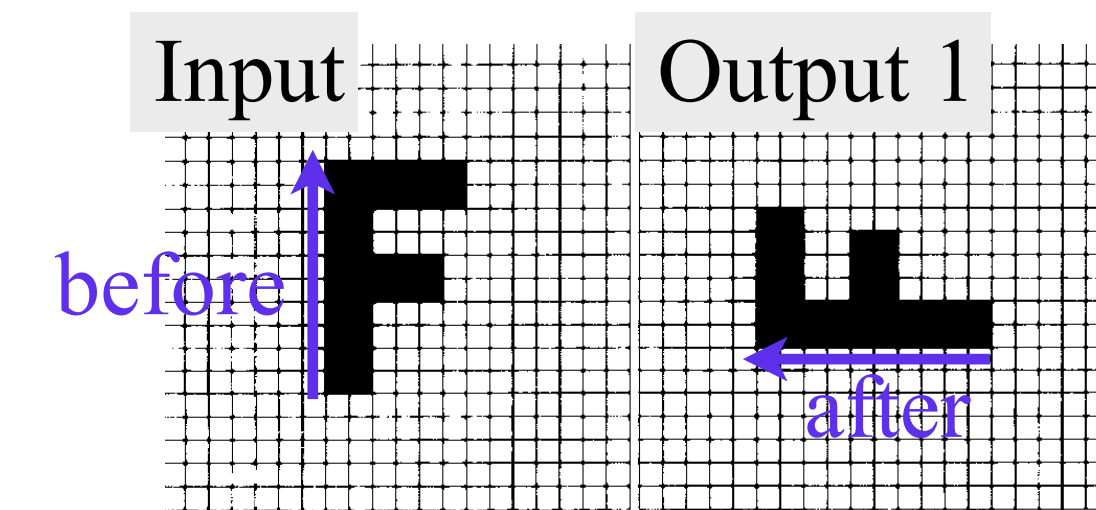
Problem statement

- **Inputs:** One image, two lists of segments before and after, in the image domain
- **Goal:** warp the image “following” the displacement of the segments



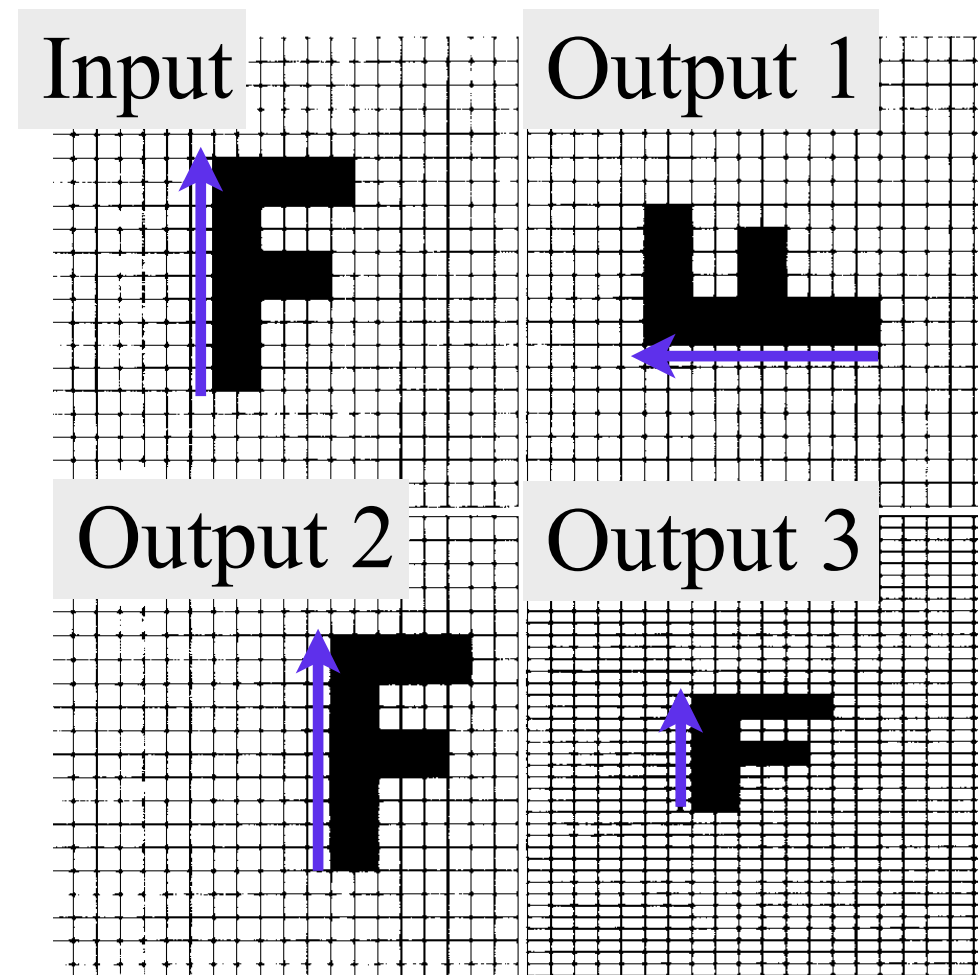
Idea

- **Each before/after pair of segment implies a planar transformation**
 - simple and affine



Single line transforms

- Each before/after pair of segment implies a planar transformation
 - simple and affine

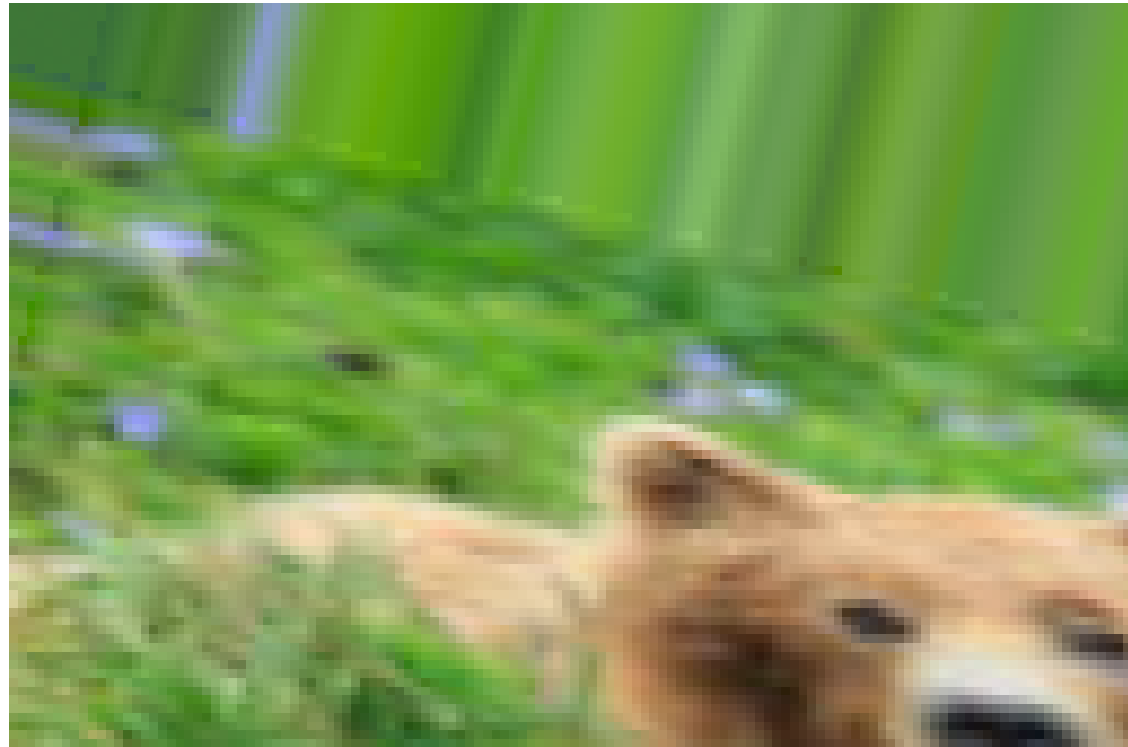


Single line transforms

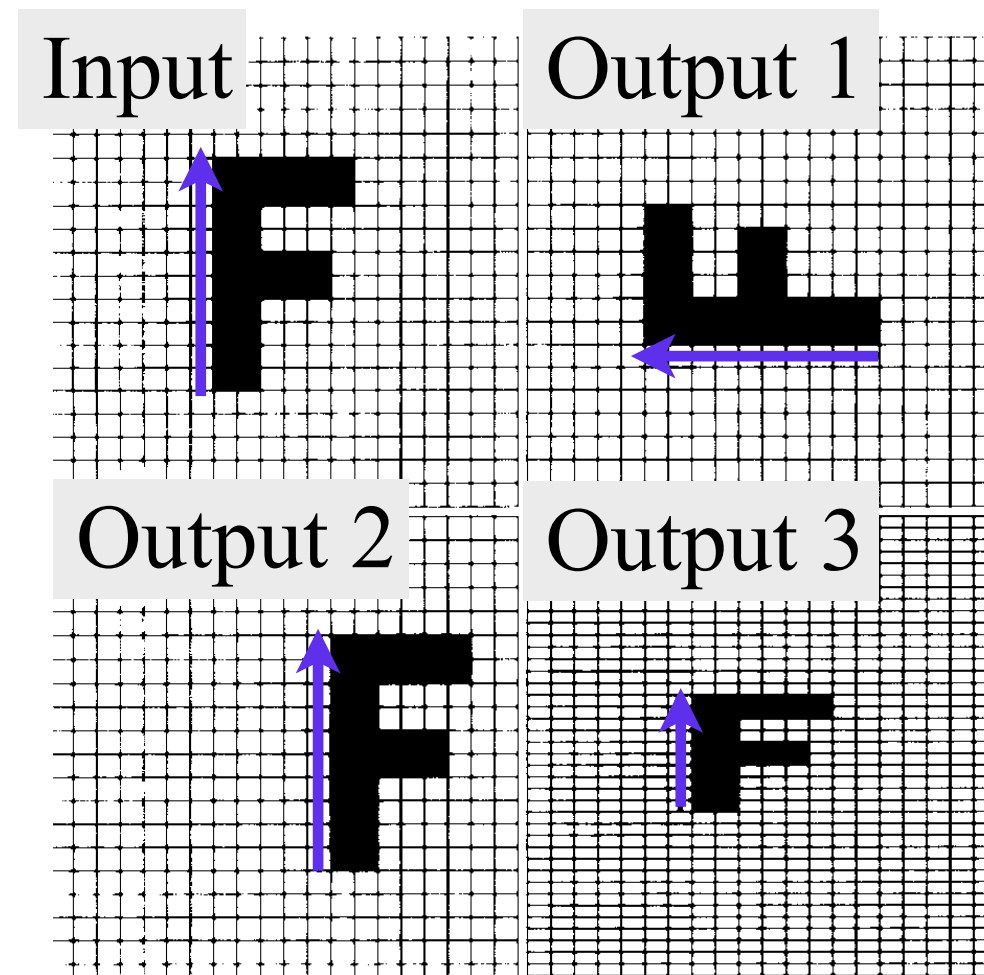
Test



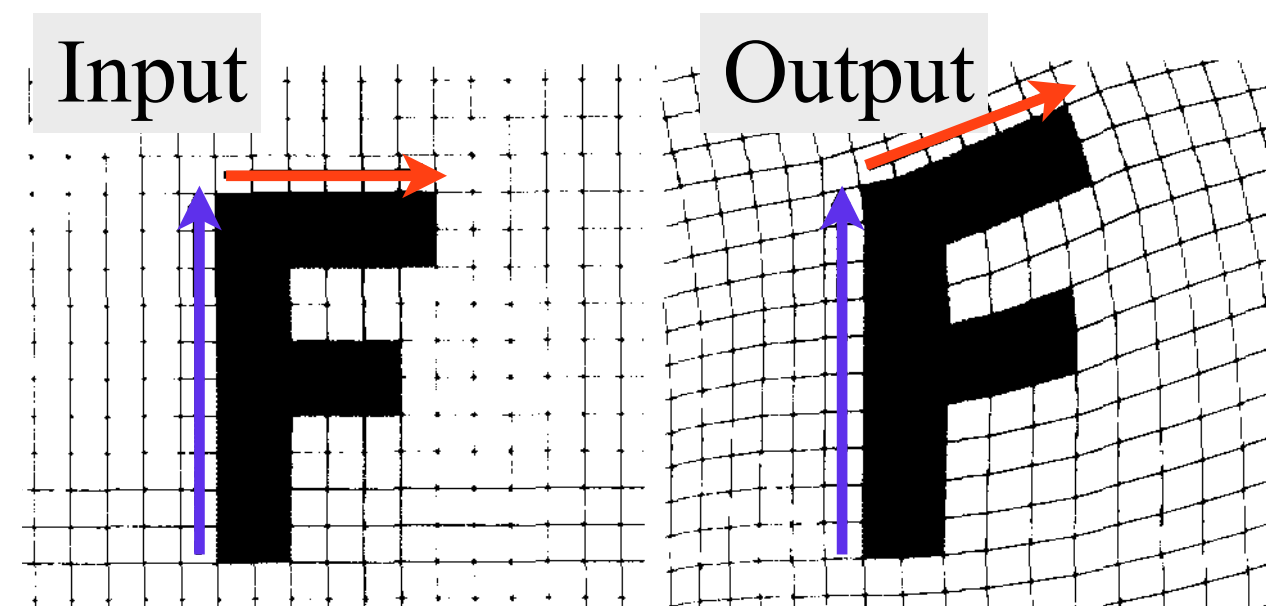
→ `warpBy1(im, segment(0,0, 10,0), segment(10, 10, 30, 15))` →



