Image Compositing and Morphing

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Princeton University
C0S 426, Fall 2000

Image Processing

- Quantization
  - Uniform Quantization
  - Random dither
  - Ordered dither
  - Floyd-Steinberg dither
- Pixel operations
  - Add random noise
  - Add luminance
  - Add contrast
  - Add saturation
- Filtering
  - Blur
  - Detect edges
- Warping
  - Scale
  - Rotate
  - Warp
- Combining
  - Composite
  - Morph

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Overview

- Image compositing
  - Blue-screen mattes
  - Alpha channel
  - Porter-Duff compositing algebra
- Image morphing
  - Specifying correspondences
  - Warping
  - Blending

Image Compositing

- Separate an image into “elements”
  - Render independently
  - Composite together
- Applications
  - Cel animation
  - Chroma-keying
  - Blue-screen matting

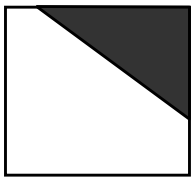
Dobkin meets Elvis

Blue-Screen Matting

- Composite foreground and background images
  - Create background image
  - Create foreground image with blue background
  - Insert non-blue foreground pixels into background

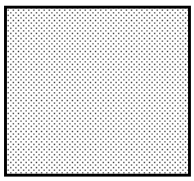
Alpha Channel

- Encodes pixel coverage information
  - $\alpha = 0$: no coverage (or transparent)
  - $\alpha = 1$: full coverage (or opaque)
  - $0 < \alpha < 1$: partial coverage (or semi-transparent)
- Example: $\alpha = 0.3$



Partial Coverage

or



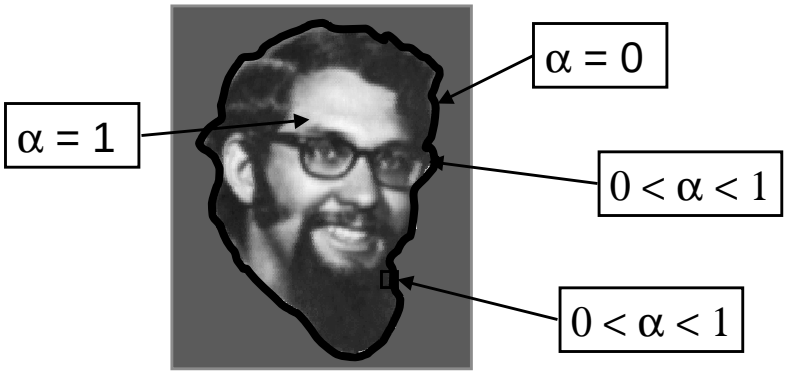
Semi-Transparent

Pixels with Alpha

- Alpha channel convention:
  - (r, g, b, α) represents a pixel that is α covered by the color C = (r/α, g/α, b/α)
    - »Color comonents are premultiplied by α
    - »Can display (r,g,b) values directly
    - »Closure in composition algebra
- What is the meaning of the following?
  - (0, 1, 0, 1) = Full green, full coverage
  - (0, 1/2, 0, 1) = Half green, full coverage
  - (0, 1/2, 0, 1/2) = Full green, half coverage
  - (0, 1/2, 0, 0) = No coverage

Compositing with Alpha

- Controls the linear interpolation of foreground and background pixels when elements are composited



Semi-Transparent Objects

- Suppose we put A over B over background G
  - How much of B is blocked by A?

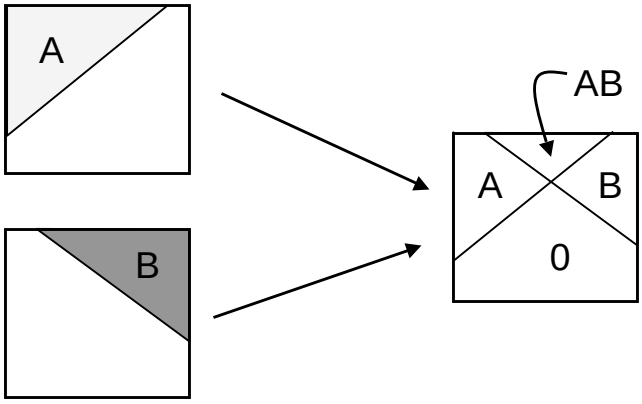
    α_A
  - How much of B shows through A?

