Advanced Image Manipulation

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Recap

- What's wrong with forward mapping?
  - Missing pixels & double pixels
- Will backwards mapping always results in one-to-one pixel coverage?
  - No
- How do we fix this?
  - Resampling – weighted avg of nearby pixels
- How can we solve quantization errors?
  - Spread errors to nearby pixels
- Contrast vs Sharpness
- Contrast vs Saturation

2

Outline

- Image Compositing
- Image Morphing
- Content-aware Image Editing & Image Inpainting

3

Outline

- **Image Compositing**
- Image Morphing
- Content-aware Image Editing & Image Inpainting

4

CG Folks Winning Oscars

Smith Duff (Oscar) Catmull Porter

5

Compositing

- Key issues in computer graphics:
  - Take images from two sources
  - Combine them
- Three approaches
  - Blue screen matting
  - Alpha channel
  - Porter-Duff compositing algebra

6

Image Compositing

- Separate an image into elements
  - Rendered independently
  - Composite together
- Applications
  - Cel animation
  - Chroma-keying
  - Blue-screen matting
- Compositing saves us from re-rendering new images for each new background

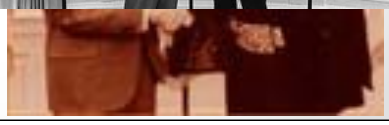


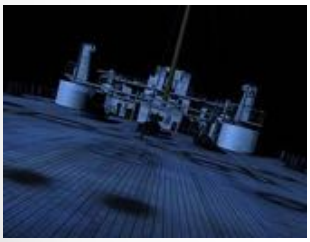
Image Composting Example

Jurassic Park '93

8

Compositing Example




[*Titanic* ; DigitalDomain; vfxhq.com]

Compositing

- Key issues in computer graphics:
  - Take images from two sources
  - Combine them
- Three approaches
  - **Blue screen matting**
  - Alpha channel
  - Porter-Duff compositing algebra

10

Blue Screen Matting

- Photograph object against blue background
  - Q: Why blue?
  - A: We want colors far from skin tones
- Take all non-blue pixels (foreground)
- Add on top of 2nd image
- Problems?:
  - Aliasing (esp. hair)
  - No notion of partial coverage

Binary image mask issues

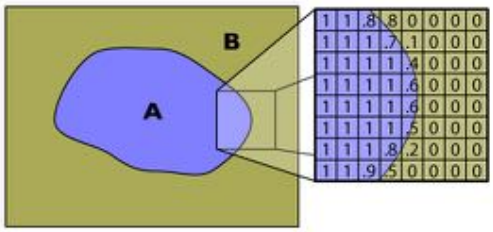
- First idea: store one bit per pixel
  - answers question "is this pixel part of the foreground?"

[Chuang et al. / Corel]

  - causes jaggies similar to point-sampled rasterization
  - same problem, same solution: intermediate values

Partial pixel coverage

- The problem: pixels near boundary are not strictly foreground or background



  - how to represent this simply?
  - interpolate boundary pixels between the fg. and bg. colors

Compositing

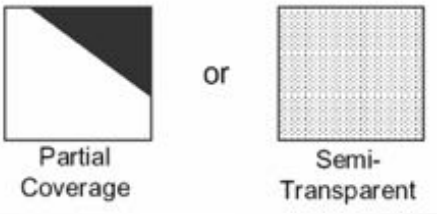
- Key issues in computer graphics:
  - Take images from two sources
  - Combine them
- Three approaches
  - Blue screen matting
  - **Alpha channel (Smith & Catmull)**
  - Porter-Duff compositing algebra

14

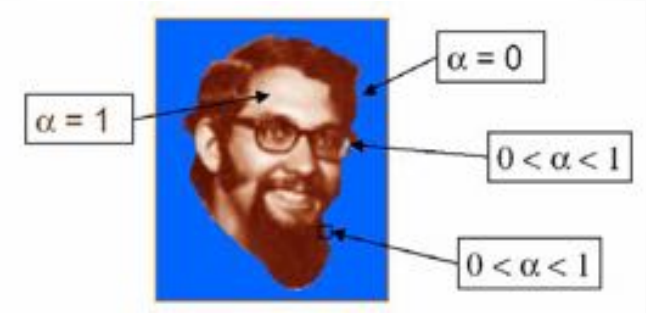
Alpha channel

- Images stored as 32 bits: RGB α
- α represents coverage (0 = transparent, 1 = opaque)
- Simple compositing:
  - OUT = α Foreground + (1- α)Background