- Each before/after pair of segment implies a planar transformation
- Then take weighted average of transformations



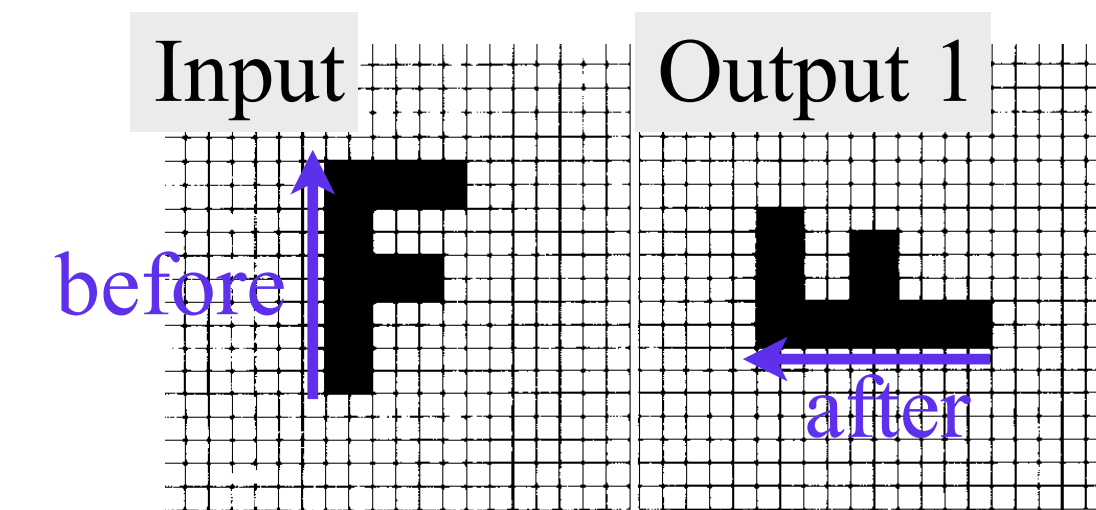
Single line transforms



Transform wrt 2 lines

Back to single segment

- Each before/after pair of segment implies a planar transformation
 - simple and affine



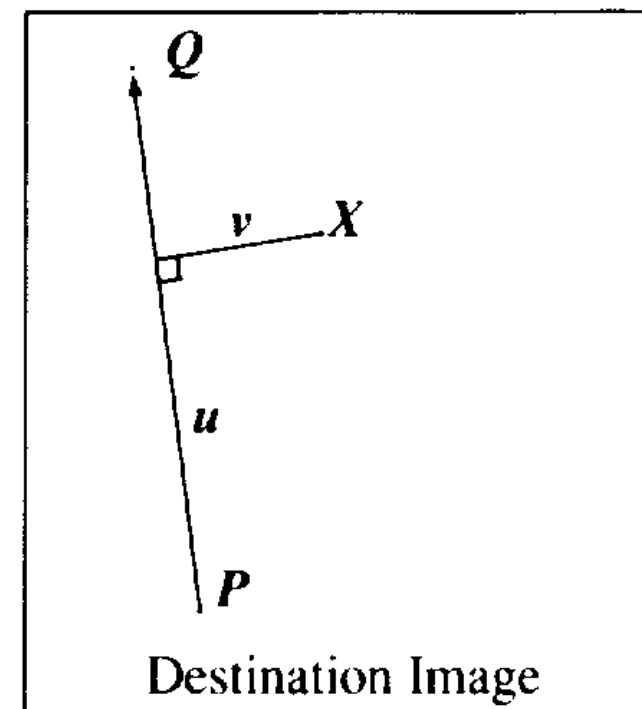
Single line transforms

Linear algebra refresher



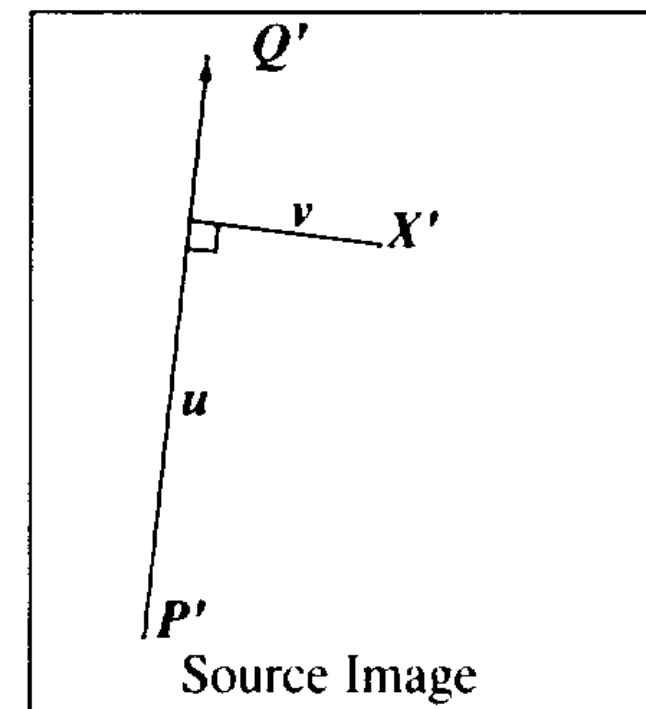
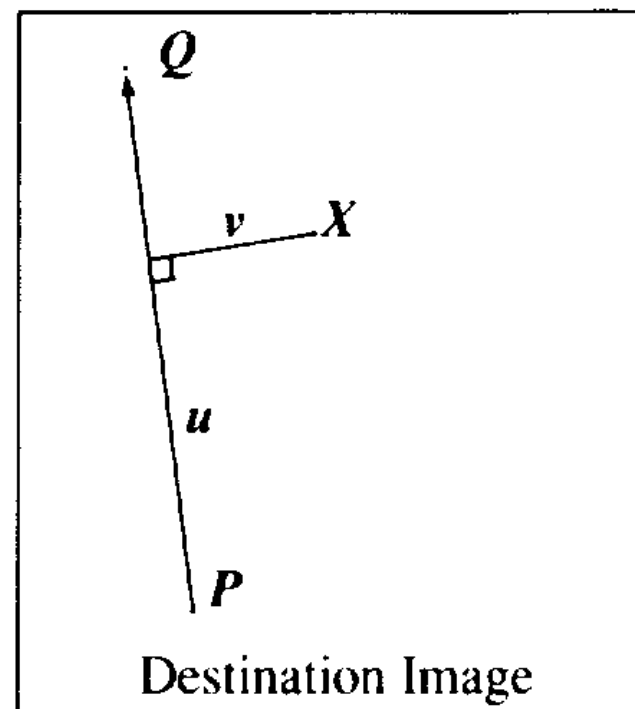
Transform wrt 1 segment

- **Define a coordinate system with respect to segment**
 - 1 dimension, u , along segment
 - 1 dimension, v , orthogonal to segment



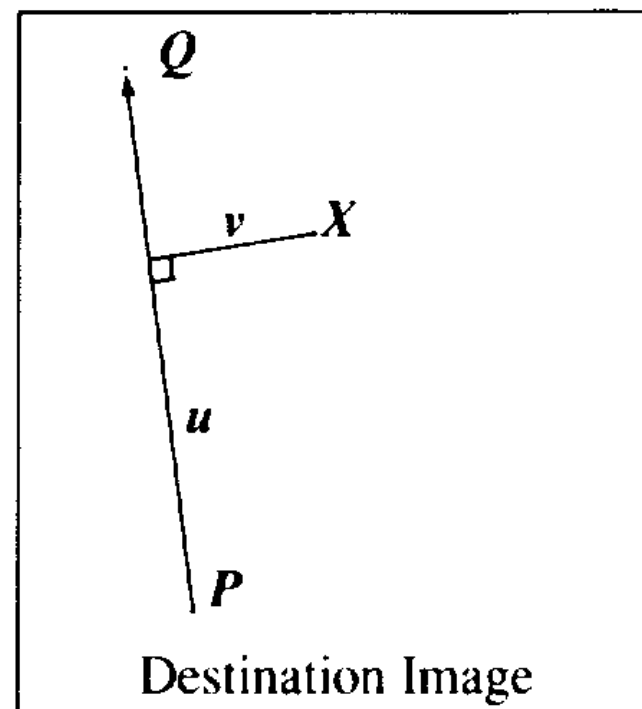
Transform wrt 1 segment

- **Define a coordinate system with respect to segment**
 - 1 dimension, u , along segment
 - 1 dimension, v , orthogonal to segment
- **Compute u , v in one image**
 - The after one, because we use the inverse transform
- **Compute point corresponding to u , v in second image**



Computing u , v

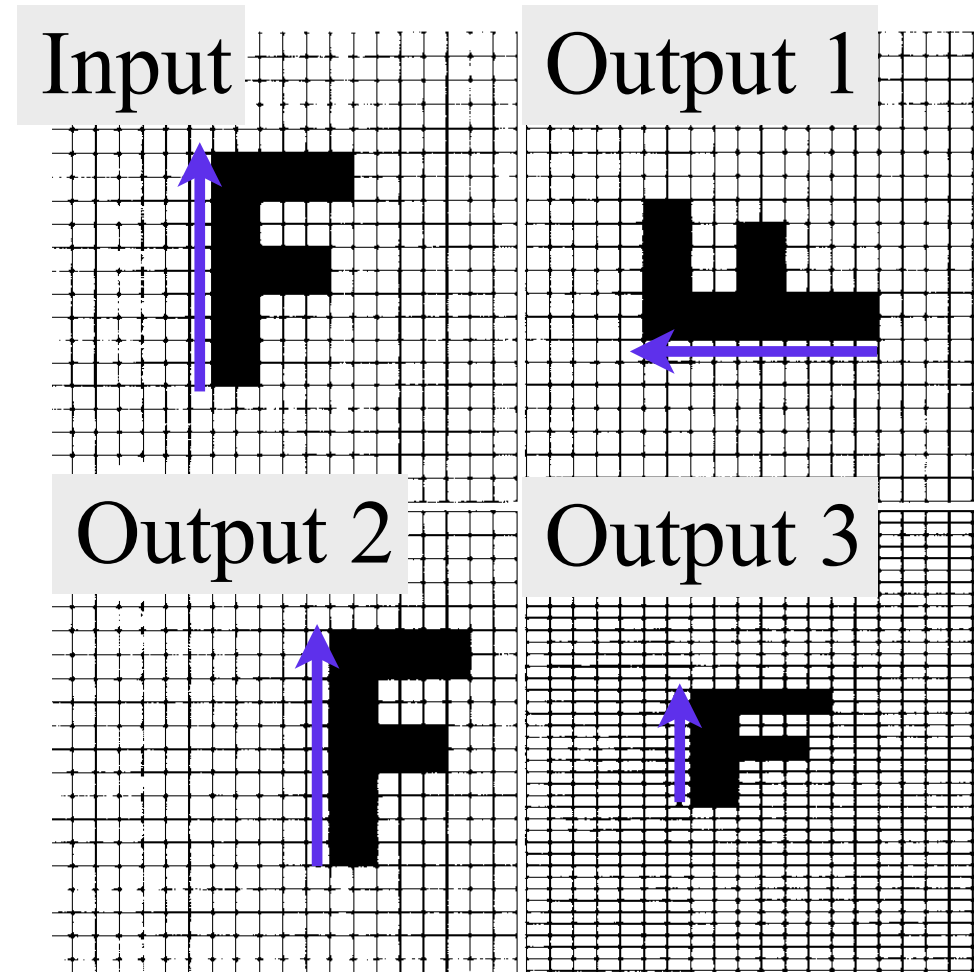
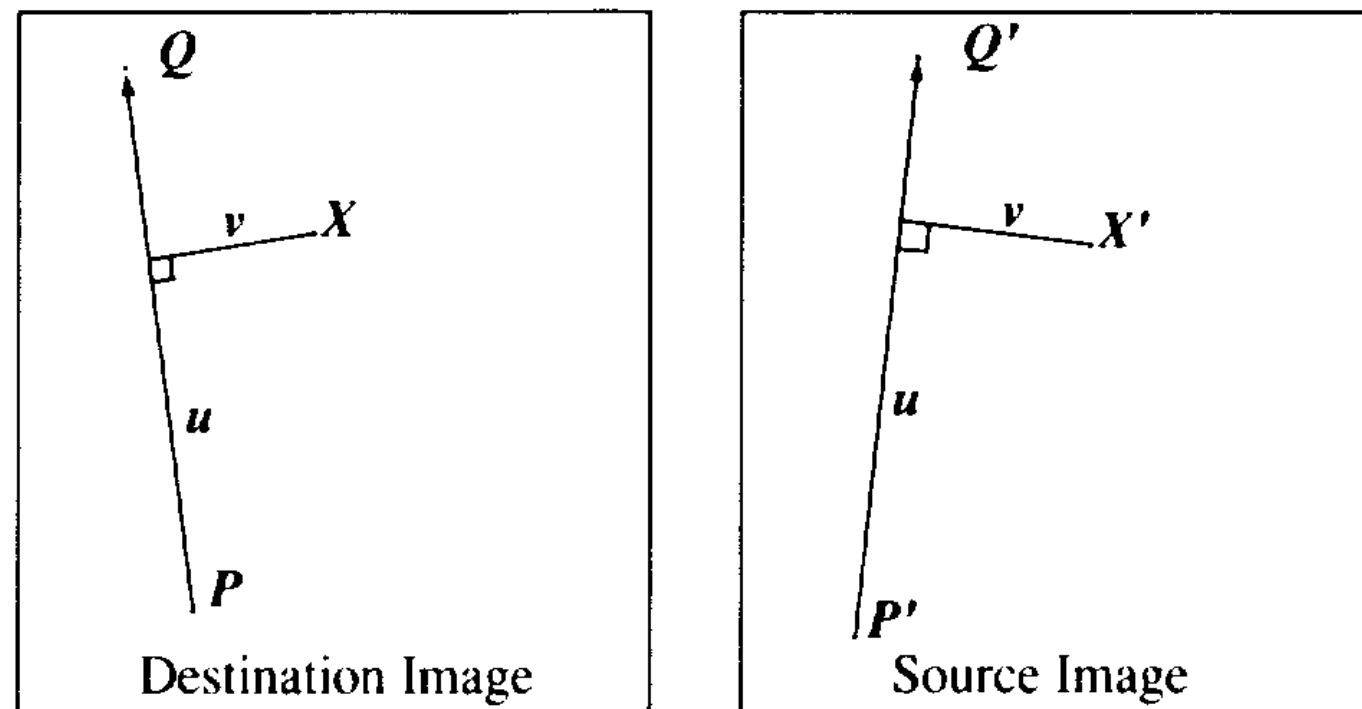
- $u = \mathbf{PX} \cdot \mathbf{PQ} / \|\mathbf{PQ}\|^2$
 - this way u is 0 at P and 1 at Q
- $\mathbf{v} = \mathbf{PX} \cdot \text{perpendicular}(\mathbf{PQ}) / \|\mathbf{PQ}\|$
 - where $\text{perpendicular}(\mathbf{PQ})$ is $\mathbf{PQ}$ rotated by 90 degrees, and has length $\|\mathbf{PQ}\|$
 - unlike u which is normalized, v is in distance units