    $(1-\alpha_A)$
  - How much of G shows through both A and B?

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

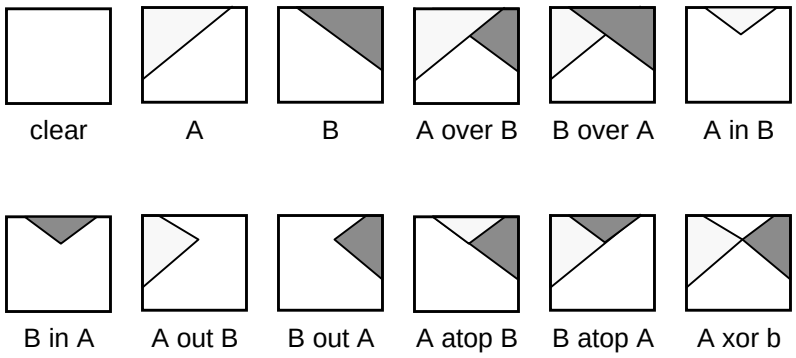
Opaque Objects

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



Composition Algebra

- 12 reasonable combinations



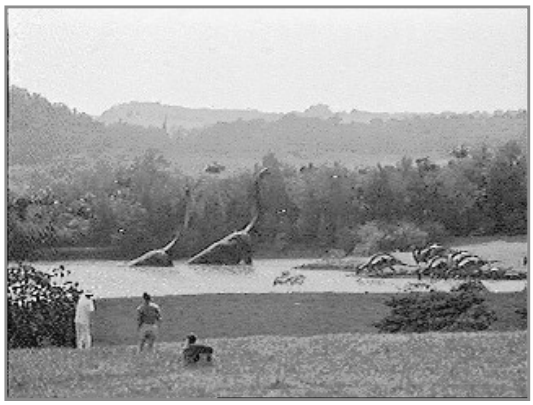
Porter & Duff ‘84

Over Operator

- For C_B and C_F, which are not premultiplied:
  - $C' = \alpha_B(1-\alpha_F)*C_B + \alpha_F*C_F$
  - $\alpha = \alpha_B(1-\alpha_F) + \alpha_F$
- For C'_B and C'_F, which are premultiplied:
  - $C' = (1-\alpha_B)*C'_F + C'_B$
  - $\alpha = \alpha_B(1-\alpha_F) + \alpha_F$

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

Image Composition Example



Jurasic Park

Overview

- Image compositing
  - Blue-screen mattes
  - Alpha channel
  - Porter-Duff compositing algebra
- Image morphing
  - Specifying correspondences
  - Warping
  - Blending

Image Morphing

- Animate transition between two images

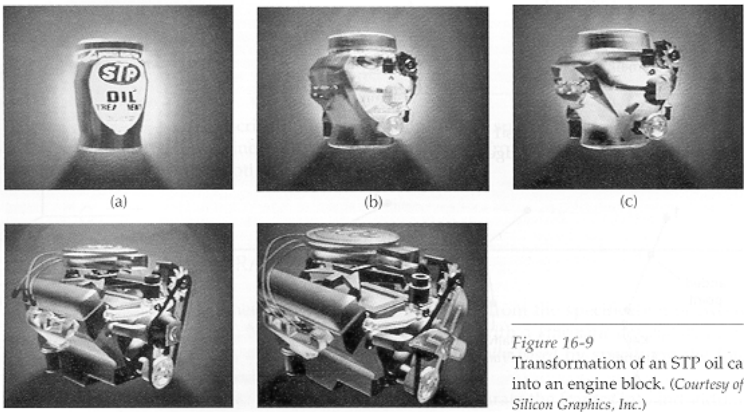


Figure 16-9
Transformation of an STP oil ca into an engine block. (*Courtesy of Silicon Graphics, Inc.*)

H&B Figure 16.9

Cross-Dissolving

- Blend images with “over” operator
  - alpha of bottom image is 1.0
  - alpha of top image varies from 0.0 to 1.0