- Example: $\alpha = 0.3$



Alpha Channel

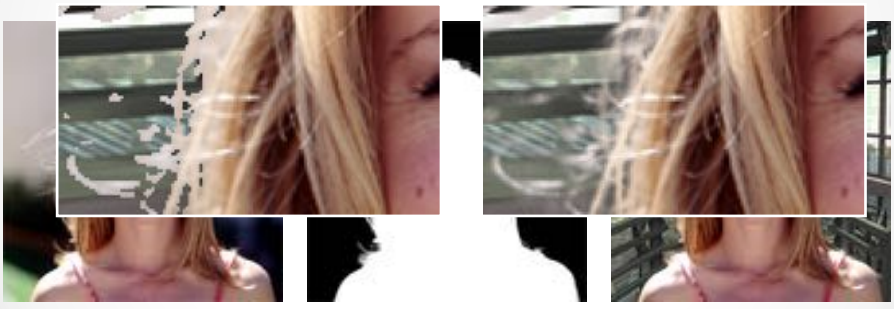


Pixel Storage Convention

- Premultiplication
  - Color C = (r,g,b) with coverage α is often represented at (αr, αg, αb, α)
  - R,G,B values can be displayed directly
  - Simplifies composition algebra (closure)
- What is (α, C) for the following?
  - (0,1,0,1) = ? Full green, full coverage
  - (0, ½, 0, 1) = ? Half green, full coverage
  - (0, ½, 0, ½) = ? Full green, half coverage
  - (0, ½, 0, 0) = ? ??? (No Coverage…)

17

Alpha compositing—example



[Chuang et al. / Corel]

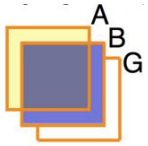
Compositing

- Key issues in computer graphics:
  - Take images from two sources
  - Combine them
- Three approaches
  - Blue screen matting
  - Alpha channel
  - **Porter-Duff compositing algebra**

19

Semi-Transparent Objects

- Suppose we put A over B over background G



- How much of B is blocked by A?

$$(\alpha_A)$$

- How much of B shows through A?

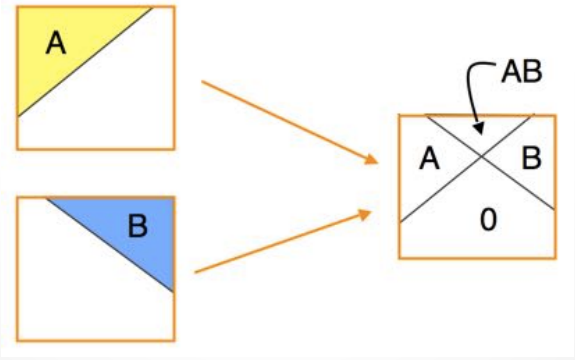
$$(1-\alpha_A)$$

- How much of G shows through both A and B?

$$(1-\alpha_A)(1-\alpha_B)$$

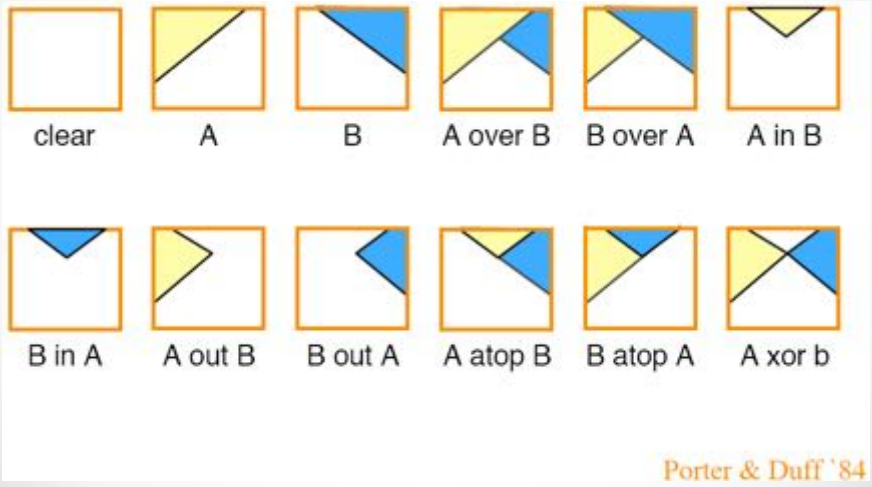
Opaque Coverage

- How do we combine 2 partially covered pixels?
  - 3 possible colors (0, A, B)
  - 4 regions (0, A, B, AB)