Transforming a point given u, v



- $X' = P' + uP'Q + v \text{ perpendicular}(P'Q) / \|P'Q\|$
- The u component is scaled according to segment scaling
- But v is absolute (see output3)
 - They say they tried to scale v as well but it didn't work as well



Single line transforms

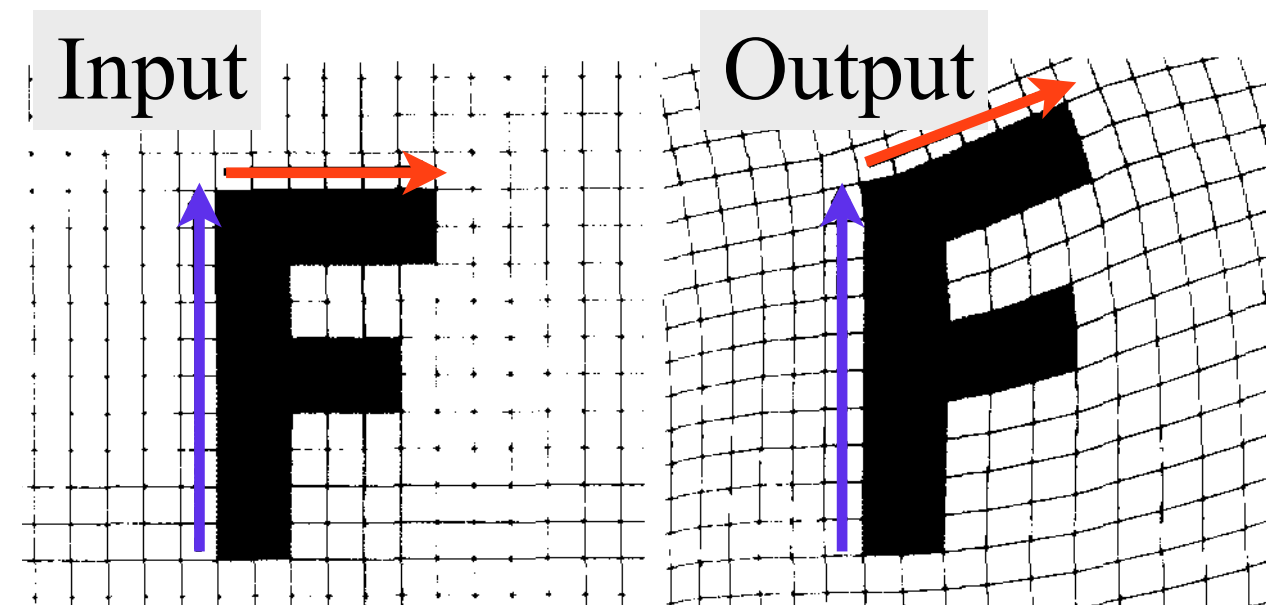
Questions?



Multiple segments

- **For each point X**
 - For each segment pair $s_before[i]$, $s_after[i]$
 - Transform X into X'i according to this pair
 - Compute weighted average of all transformed X'i
 - weight according to distance to segments

$$weight = \left(\frac{length^p}{a + dist} \right)^b$$



where a, b, p
control the influence

Transform wrt 2 lines

Distance to a segment

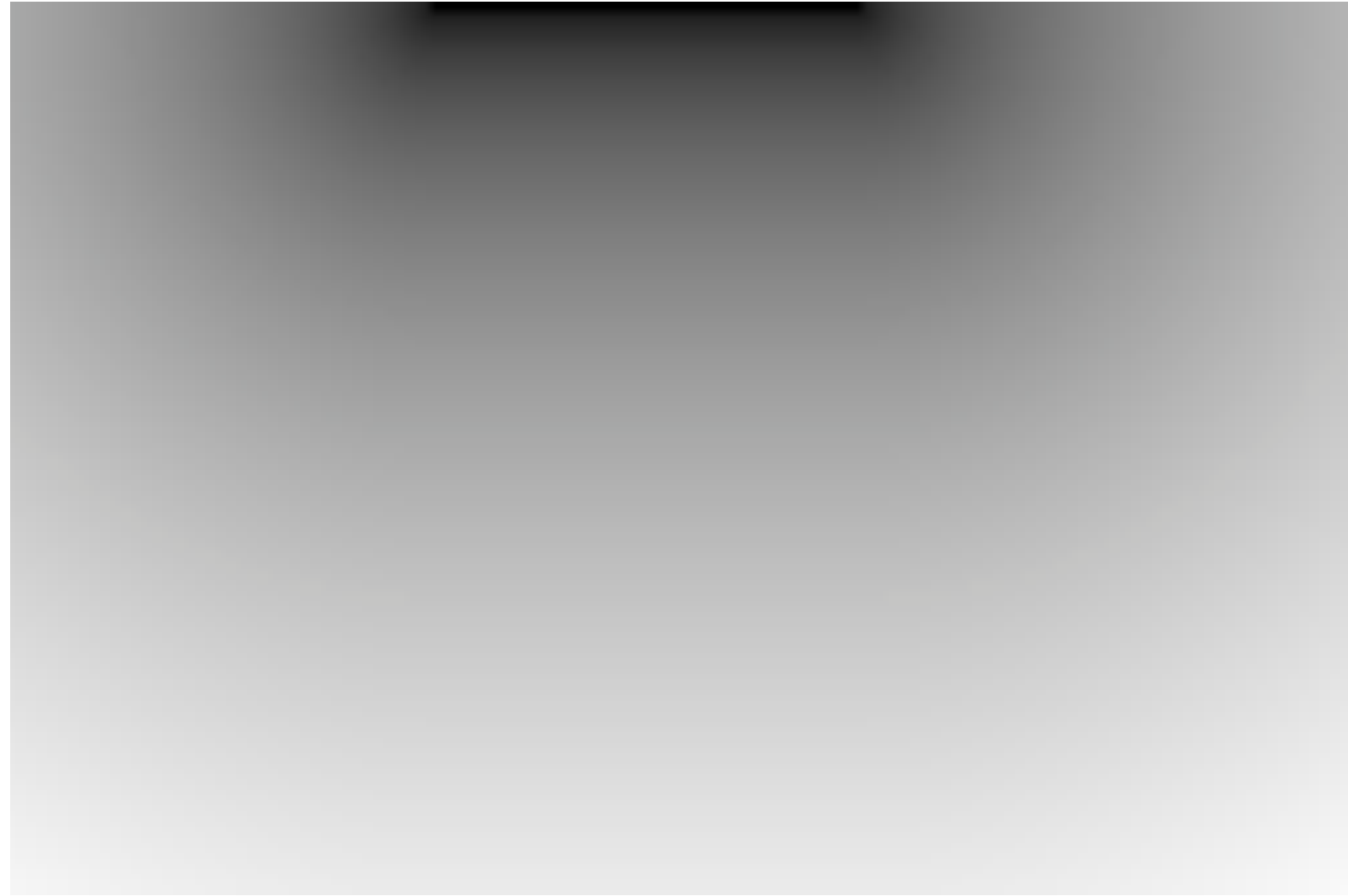


- **Multiple cases...**
 - dot product, test >0 , <1

Debugging: example



- **Debugging my distance function**



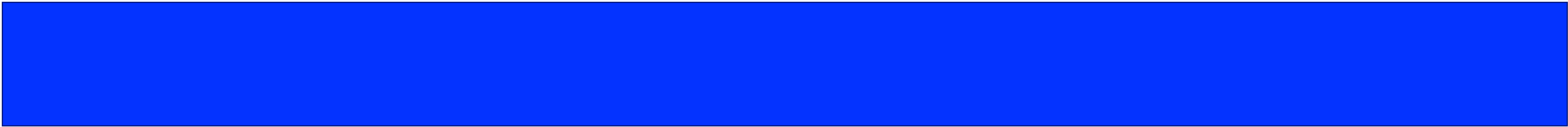
Questions?

