Matting

15-463: Rendering and Image Processing
Alexei Efros

...with many slides from Kyros Kutulakos

Today
Catch up from last time
  • Video Textures for human actors (“Do as I do”)

Blue Screen Matting

Environment Matting
How does Superman fly?

Super-human powers?
OR
Image Matting and Compositing?

“Pulling a Matte”

Problem Definition:
- The separation of an image $C$ into
  - A foreground object image $C_o$,
  - a background image $C_b$,
  - and an alpha matte $\alpha$
- $C_o$ and $\alpha$ can then be used to composite the foreground object into a different image

Hard problem
- Even if alpha is binary, this is hard to do automatically (image segmentation problem)
- For movies/TV, manual segmentation of each frame is infeasible
- Need to make a simplifying assumption…
Blue Screen

Blue Screen matting

Most common form of matting in TV studios & movies

Petros Vlahos invented blue screen matting in the 50s. His Ultimatte® is still the most popular equipment. He won an Oscar for lifetime achievement.

A form of background subtraction:
- Need a known background
- Compute alpha as $\text{SSD}(C,C_b) > \text{threshold}$
  - Or use Vlahos' formula: $\alpha = 1 - p_1(B - p_2G)$
- Hope that foreground object doesn’t look like background
  - no blue ties!
- Why blue?
- Why uniform?
The Ultimatte

Blue screen for superman?
Semi-transparent mattes

What we really want is to obtain a true alpha matte, which involves semi-transparency
- Alpha between 0 and 1

Matting Problem: Mathematical Definition

For every pixel in the composite image,

given
- backing color $C_k = [R_k, G_k, B_k]$, and
- composite pixel color $C = [R, G, B]$

compute
- foreground pixel color $C_0 = [R_0, G_0, B_0, \alpha_0]$ ( = $[\alpha_0 R_0, \alpha_0 G_0, \alpha_0 B_0]$ ) such that

The matting equation

$$C = C_0 + (1 - \alpha_0) C_k$$
Why is general matting hard?

Matting Equation:
\[ C = C_o + (1 - \alpha_o) C_k \]

Solution #1: No Blue!

Matting Equation:
\[ C = C_o + (1 - \alpha_o) C_k \]

- If we know that the foreground contains no blue, we have \( B_o = 0 \)
- This leaves us with 3 equations and 3 unknowns, which has exactly one solution

Main difficulty:
\[
\begin{align*}
R &= \alpha_o R_k + (1 - \alpha_o) R_b \quad \text{← 3. Solve for } R_o \\
G &= \alpha_o G_k + (1 - \alpha_o) G_b \quad \text{← 2. Solve for } G_o \\
B &= B_k - \alpha_o B_b \quad \text{← 1. Solve for } \alpha_o
\end{align*}
\]
Solution #2: Gray or Flesh

Matting Equation:

\[ C = C_o + (1 - \alpha_o) C_k \]

- If we know that the foreground contains gray, that means that \( R_o = B_o = G_o \)
- This leaves us with 3 equations and 2 unknowns

---

Triangulation Matting (Smith & Blinn)

Matting Equation:

\[ C = C_o + (1 - \alpha_o) C_k \]

- Instead of reducing the number of unknowns, we could attempt to increase the number of equations
- One way to do this is to photograph an object of interest in front of two known but distinct backgrounds

- Equations: 6 (3 for each composite)
- Unknowns: 4
- Since each pixel is processed independently, the backgrounds don’t need to be a constant backing color
The Algorithm

For every pixel $p$ in the composite image, given

- backing color $C_{k1} = [R_{k1}, G_{k1}, B_{k1}]$ at $p$,
- backing color $C_{k2} = [R_{k2}, G_{k2}, B_{k2}]$ at $p$,
- composite pixel color $C_1 = [R_1, G_1, B_1]$ at $p$, and
- composite pixel color $C_2 = [R_2, G_2, B_2]$ at $p$,

solve the system of 6 equations

\[
\begin{align*}
R_1 &= \alpha_o R_o + (1 - \alpha_o) R_{k1} \\
G_1 &= \alpha_o G_o + (1 - \alpha_o) G_{k1} \\
B_1 &= \alpha_o B_o + (1 - \alpha_o) B_{k1} \\
R_2 &= \alpha_o R_o + (1 - \alpha_o) R_{k2} \\
G_2 &= \alpha_o G_o + (1 - \alpha_o) G_{k2} \\
B_2 &= \alpha_o B_o + (1 - \alpha_o) B_{k2}
\end{align*}
\]

for unknowns $R_o, G_o, B_o, \alpha_o$

Triangulation Matting Examples

From Smith & Blinn’s SIGGRAPH’96 paper
More Examples

More examples
Problems with Matting

Images do not look realistic
Lack of Refracted Light
Lack of Reflected Light

**Solution:**
Modify the Matting Equation

---

Environment Matting and Compositing

---

slides by Jay Hetler

Douglas E. Zongker ~ Dawn M. Werner ~ Brian Curless ~ David H. Salsin
Environment Matting Equation

\[ C = F + (1 - \alpha)B + \Phi \]

- \( C \) \sim Color
- \( F \) \sim Foreground color
- \( B \) \sim Background color
- \( \alpha \) \sim Amount of light that passes through the foreground
- \( \Phi \) \sim Contribution of light from Environment that travels through the object

Explanation of \( \Phi \)

\[ \Phi = \sum_{i=1}^{m} \int R_i(x) T_i(x) dx \]

- \( R \) – reflectance image
- \( T \) – Texture image
Performance

Calibration
Matting: 10-20 minutes extraction time for each texture map (Pentium II 400Mhz)
Compositing: 4-40 frames per second
Real-Time?
How much better is Environment Matting?

Alpha Matte  Environment Matte  Photograph

How much better is Environment Matting?

Alpha Matte  Environment Matte  Photograph
Movies!