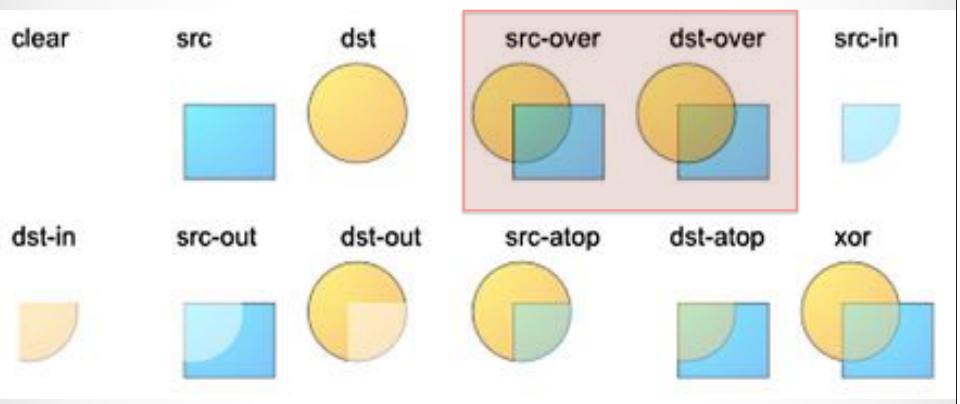


Compositing Algebra

- 12 reasonable combinations



Examples



https://www.w3.org/TR/2013/WD-compositing-1-20130625/#porterduffcompositingoperators

23

Example: C = A over B

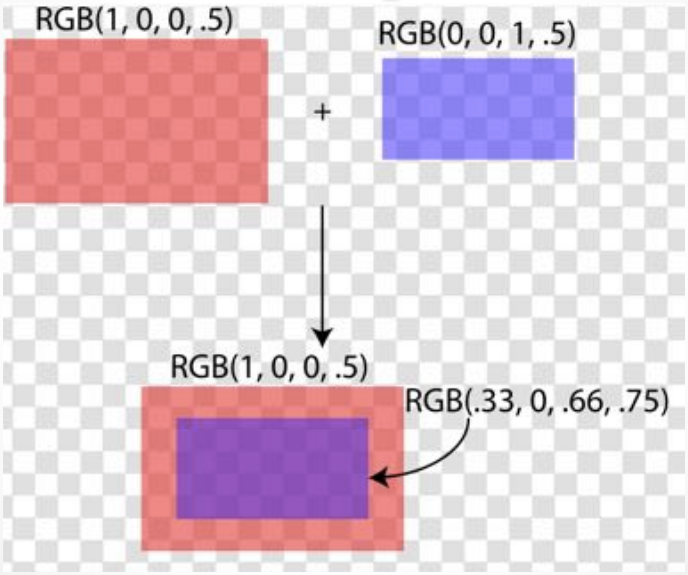
- For colors that are not premultiplied
  - $C = \alpha_A A + (1-\alpha_A)\,\alpha_B B$
  - $\alpha = \alpha_A + (1-\alpha_A)\,\alpha_B$
- For colors that are premultiplied
  - $C' = A' + (1-\alpha_A)\,B'$
  - $\alpha = \alpha_A + (1-\alpha_A)\,\alpha_B$