- **More debugging**





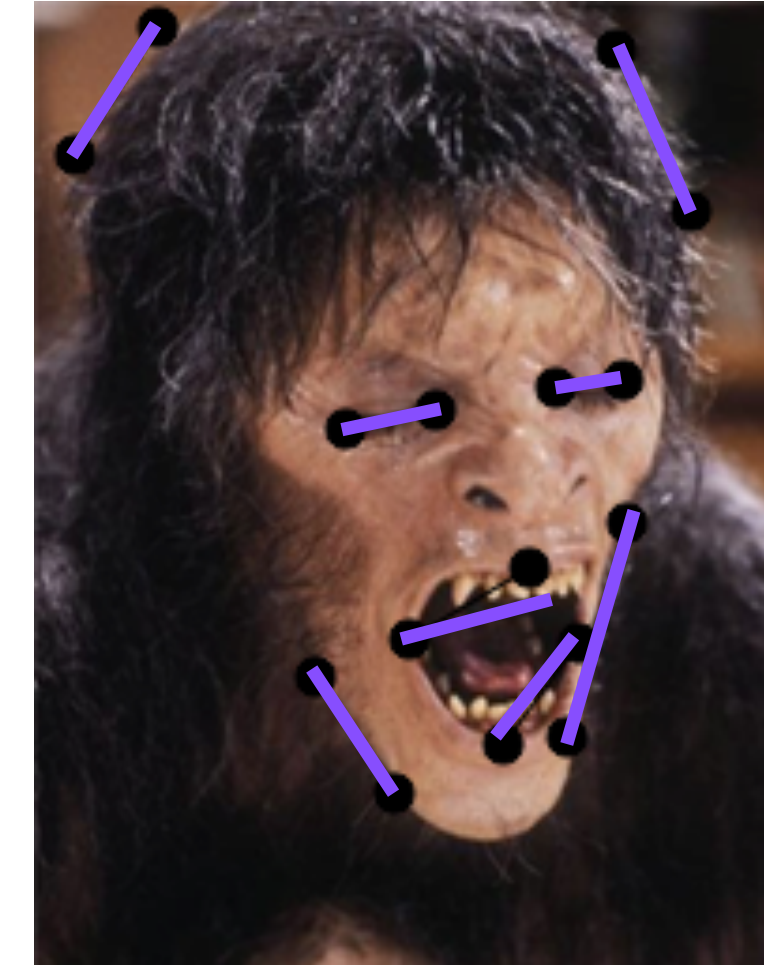
Morphing



Input images



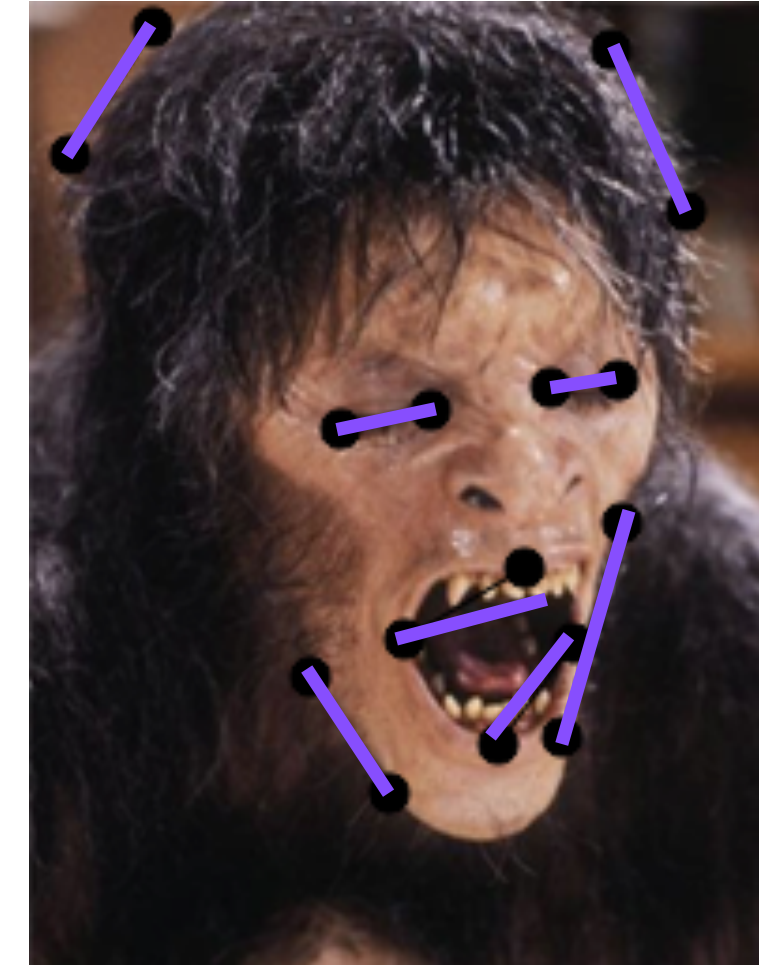
Segments



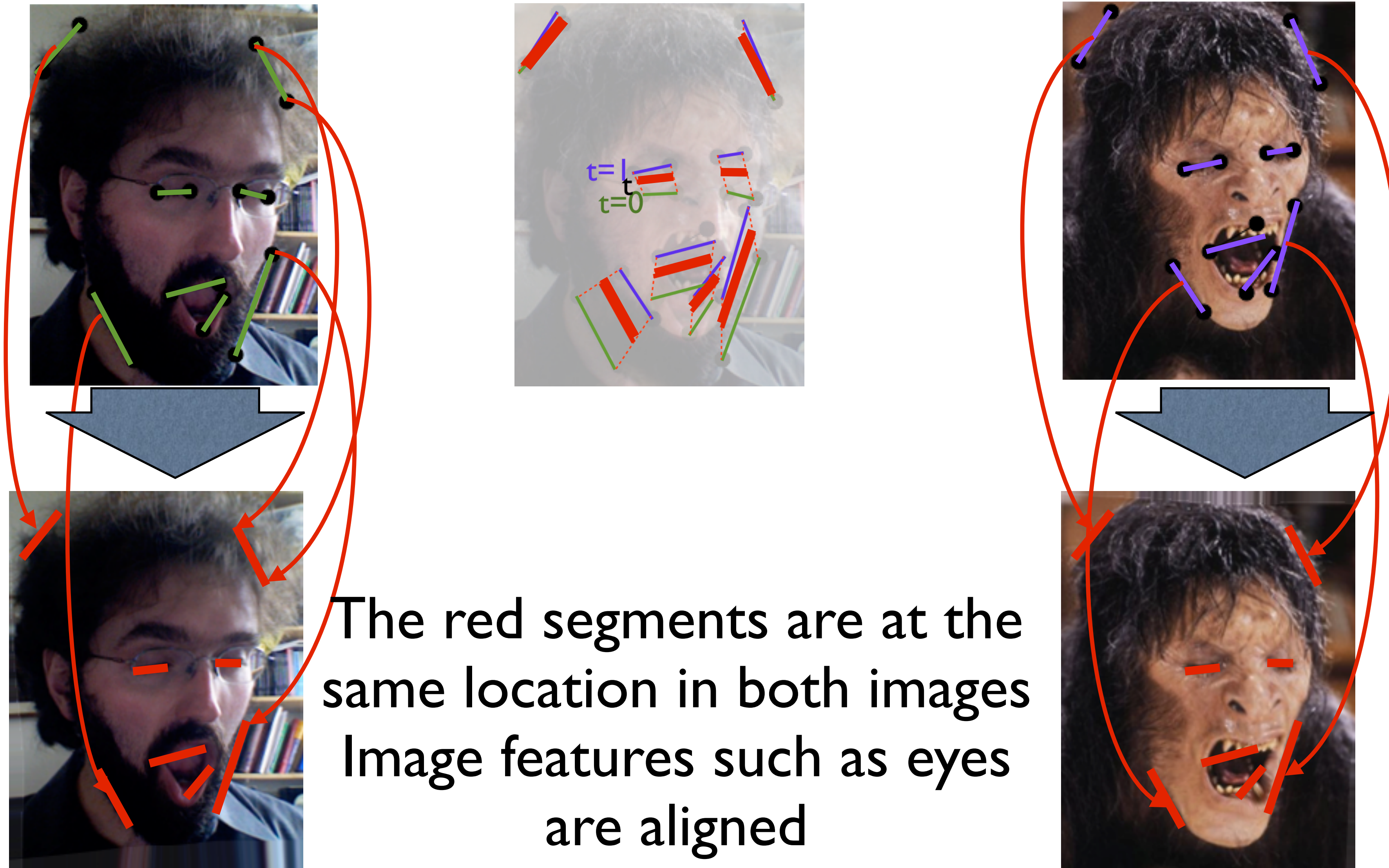
Interpolate segments



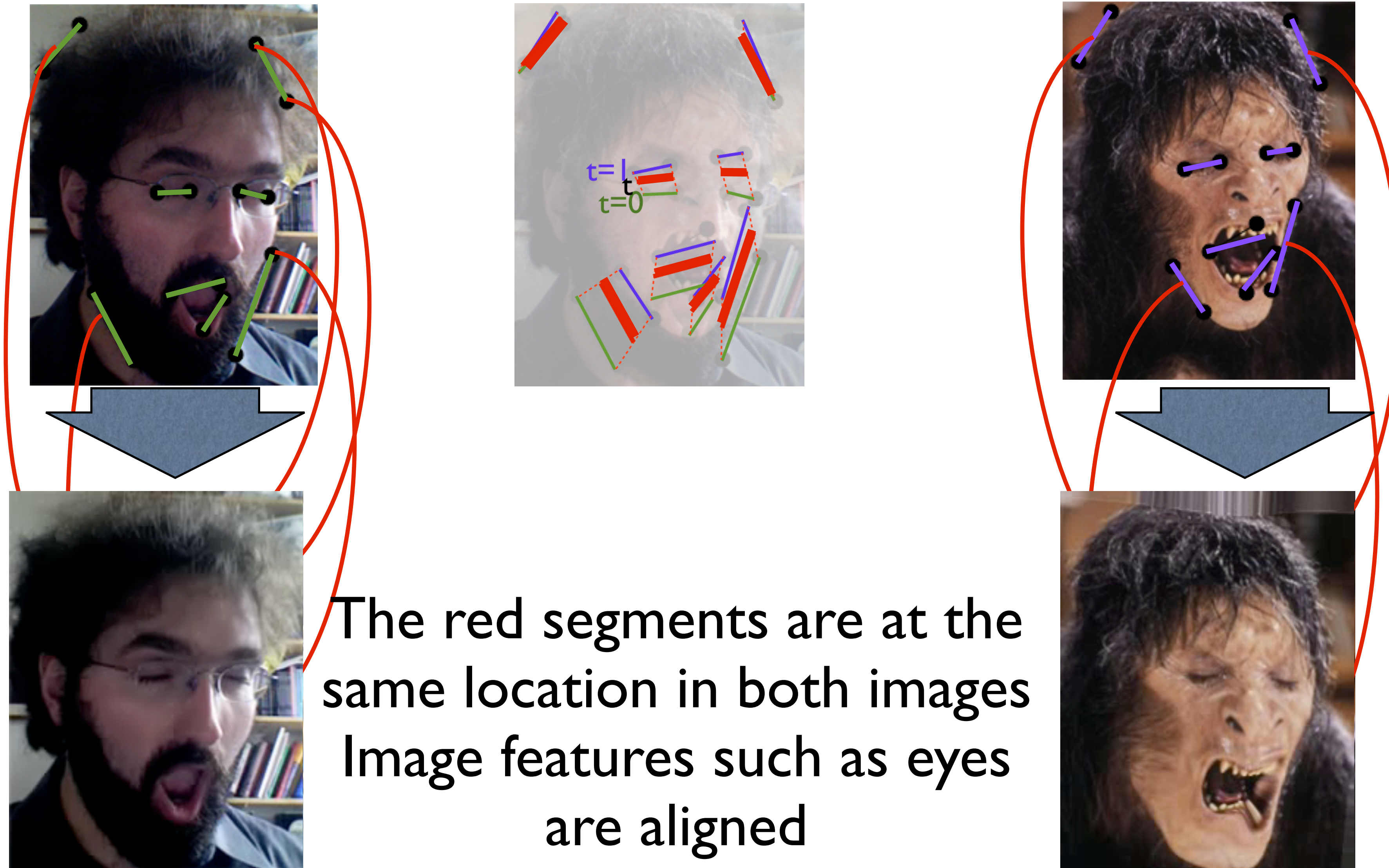
$t=0.5$



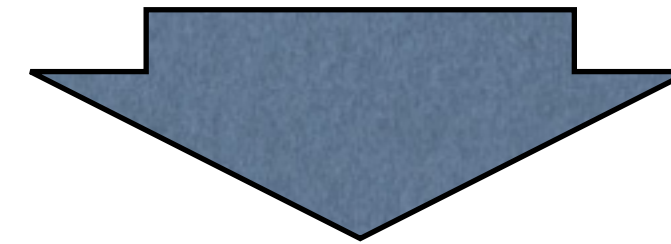
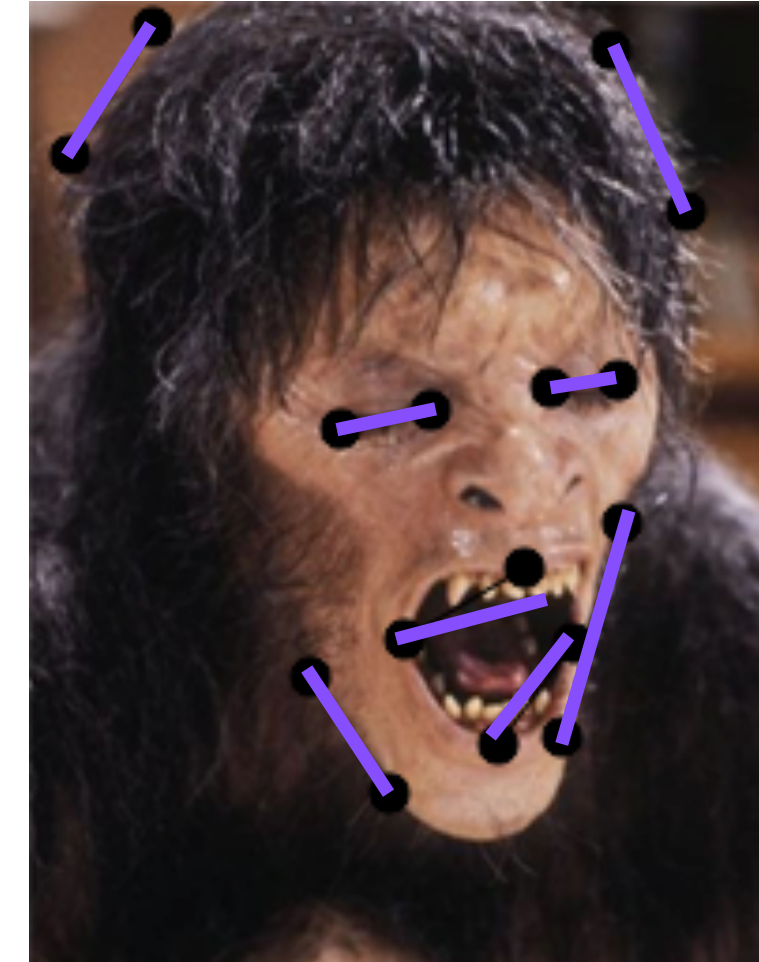
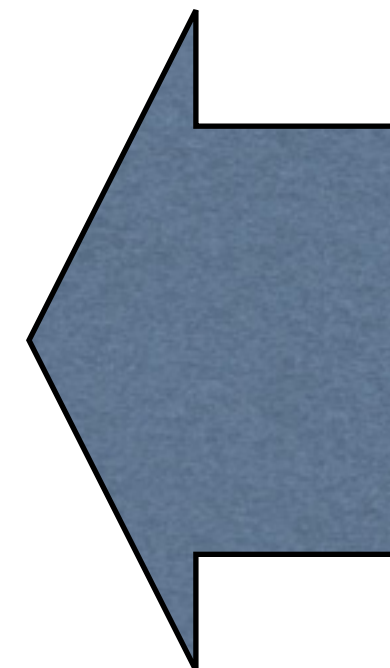
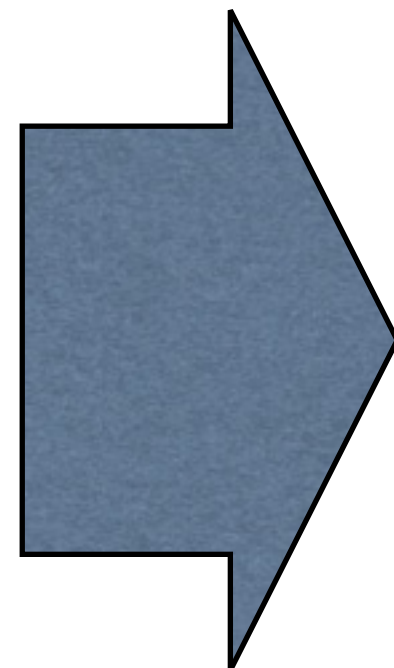
Warp images to segments[t]