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

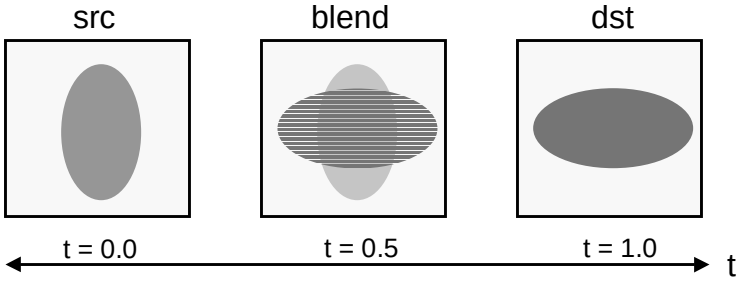


Image Morphing

- Combines warping and cross-dissolving

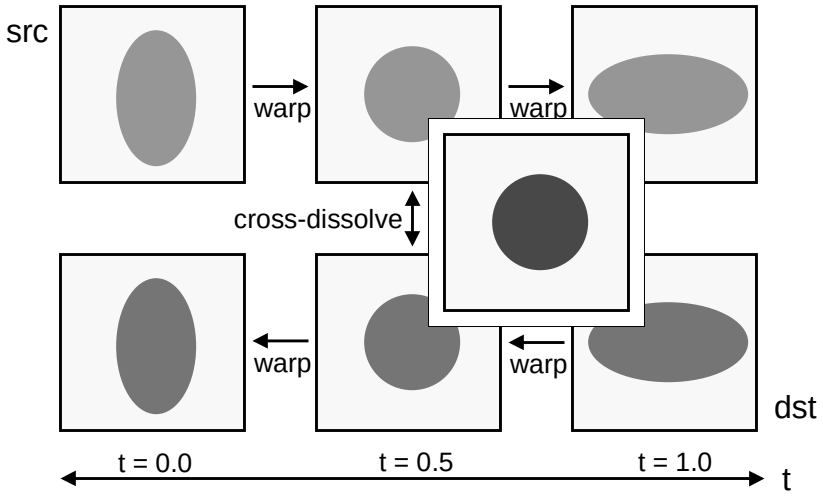


Image Morphing

- The warping step is the hard one
  - Aim to align features in images

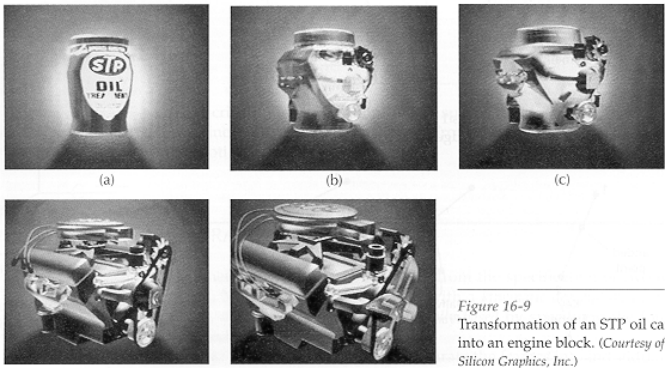
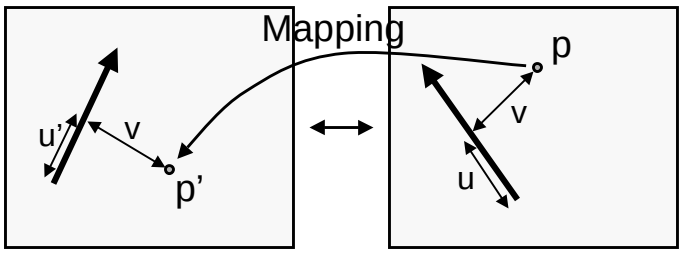


Figure 16-9
Transformation of an STP oil ca into an engine block. (*Courtesy of Silicon Graphics, Inc.*)

H&B Figure 16.9

Feature-Based Warping

- Beier & Neeley use pairs of lines to specify warp
  - Given p in dst image, where is p' in source image?