A over B

Assumption: coverages of A and B are uncorrelated for each pixel

24

Example

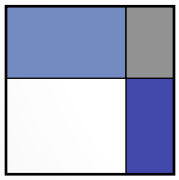


https://www.w3.org

25

Independent coverage assumption

- Why is it reasonable to blend α like a color?
- Simplifying assumption: covered areas are independent
  - that is, uncorrelated in the statistical sense



description	area
$\bar{A} \cap \bar{B}$	$(1-\alpha_A)(1-\alpha_B)$
$A \cap \bar{B}$	$\alpha_A(1-\alpha_B)$
$\bar{A} \cap B$	$(1-\alpha_A)\alpha_B$
$A \cap B$	$\alpha_A\alpha_B$

[Porter & Duff 84]

Independent coverage assumption

- Holds in most but not all cases

- This will cause artifacts
  - but we'll carry on anyway because it is simple and usually works…

Alpha compositing—failures

[Chuang et al. / Corel] [Cornell PCG]

positive correlation:
too much foreground

negative correlation:
too little foreground

Outline

- Image Compositing
- **Image Morphing**
  - Specifying correspondences
  - Warping
  - Blending
- Content-aware Image Editing & Image Inpainting

29

Image Morphing

- Animated transition between two images

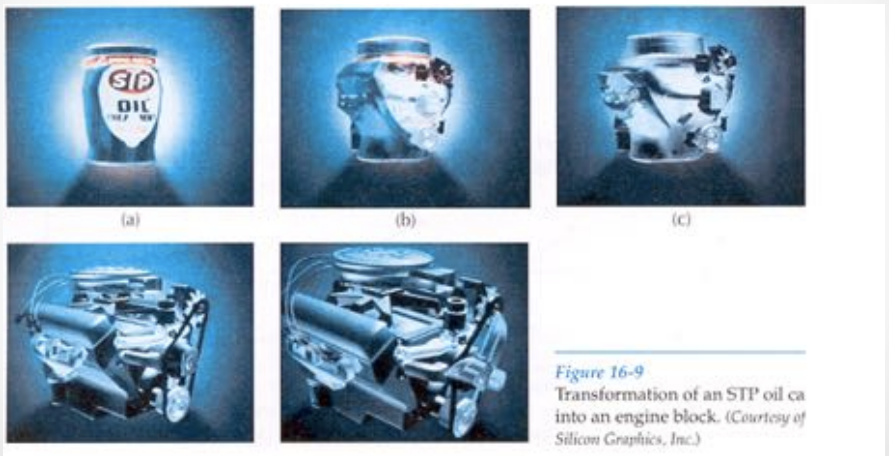


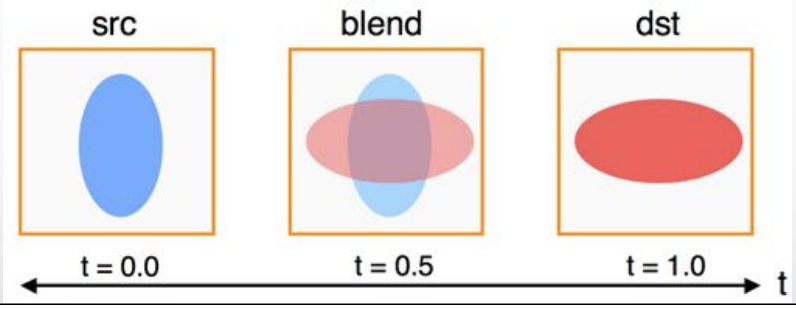
Figure 16-9
Transformation of an STP oil ca into an engine block. *(Courtesy of Silicon Graphics, Inc.)*

H&B Figure 16.9

Cross Dissolve

- Blend image with "over" operator
  - Alpha of bottom image is 1.0
  - Alpha of top images varies from 0.0 to 1.0
    - Over time

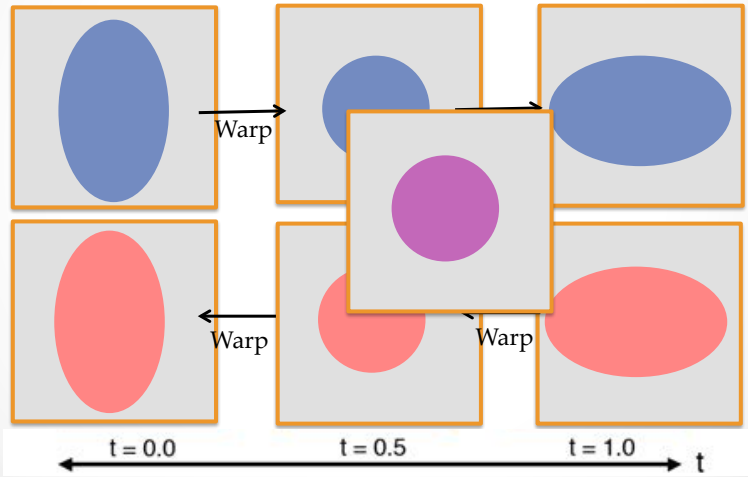
$$blend(i,j) = (1-t)\ src(i,j) + t\ dst(i,j) \quad (0 \le t \le 1)$$