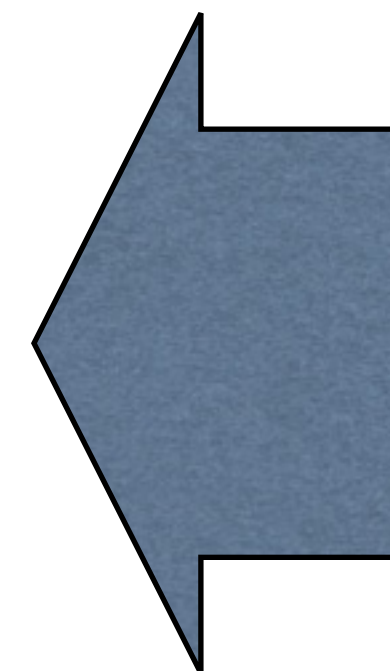
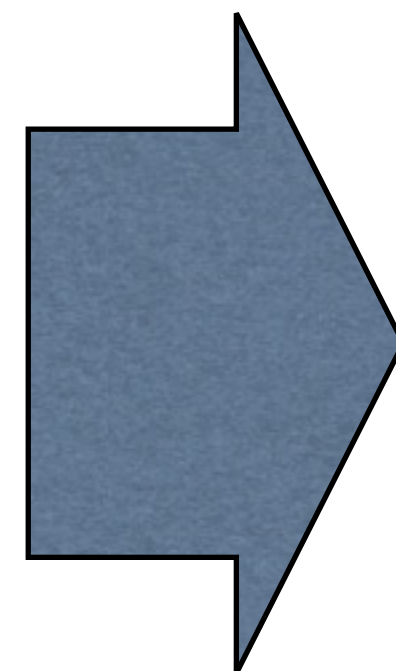
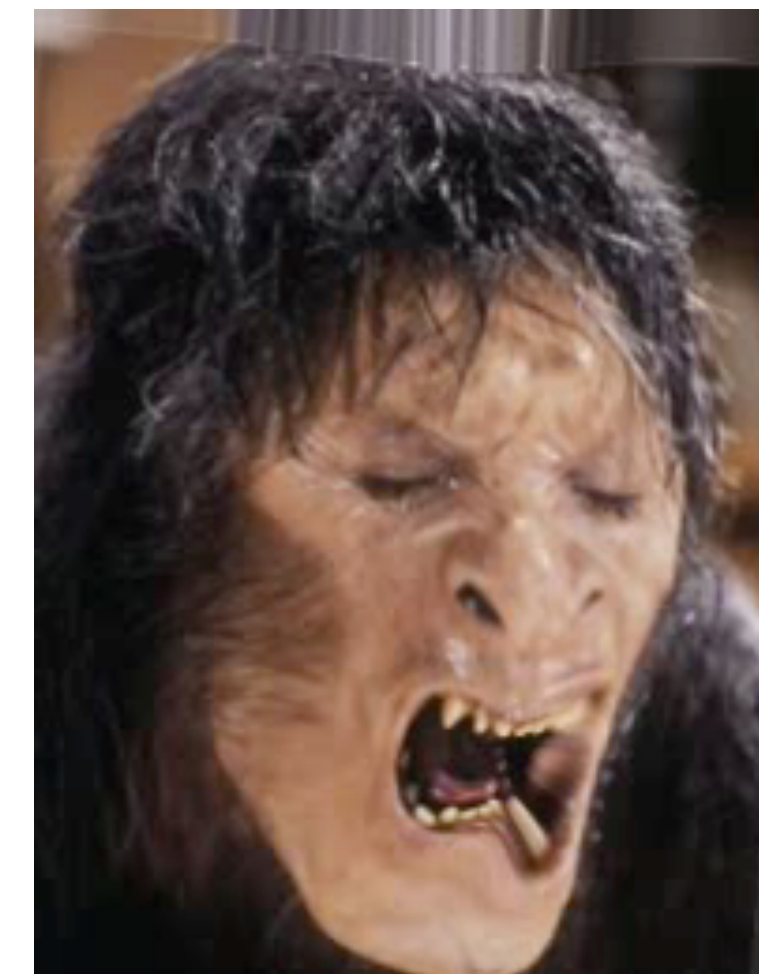
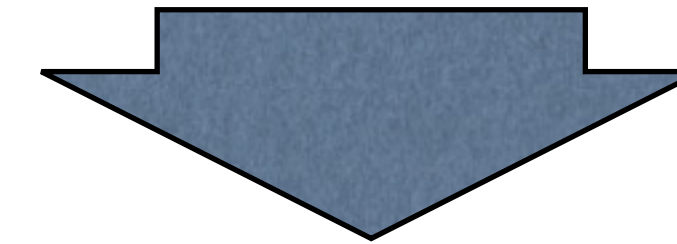
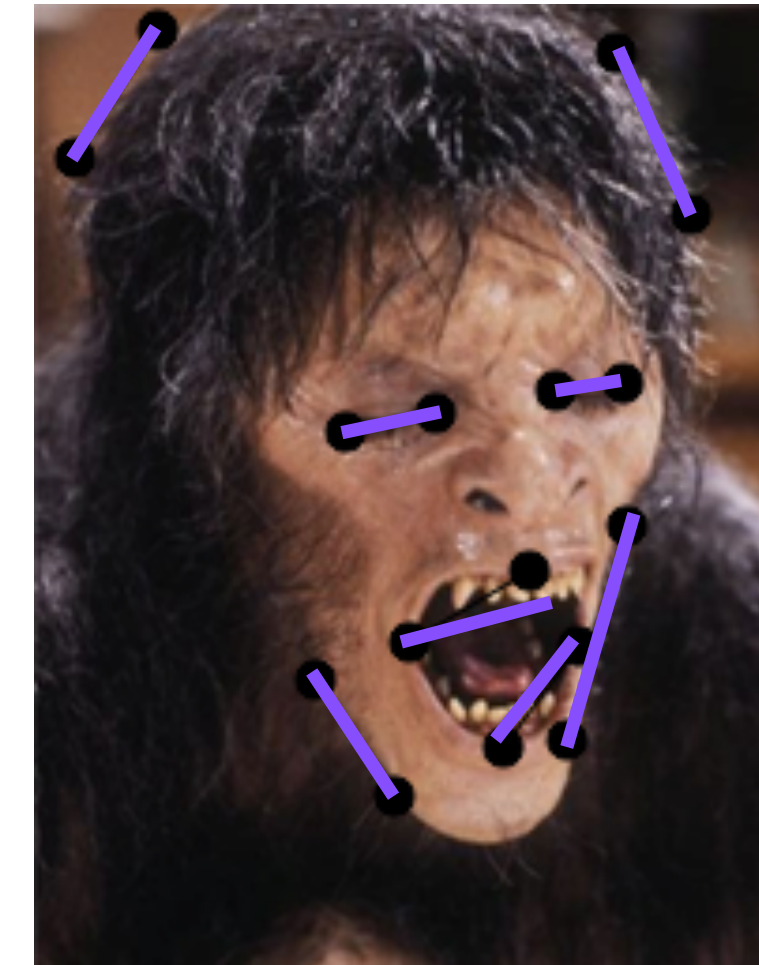
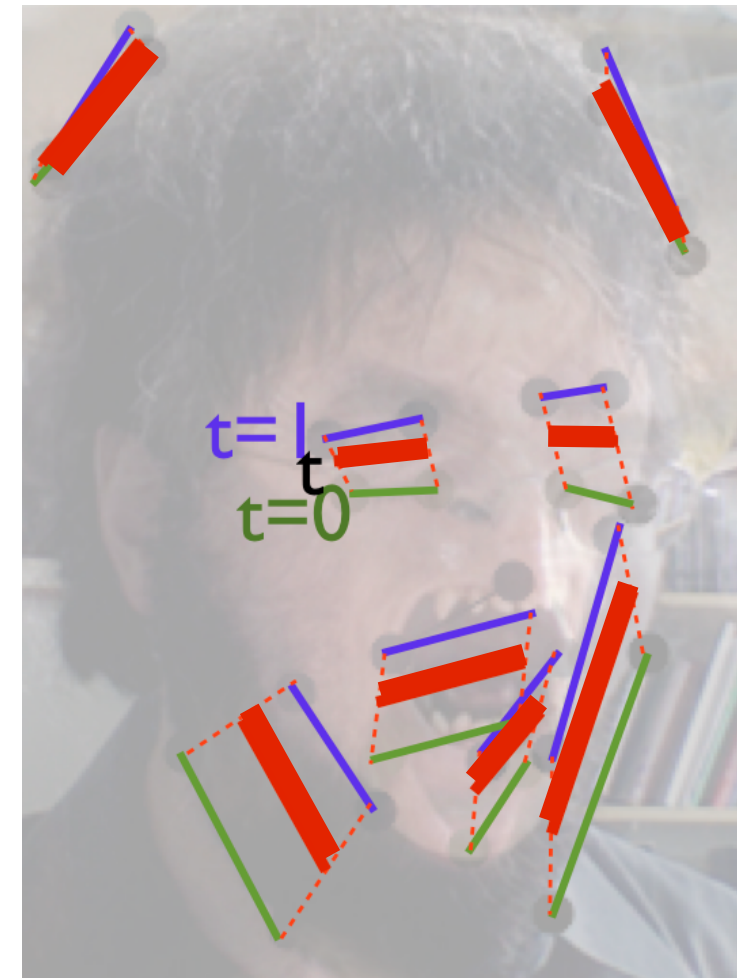
Warp images to segments[t]



Interpolate color



Interpolate color



Result



Recap

- For each intermediate frame I_t
 - Interpolate segment locations $y_i^t = (1-t) x_i^0 + t x_i^1$
 - Perform **two** warps: one for I_0 , one for I_1
 - Deduce a dense warp field from the pairs of features
 - Warp the pixels
 - Linearly interpolate the two warped images

Michael Jackson' BW

- Uses the very technique we just studied



Separating the art and the artist

- Michael Jackson has been credibly accused of sexual abuse of children
- See for example the documentary “Leaving Neverland” https://en.wikipedia.org/wiki/Leaving_Neverland

Conversation about sexual assault

- Sexual assault is bad
- Consent is paramount
- Children are not able to consent
- See something, say something
- Victims' stories are complicated. It doesn't make it any less bad.
- There can be love or feelings involved, yet sexual assault is still bad
- It can take a long time to talk. It doesn't make it less true.
- Men are more likely to be victims than falsely accused
- <https://studentlife.mit.edu/vpr/facts-and-resources>
- <https://www.rainn.org/>
- (617) 253-2300

Willow

Willow

- 1988, special effects by ILM
- First use of morphing

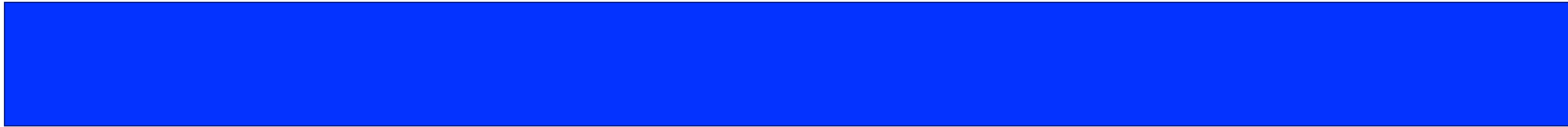


Featurette about morphing in Willow





Bells and whistles

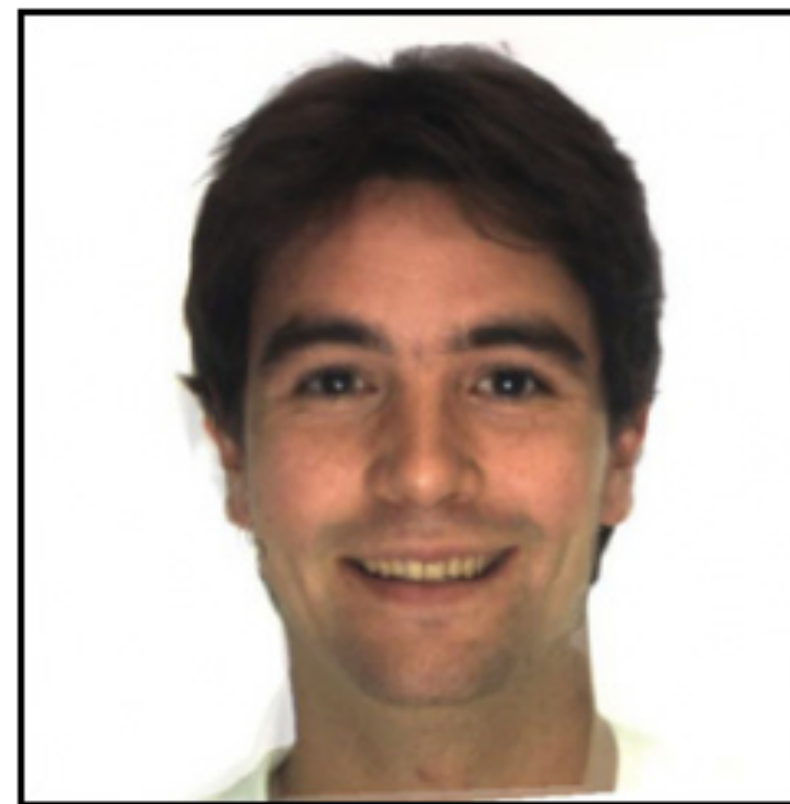


Morphing & matting

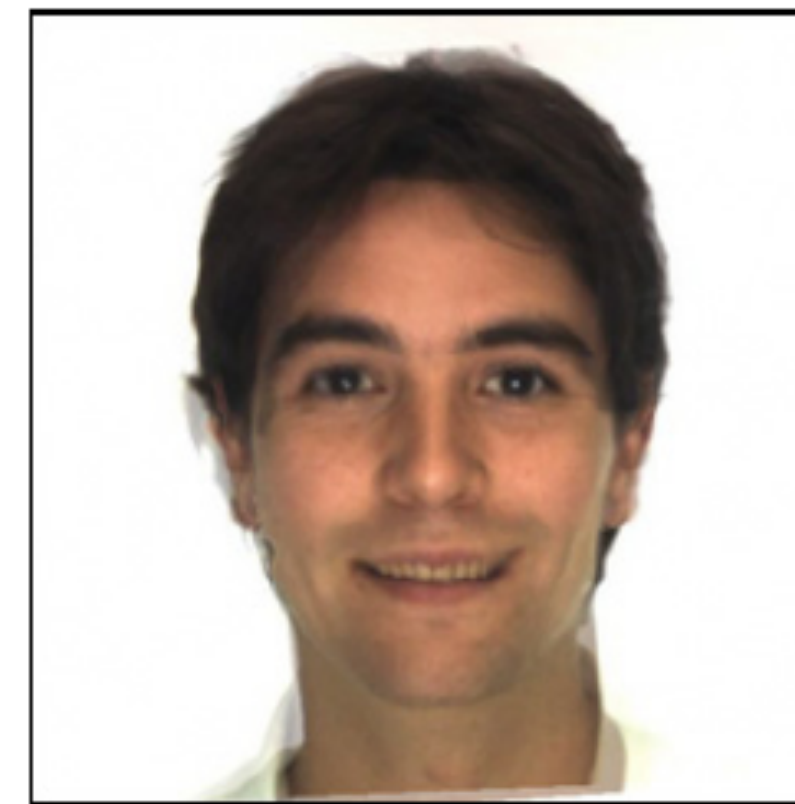
- Extract foreground first to avoid artifacts in the background