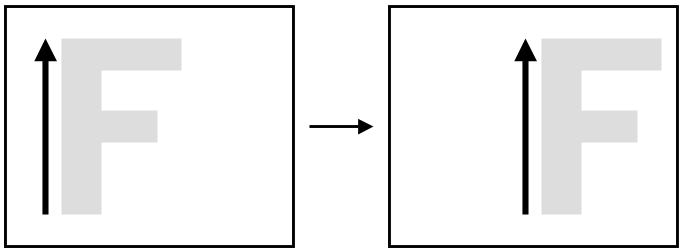
u is a fraction

v is a length (in pixels)

Beier & Neeley
SIGGRAPH 92

Warping with One Line Pair

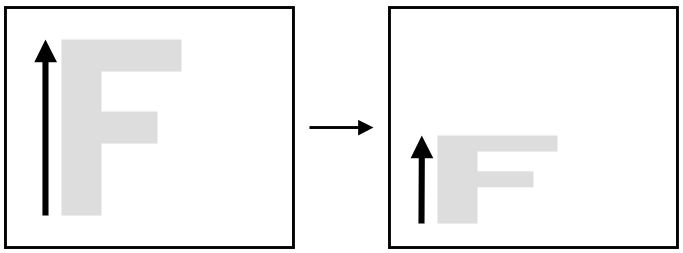
- What happens to the “F”?



Translation!

Warping with One Line Pair

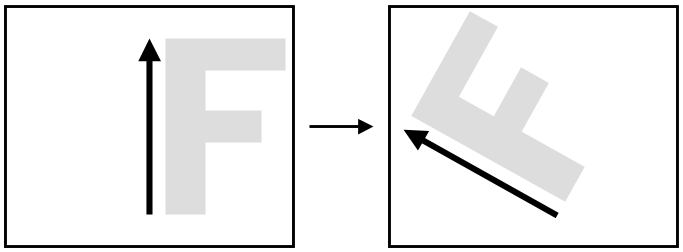
- What happens to the “F”?



Scale!

Warping with One Line Pair

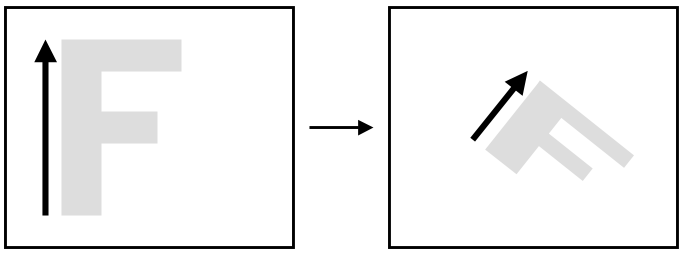
- What happens to the “F”?



Rotation!

Warping with One Line Pair

- What happens to the “F”?

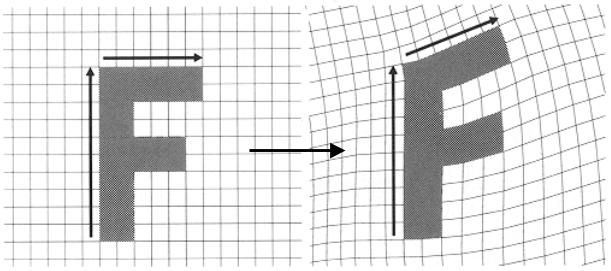


In general, similarity transformations

What types of transformations can’t be specified?

Warping with Multiple Line Pairs

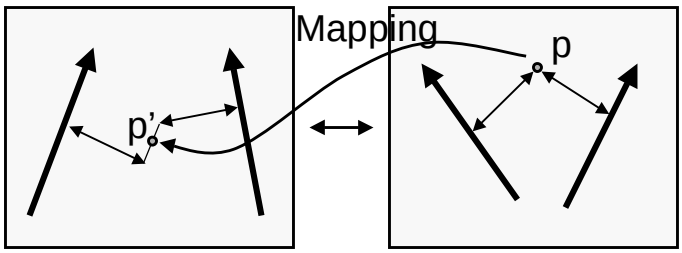
- Use weighted combination of points defined by each pair of corresponding lines



Beier & Neeley, Figure 4

Warping with Multiple Line Pairs

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



p' is a weighted average

Weighting Effect of Each Line Pair

- To weight the contribution of each line pair, 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

Warping Pseudocode

```
WarpImage(Image, L'[…], L[…])
begin
    foreach destination pixel p do
        psum = (0,0)
        wsum = 0
        foreach line L[i] in destination do
            p'[i] = p transformed by (L[i],L'[i])
            psum = psum + p'[i] * weight[i]
            wsum += weight[i]
        end
        p' = psum / wsum
        Result(p) = Image(p')
    end
end
```

