Image Compositing & Morphing

Guest Lecture by Tom Funkhouser
COS 426, Spring 2015
Princeton University
Image Processing Operations I

- Luminance
  - Brightness
  - Contrast
  - Gamma
  - Histogram equalization

- Color
  - Black & white
  - Saturation
  - White balance

- Linear filtering
  - Blur & sharpen
  - Edge detect
  - Convolution

- Non-linear filtering
  - Median
  - Bilateral filter

- Dithering
  - Quantization
  - Ordered dither
  - Floyd-Steinberg
Image Processing Operations II

- Transformation
  - Scale
  - Rotate
  - Warp

- Combining images
  - Composite
  - Morph
  - Computational photography

{ Last time

{ Today
Image Processing Operations II

• Transformation
  ▪ Scale
  ▪ Rotate
  ▪ Warp

{ Last time

Combining images
  ▪ Composite
  ▪ Morph
  ▪ Computational photography

} Today
Image Composition
Image Composition

• Issues:
  ◦ Segmentation of image into layers/regions
  ◦ Blend into single image seamlessly
Image Composition

• Issues:
  - Segmentation of image into layers/regions
    - Blend into single image seamlessly
Image Segmentation

• Chroma keying (blue- or green-screen)
  ◦ Photograph object in front of screen with known color
Image Segmentation

• Specify segmentation by hand
  ◦ Purely manual: rotoscoping (draw matte, every frame)
  ◦ Semi-automatic: graph min-cut (draw a few strokes)
    Separate image regions along minimal cuts (where edges measure differences between adjacent pixels)
Image Segmentation

- Novel methods, e.g. flash matting

Sun et al., 2006
Image Composition

• Issues:
  ◦ Segmentation of image into layers/regions
  ➢ Blend into single image seamlessly
Image Blending

• **Ingredients**
  - Background image
  - Foreground image

• **Goal**
  - Put foreground over background seamlessly
Blending with Alpha Channel

Alpha controls the linear interpolation of foreground and background pixels when elements are composited.

\[ \alpha = 1 \]

\[ 0 < \alpha < 1 \]
Blending with Alpha Channel

• Alpha 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
Blending with Alpha Channel

- Example: $C = A$ Over $B$
  - $C' = \alpha_A A + (1-\alpha_A) \alpha_B B$
  - $\alpha = \alpha_A + (1-\alpha_A) \alpha_B$

Assumption: coverages of $A$ and $B$ are uncorrelated for each pixel
Other Composition Operations

- Ways to combine 2 partially covered pixels?
  - 3 possible colors (0, A, B)
  - 4 regions (0, A, B, AB)
Other Composition Operations

Composition algebra – 12 combinations

\[ C' = F_A \alpha_A A + F_B \alpha_B B \]

<table>
<thead>
<tr>
<th>Operation</th>
<th>( F_A )</th>
<th>( F_B )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>A over B</td>
<td>1</td>
<td>1 - ( \alpha_A )</td>
</tr>
<tr>
<td>B over A</td>
<td>1 - ( \alpha_B )</td>
<td>1</td>
</tr>
<tr>
<td>A in B</td>
<td>( \alpha_B )</td>
<td>0</td>
</tr>
<tr>
<td>B in A</td>
<td>0</td>
<td>( \alpha_A )</td>
</tr>
<tr>
<td>A out B</td>
<td>1 - ( \alpha_B )</td>
<td>0</td>
</tr>
<tr>
<td>B out A</td>
<td>0</td>
<td>1 - ( \alpha_A )</td>
</tr>
<tr>
<td>A atop B</td>
<td>( \alpha_B )</td>
<td>1 - ( \alpha_A )</td>
</tr>
<tr>
<td>B atop A</td>
<td>1 - ( \alpha_B )</td>
<td>( \alpha_A )</td>
</tr>
<tr>
<td>A xor B</td>
<td>1 - ( \alpha_B )</td>
<td>1 - ( \alpha_A )</td>
</tr>
</tbody>
</table>

Porter & Duff `84
Image Composition Example

Stars

Planet

Image Composition Example

Image Composition Example

[BFire out Planet]

[Composite]