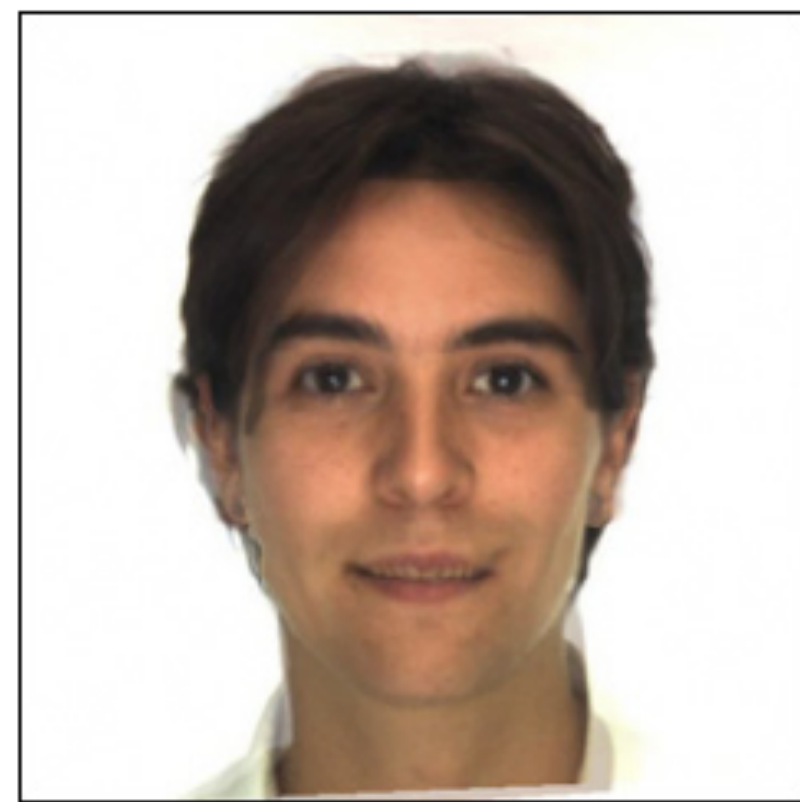
(c) $\alpha = 0.0$



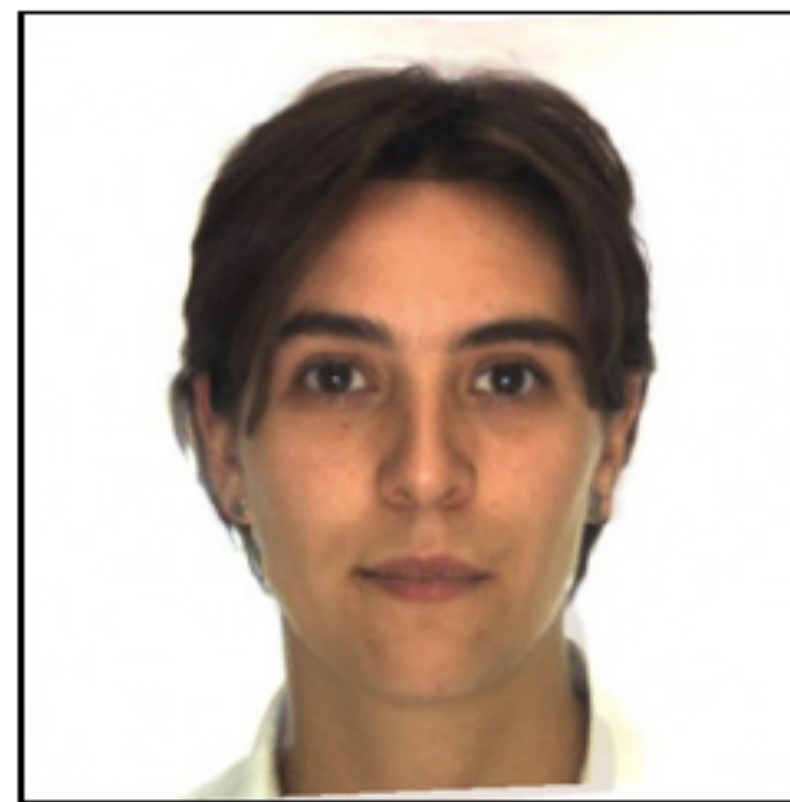
(d) $\alpha = 0.2$



(e) $\alpha = 0.4$



(f) $\alpha = 0.6$



(g) $\alpha = 0.8$



(h) $\alpha = 1.0$

Uniform morphing

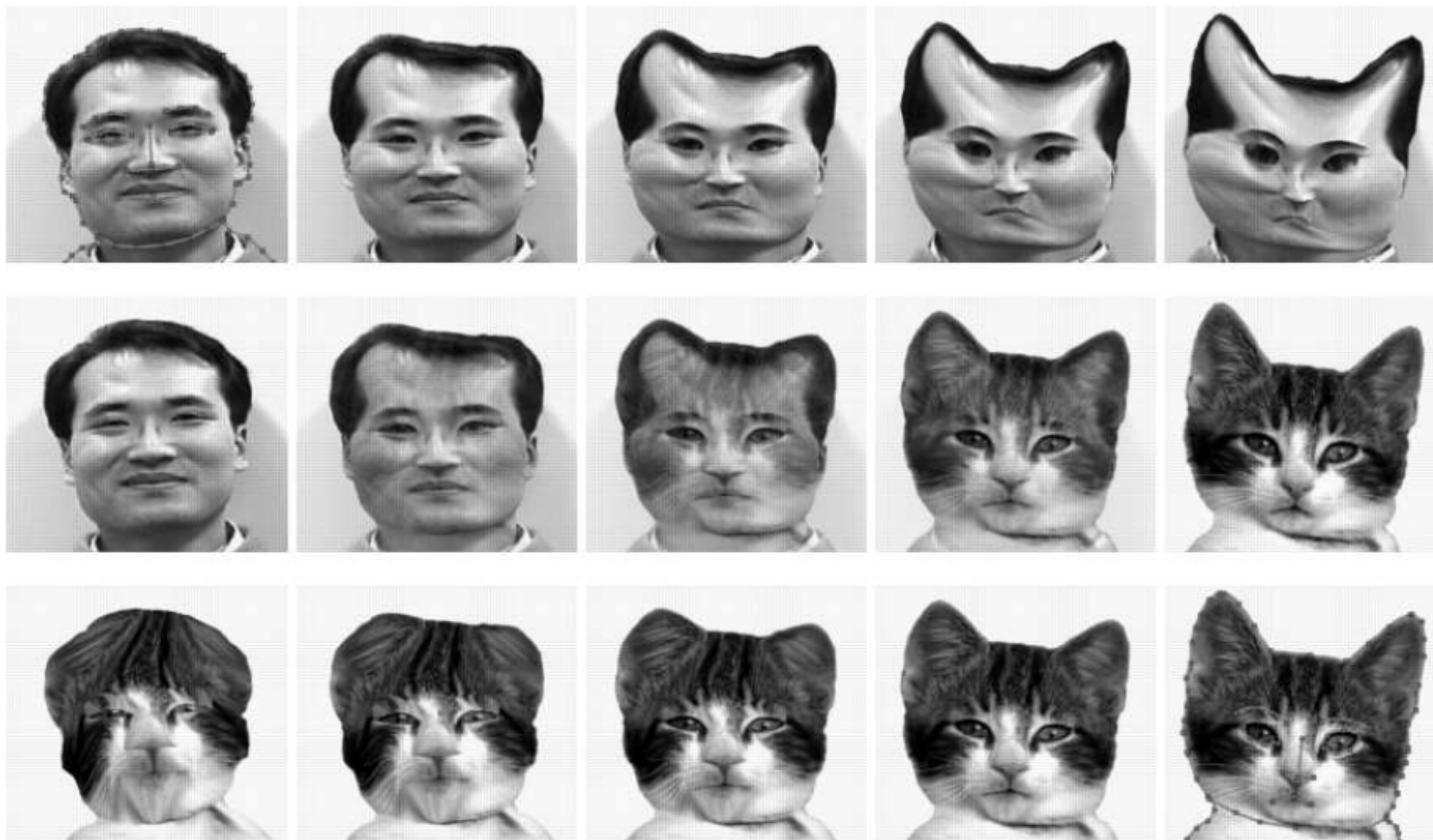


Figure 4. Uniform metamorphosis

Non-uniform morphing

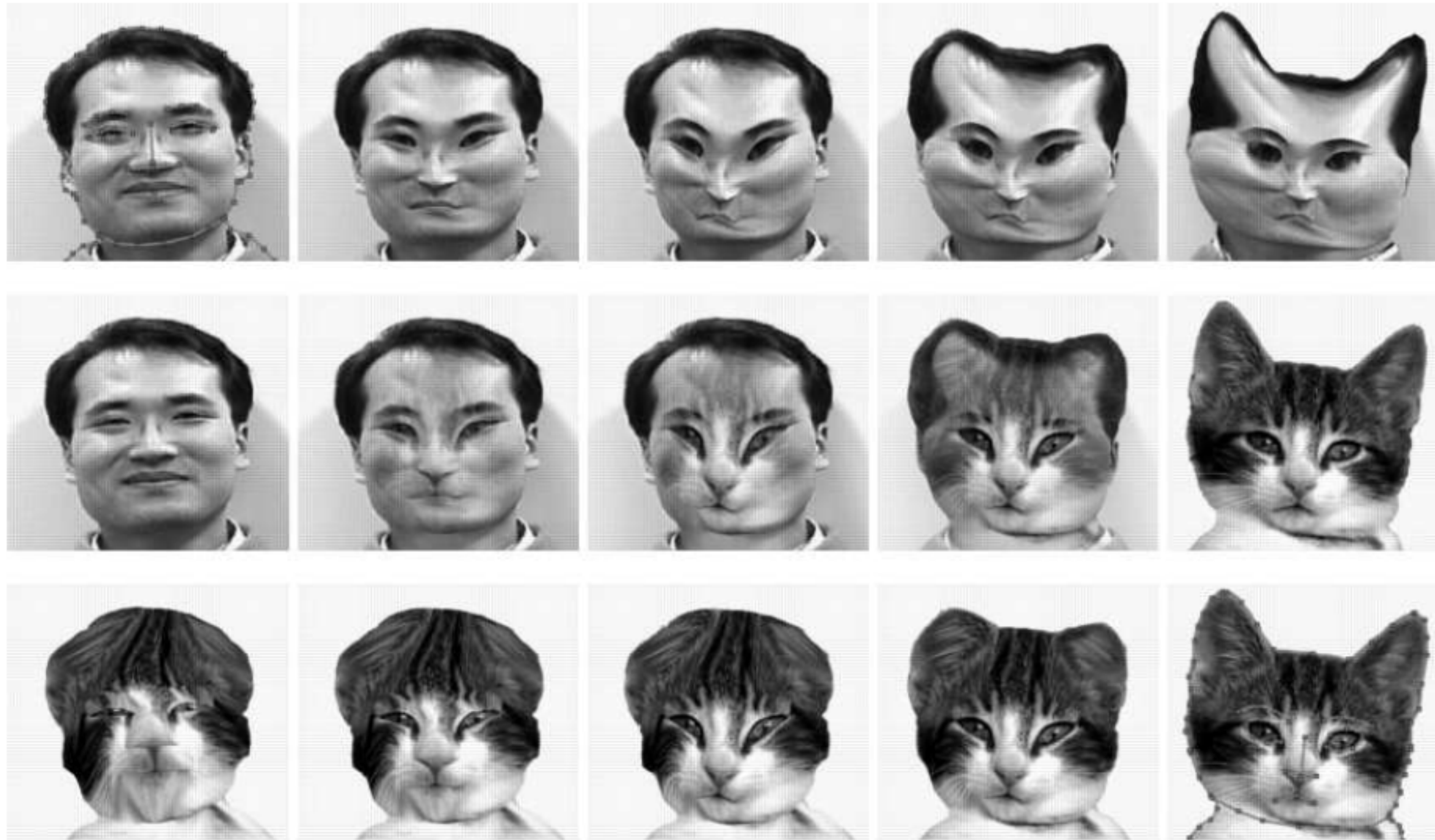


Figure 5. Nonuniform metamorphosis

<http://www-cs.ccny.cuny.edu/~wolberg/pub/cgi96.pdf>