31

Morphing

- Warping, then blending



32

But how to warp…

- We must specify pixel-to-pixel correspondences for each timestep!
  - Artist intensive job

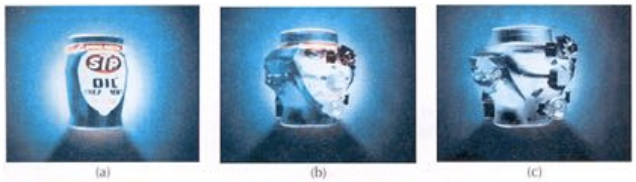


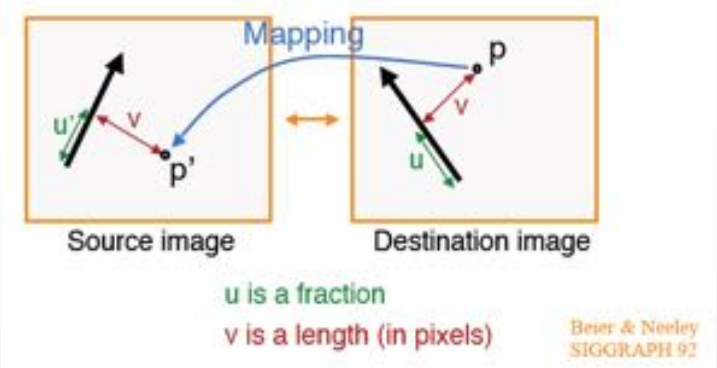
Figure 16-9
Transformation of an STP oil ca into an engine block. *(Courtesy of Silicon Graphics, Inc.)*

H&B Figure 16.9

33

Specifying Warping

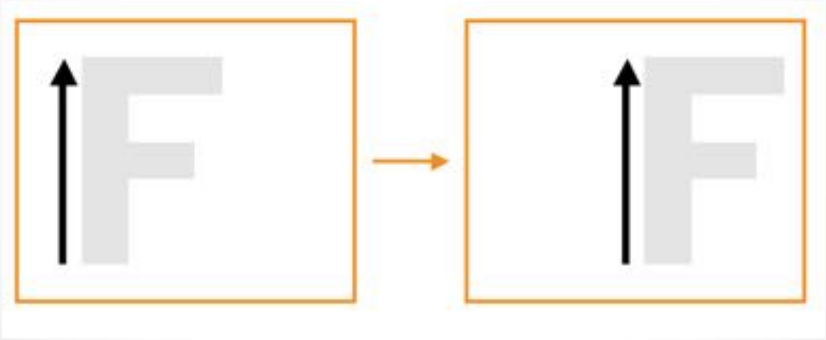
- We can use constructs to make specification easier
  - E.g., Matched pairs of lines (Beies & Neeley)



34

Example

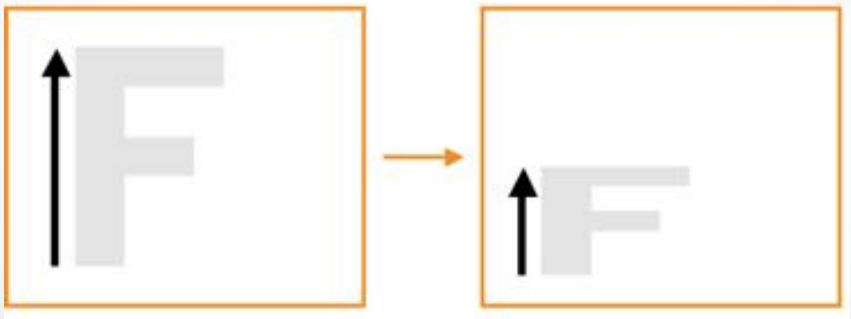
- Shifting line (no scale or rotation)
  - Translation!