Morphing Pseudocode

```
GenerateAnimation(Image0, L0[…], Image1, L1[…])
begin
    foreach intermediate frame time t do
        for i = 1 to number of line pairs do
            L[i] = line t-th of the way from L0 [i] to L1 [i]
        end
        Warp0 = WarpImage(Image0, L0, L)
        Warp1 = WarpImage(Image1, L1, L)
        foreach pixel p in FinalImage do
            Result(p) = (1-t) Warp0 + t Warp1

    end
end
```

Beier & Neeley Example

Image$_0$

Warp$_0$

Result

Image$_1$

Warp$_1$

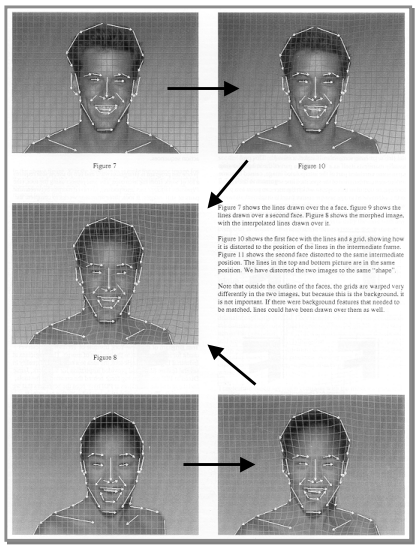


Figure 7

Figure 10

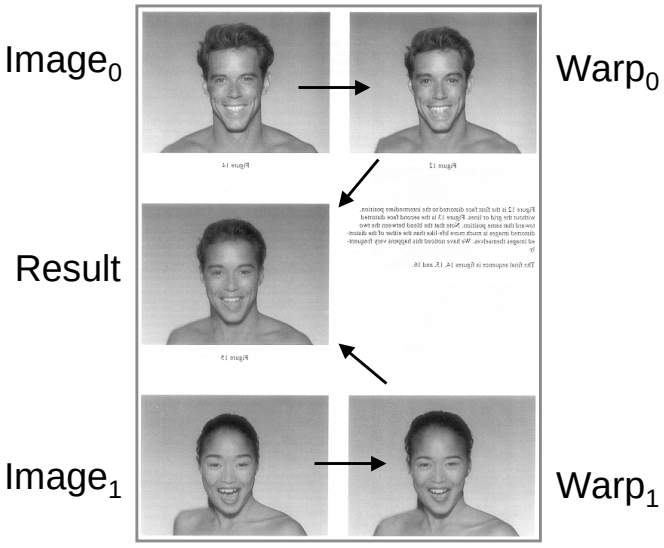
Figure 7 shows the lines drawn over the a face, figure 9 shows the lines drawn over a second face. Figure 8 shows the morphed image, with the interpolated lines drawn over it.

Figure 10 shows the first face with the lines and a grid, showing how it is distorted to the position of the lines in the intermediate frame. Figure 11 shows the second face distorted to the same intermediate position. The lines in the top and bottom picture are in the same position. We have distorted the two images to the same "shape".

Note that outside the outline of the faces, the grids are warped very differently in the two images, but because this is the background, it is not important. If there were background features that needed to be matched, lines could have been drawn over them as well.

Figure 8

Beier & Neeley Example



CS426 Examples

CS426 Class, Fall98

Robert Osada, Fall00

Summary

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  - Alpha channel
  - Porter-Duff compositing algebra
- Image morphing
  - Specifying correspondences
  - Warping
  - Blending

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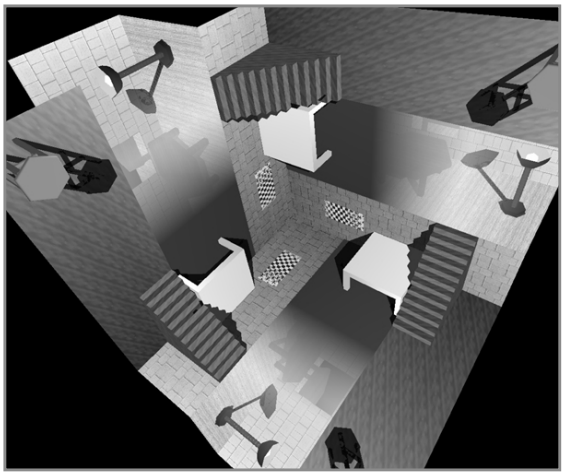
Next Time: 3D Rendering



Misha Kazhdan,
CS426, Fall99