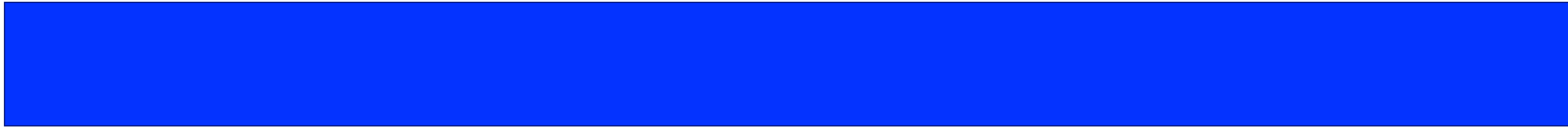
Video

- **Lots of manual work**





Recap & Significance

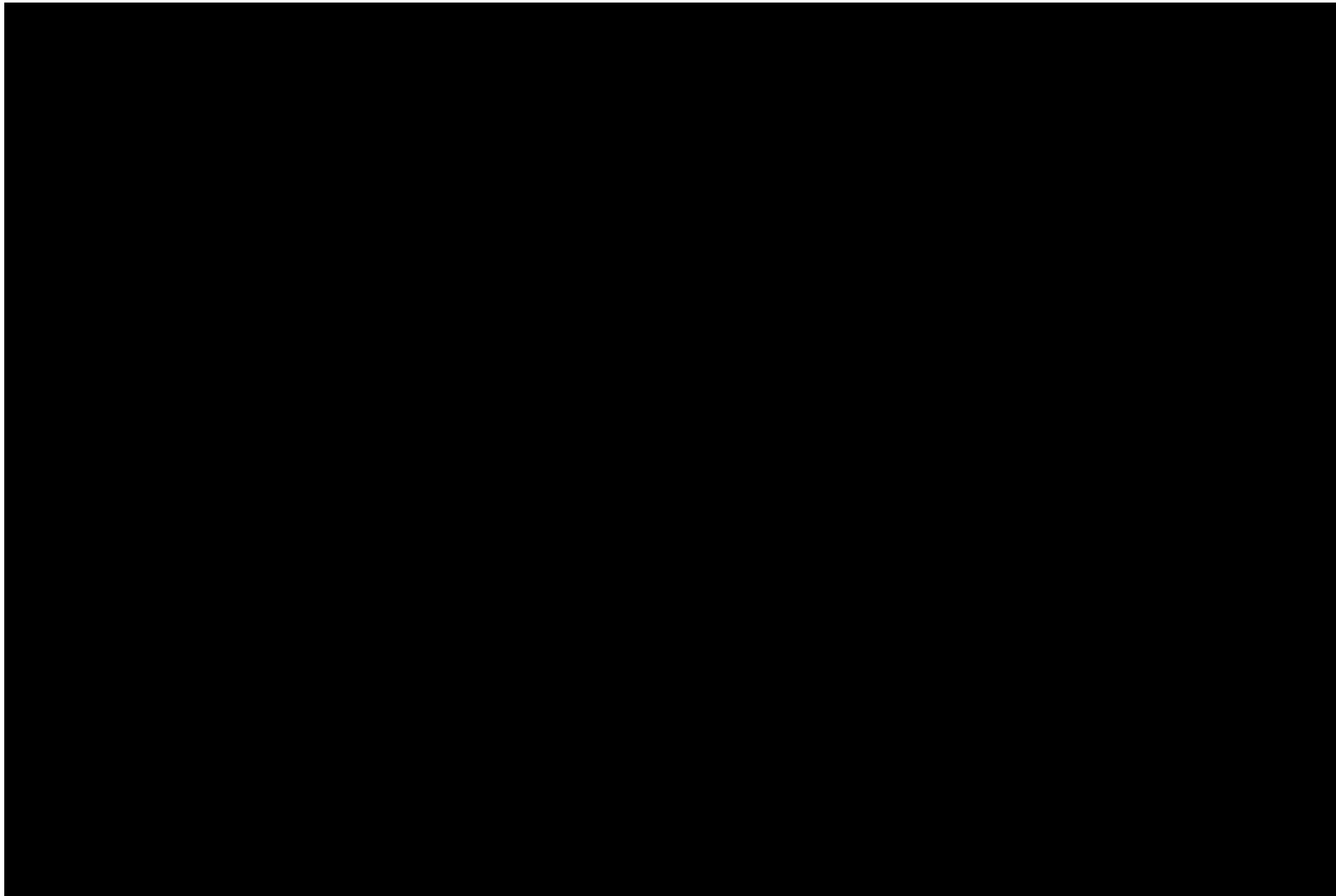


Recap

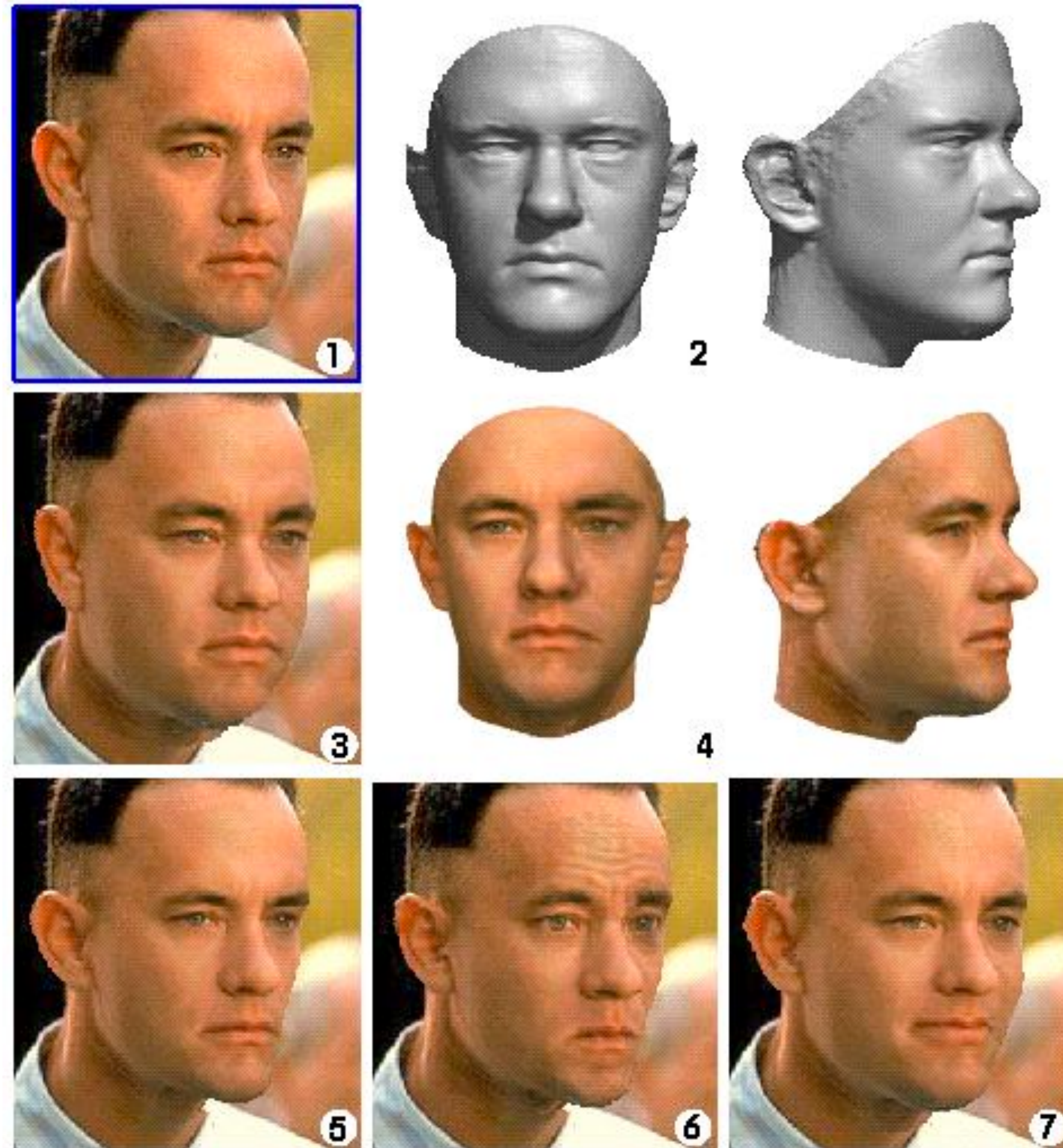
- **Idea that linear interpolation introduces blur**
- **Separation of shape and color**
- **Idea of non-rigid alignment of different images**
 - Applications to medical data
- **Applications, related to**
 - Special effects
 - Face recognition
 - Video frame interpolation
 - MPEG