35

Example 2

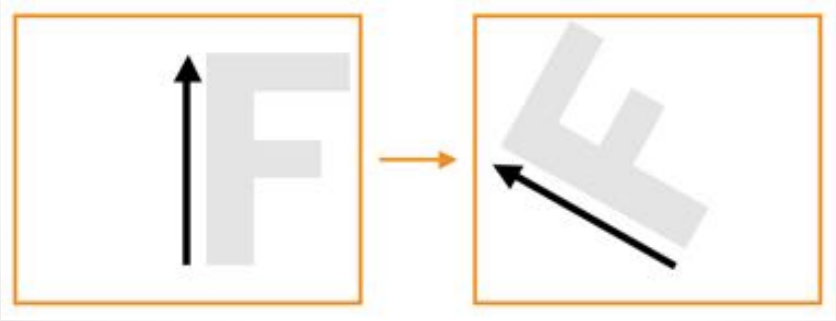
- Shrinking the line:
  - Scaling!



36

Example 3

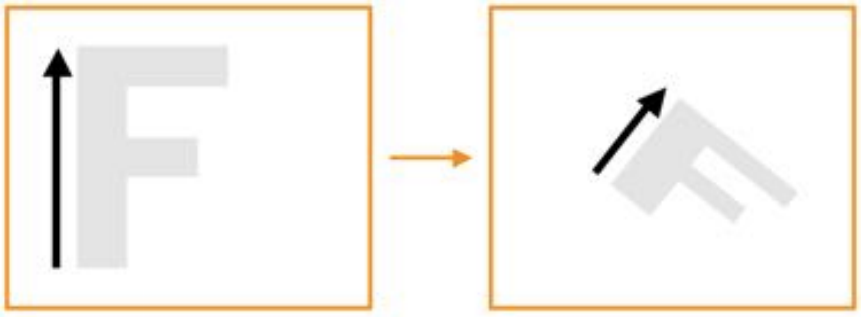
- Rotating the line
  - Rotation!



37

Arbitrary Line Pairs

- General transforms possible

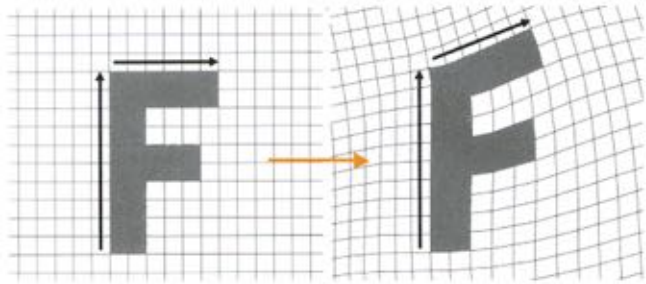


What transformations can't we specify with a line pair?

38

Multiple Line Pairs

- Transformation specified by weighted combination of points

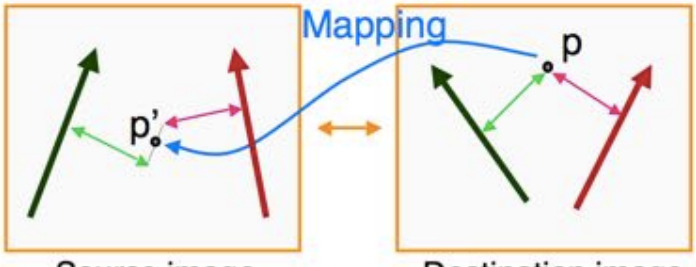


Beier & Neeley, Figure 4

39

Warping: Multiple Pairs

- Use weighted combination of points defined by each pair of corresponding lines



p' is a weighted average

40

Weighted Pairs

- To weight contributions Beier & Neeley use:

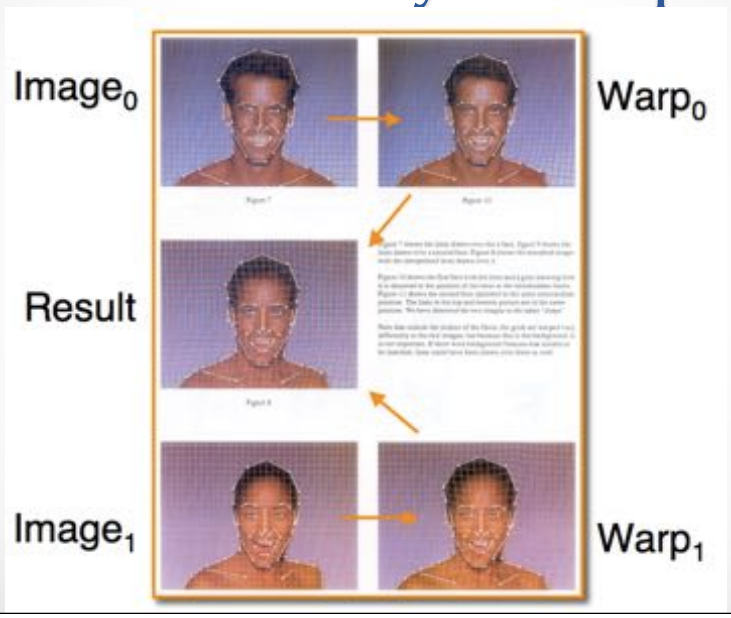
$$weight[i] = \left(\frac{length[i]^p}{a + dist[i]} \right)^b$$

Where:

- *length[i]* is the length of L[i]
- *dist[i]* is the distance from X to L[i]
- *a, b, p* are constants that control the warp

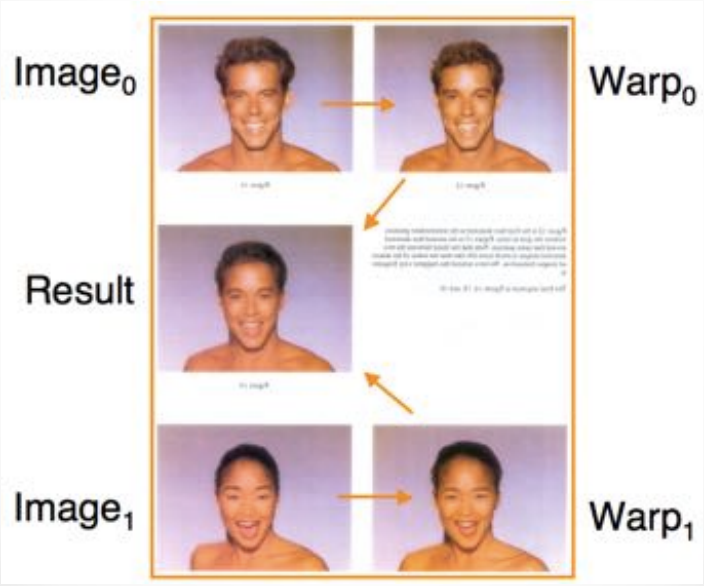
41

Beier & Neely Example



42

Beier & Neely Example



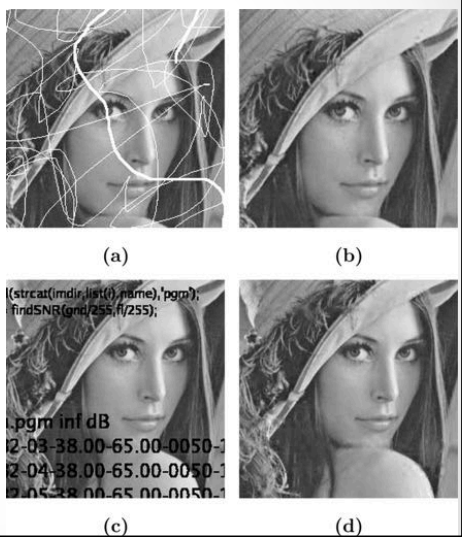
43

Morphing Uses

- Willow - 1988
- Terminator 2 – 1991
- Jackson's Black or White – 1991
  - http://www.youtube.com/watch?v=F2AitTPI5U0

Image Inpainting

- Intelligent Filling in of unknown pixels
- Strategy:
  - Find similar patches elsewhere in same picture



Next Time

- Display Technologies
- Color Theory

46