COS426 Examples

Einstein and me on the Beach

Darin Sleiter

Kenrick Kin
Beyond simple compositing

- Solve for image samples that follow gradients of source subject to boundary conditions imposed by dest

\[
\begin{align*}
\nabla^2 f &= \nabla \cdot \mathbf{v} \\
f \big|_{\partial \Omega} &= f^* \big|_{\partial \Omega}
\end{align*}
\]
Poisson Image Blending

sources

destinations

cloning

seamless cloning
Poisson Image Blending
Poisson Image Blending

http://www.csie.ntu.edu.tw/~r00944002/CPHW2/result.htm
Digital Image Processing

- Changing intensity/color
  - Linear: scale, offset, etc.
  - Nonlinear: gamma, saturation, etc.
  - Add random noise

- Filtering over neighborhoods
  - Blur
  - Detect edges
  - Sharpen
  - Emboss
  - Median

- Moving image locations
  - Scale
  - Rotate
  - Warp

- Combining images
  - Composite
  - Morph

- Quantization

- Spatial / intensity tradeoff
  - Dithering
Image Morphing

- Animate transition between two images

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

\[
\text{blend}(i,j) = (1-t) \, \text{src}(i,j) + t \, \text{dst}(i,j) \quad (0 \leq t \leq 1)
\]

\[
\begin{align*}
\text{src} & \quad \text{t = 0.0} \\
\text{blend} & \quad \text{t = 0.5} \\
\text{dst} & \quad \text{t = 1.0}
\end{align*}
\]

\( t \)
Image Morphing

- Combines warping and cross-dissolving

\[ \text{src} \rightarrow \text{warp} \rightarrow \text{dst} \]
\[ \text{cross-dissolve} \]

\[ t = 0.0 \rightarrow t = 0.5 \rightarrow t = 1.0 \]
Figure 7 shows the lines drawn over the face. Figure 8 shows the lines drawn over a second face. Figure 9 shows the warped 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 face in the intermediate frame. Figure 11 shows the second face distorted to the same intermediate pose. 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.
Beier & Neeley Example

Image_0 → Warp_0 → Result → Image_1 → Warp_1
Beier & Neeley Example

Black or White, Michael Jackson
Line Correspondence Mappings

- Beier & Neeley use pairs of lines to specify 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
    end
    Result(p) = Resample(p’)
end
end
Morphing Pseudocode

GenerateAnimation(Image_0, L_0[...], Image_1, L_1[...])
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 L_0 [i] to L_1 [i]
        end
        Warp_0 = WarpImage(Image_0, L_0, L)
        Warp_1 = WarpImage(Image_1, L_1, L)
        foreach pixel p in FinalImage do
            Result(p) = (1-t) Warp_0 + t Warp_1
        end
    end
end
COS426 Example

Amy Ousterhout
COS426 Examples

ckctwo

Jon Beyer
COS426 Examples from Last Year

Sam Payne

Matt Matl
COS426 Examples from Last Year
Image Composition Applications

- Computational photography: enable new photographic effects that inherently use multiple images + computation + composition
Image Composition Applications

- Extended depth-of-field
Image Composition Applications

- High dynamic range images
Image Composition Applications

• High dynamic range images
Image Composition Applications

- Flash / No flash
Image Composition Applications

- Stoboscopic images
Image Composition Applications

- Photo montage
Image Composition Applications

• Photo montage
Image Composition Applications

- Removing people
Scene Completion Using Millions of Photographs

James Hays and Alexei A. Efros

SIGGRAPH 2007

Slides by J. Hays and A. Efros
Texture synthesis result
Image Completion

Hays et al. SIGGRAPH 07
Image Completion

2.3 Million unique images from Flickr
Scene Completion Result

Hays et al. SIGGRAPH 07
Image Completion Algorithm

Input image → Scene Descriptor → Image Collection

Mosaicing

20 completions

200 matches
Image Completion
... 200 best matches

Hays et al. SIGGRAPH 07
Image Completion
Image Completion Result
Image Completion Results
Summary

• Image compositing
  ◦ Alpha channel
  ◦ Porter-Duff compositing algebra

• Image morphing
  ◦ Warping
  ◦ Compositing

• Computational photography
Next Time: 3D Modeling

Hoppe