More morphing madness

- **Gondry's Rolling Stones Video**



Morphable models



<http://gravis.cs.unibas.ch/Sigg99.html>

Morphable models

ORIGINAL



CARICATURE



ORIGINAL



CARICATURE



MORE MALE



FEMALE



SMILE



FROWN



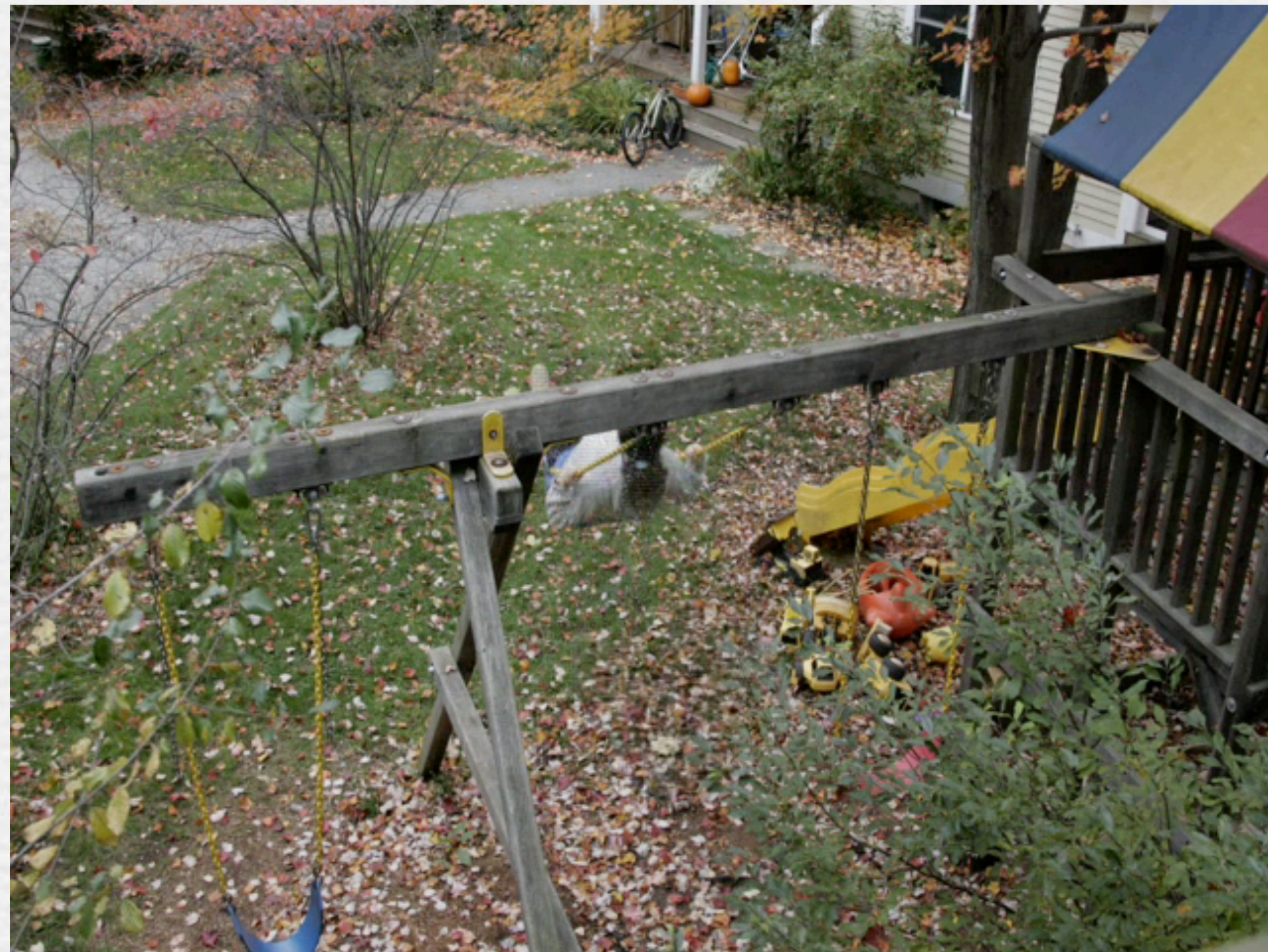
WEIGHT



HOOKED NOSE

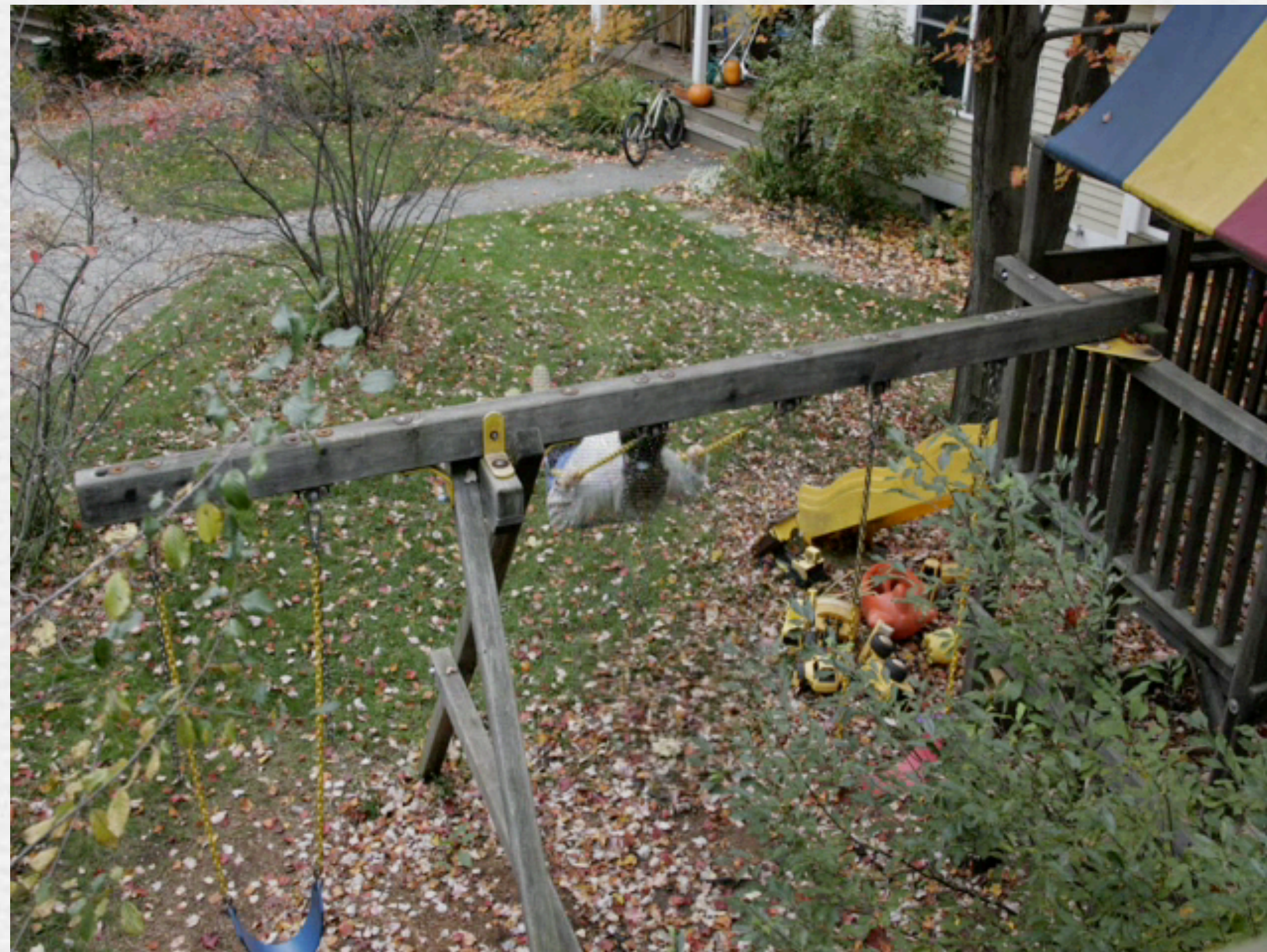
Application: Motion magnification

- ♦ *with Liu, Torralba, Freeman & Adelson [Siggraph 2005]*
- ♦ Analyze motion in video (robust to occlusion)
- ♦ Warp according to magnified motion



Motion magnification

- ♦ *with Liu, Torralba, Freeman & Adelson [Siggraph 2005]*
- ♦ Analyze motion in video (robust to occlusion)
- ♦ Magnify motion that is hard to see



Motion Magnification

Ce Liu

Antonio Torralba

William T. Freeman

Fredo Durand

Edward H. Adelson

Massachusetts Institute of Technology

Computer Science and Artificial Intelligence Laboratory

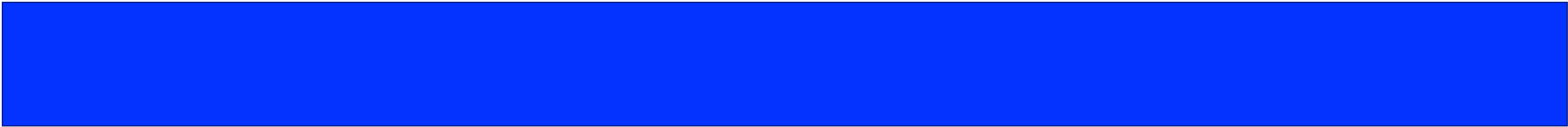


SIGGRAPH2005

The 32nd International Conference on Computer Graphics and Interactive Techniques

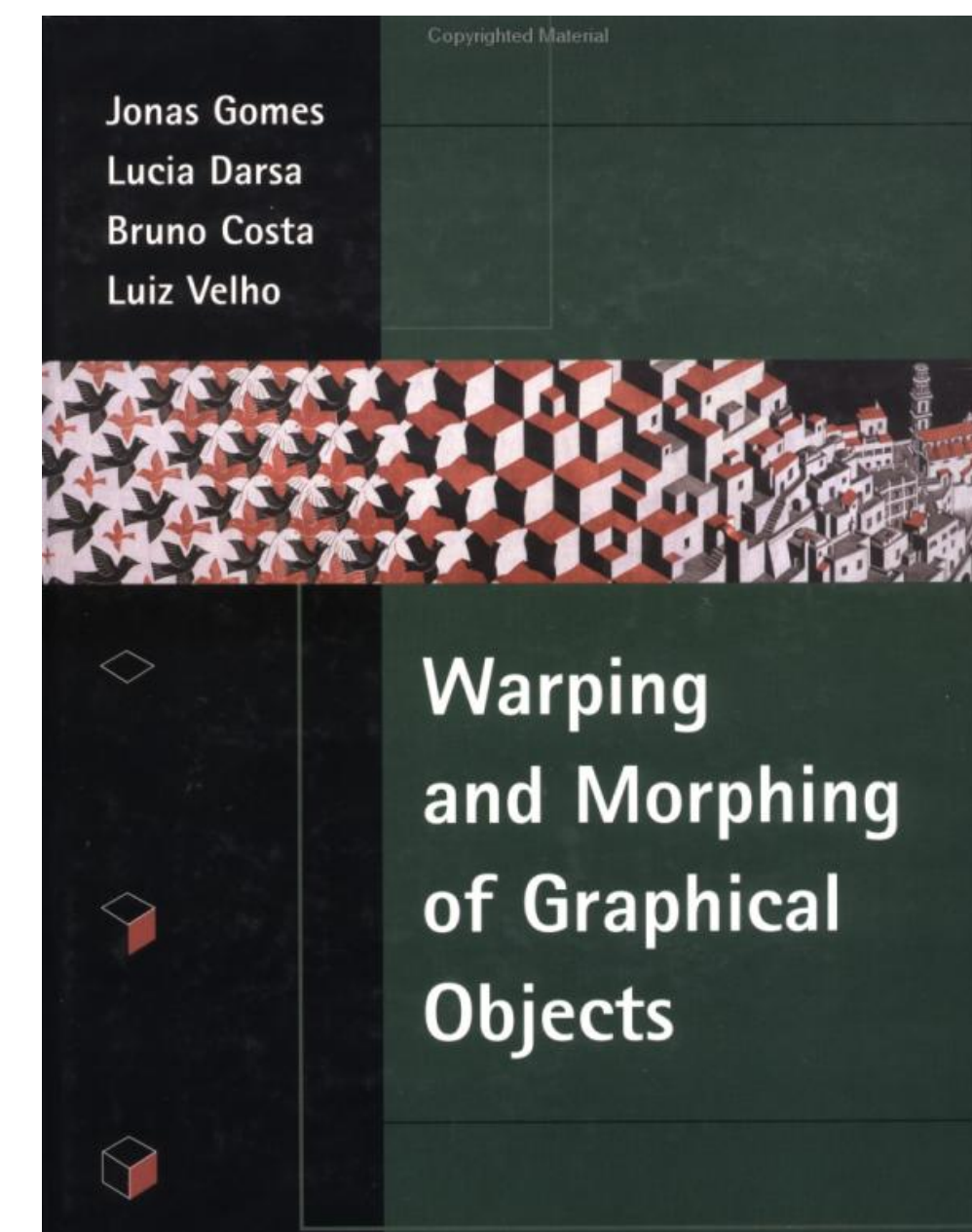
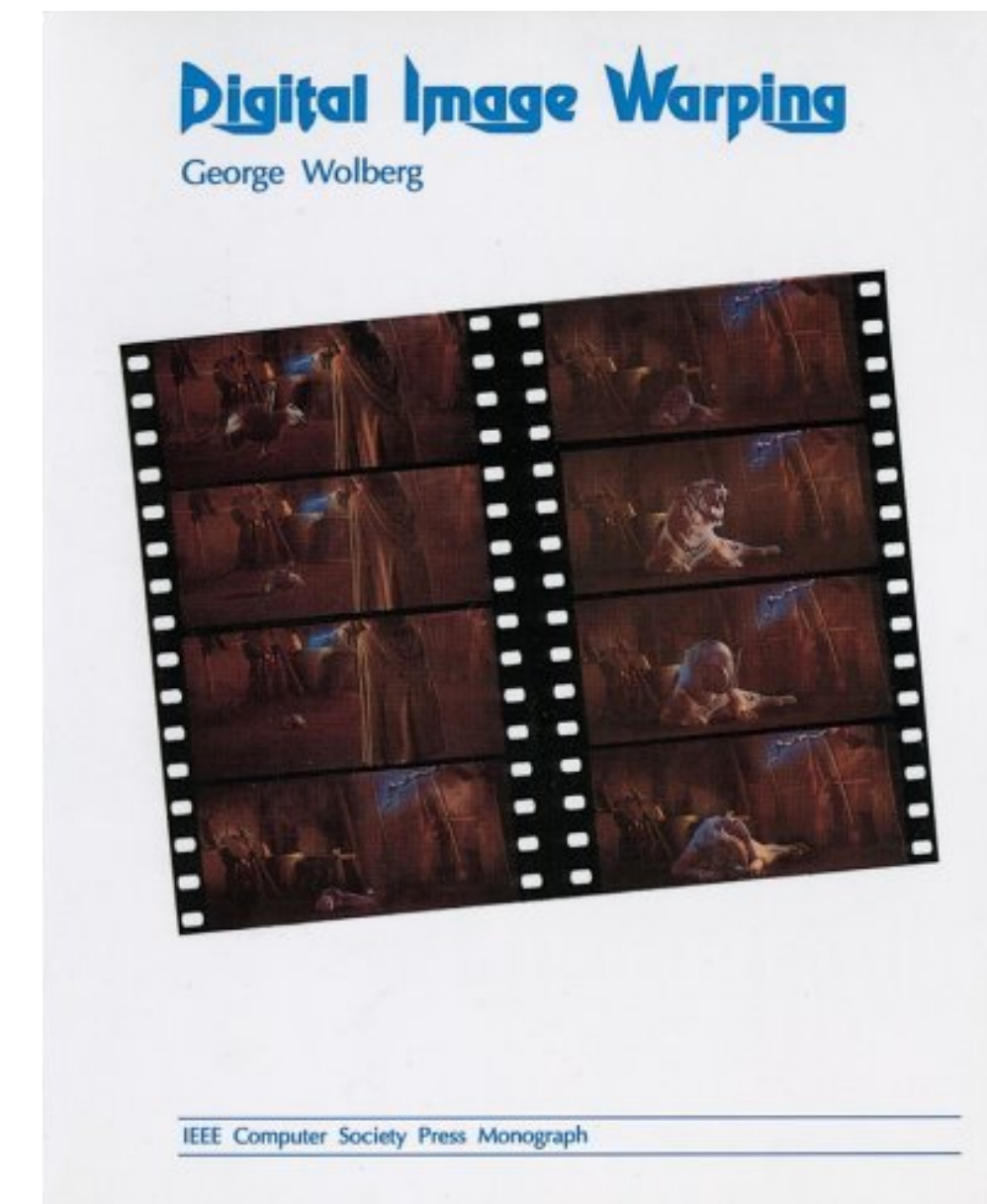


References



Refs

- <http://portal.acm.org/citation.cfm?id=134003&coll=GUIDE&dl=GUIDE&CFID=72901489&CFTOKEN=24335444>
- <http://www.visgraf.impa.br/cgi-bin/morphQuery.cgi?output=html>
- <http://www.cg.tuwien.ac.at/research/ca/mrm/>
- <http://w3.impa.br/~morph/sites.html>
- <http://w3.impa.br/~morph/sig-course/slides.html>
- <http://www.owlnet.rice.edu/~elec539/Projects97/morphjrks/morph.html>
- <http://www.fmrib.ox.ac.uk/~yongyue/thinplate.html>
- http://www.uoguelph.ca/~mwirth/PHD_Chapter4.pdf



Software

- <http://www.morpheussoftware.net/>
- <http://www.debugmode.com/winmorph/>
- http://www.stoik.com/products/morphman/mm1_main.htm
- http://www.creativecow.net/articles/zwar_chris/morph/index.html
- <http://meesoft.logicnet.dk/SmartMorph/>
- <http://www.asahi-net.or.jp/~FX6M-FJMY/mop00e.html>
- <http://morphing-software-review.toptenreviews.com/>
- <http://www.freedownloadscenter.com/Search/morphing.html>

Advanced use of warping

- <http://www.collegehumor.com/video/6705603/north-korean-photoshop-tutorial>