5. Image Compositing

Reading

Highly recommended:

- Thomas Porter and Tom Duff, Compositing digital images. *Computer Graphics* (SIGGRAPH '84) 18(3), 253-259.

Optional:

- Angel, 10.8.1–10.8.2.
- Foley *et al.*., Section 17.6
- Neider *et al.*., Chapter 7

Outline of lecture

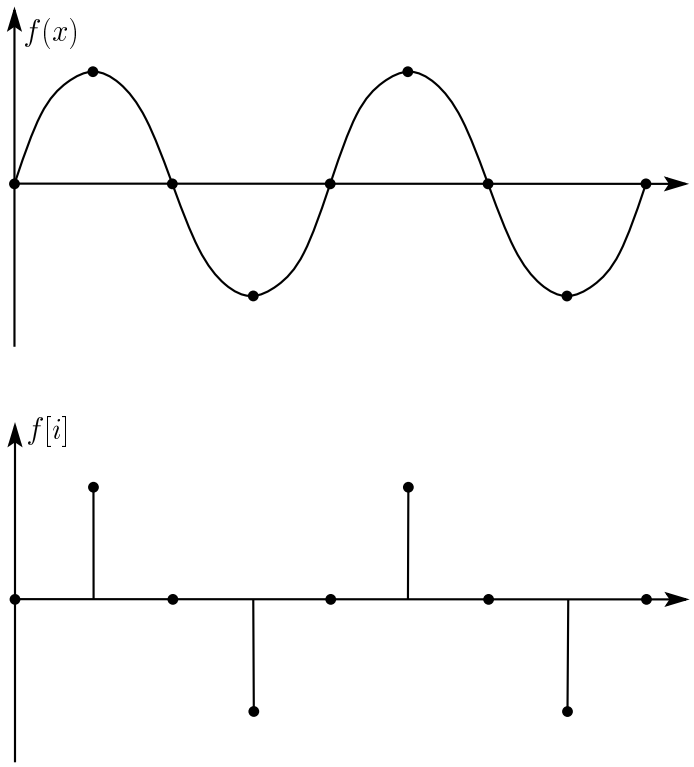
- Aliasing and anti-aliasing
- Motivation for image compositing
- The alpha channel
- Deriving the compositing algebra
- The various compositing operators
- Compositing arithmetic

Aliasing

Consider a continuous function $f(x)$. Now sample it at intervals Δ to give $f[i] = f(i\Delta)$.

Q: How well does $f[i]$ approximate $f(x)$?

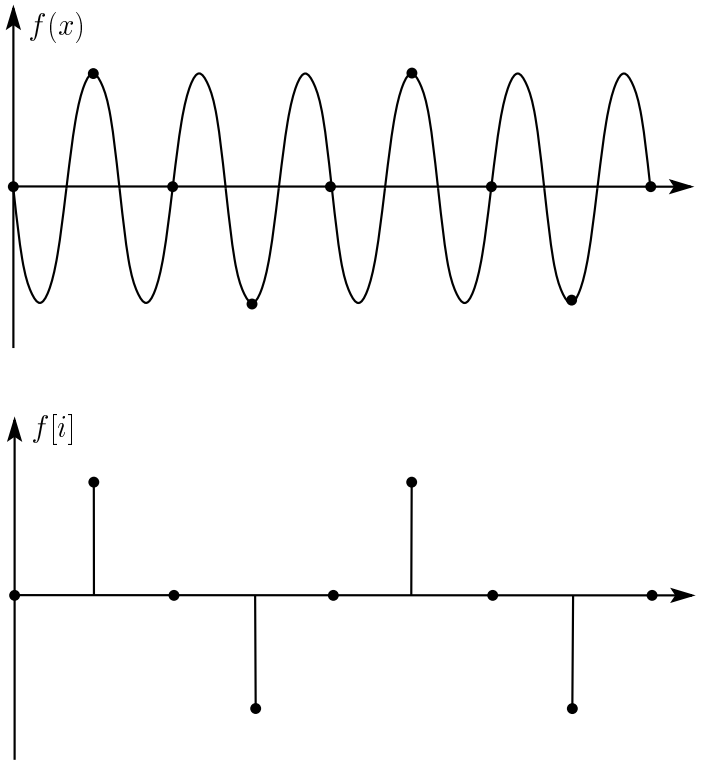
Consider sampling a sinusoid:



In this case, the sinusoid is reasonably well approximated by the samples.

Aliasing, cont'd

Now consider sampling a higher frequency sinusoid



We get the exact same samples, so we seem to be approximating the first lower frequency sinusoid again.

We say that, after sampling, the higher frequency sinusoid has taken on a new "alias", i.e., changed its identity to be a lower frequency sinusoid.

Practical examples of aliasing

Rapidly varying signal:

Drawing a polygon into the frame buffer:

Temporal aliasing:

Anti-aliasing

Q: How do we avoid aliasing artifacts?

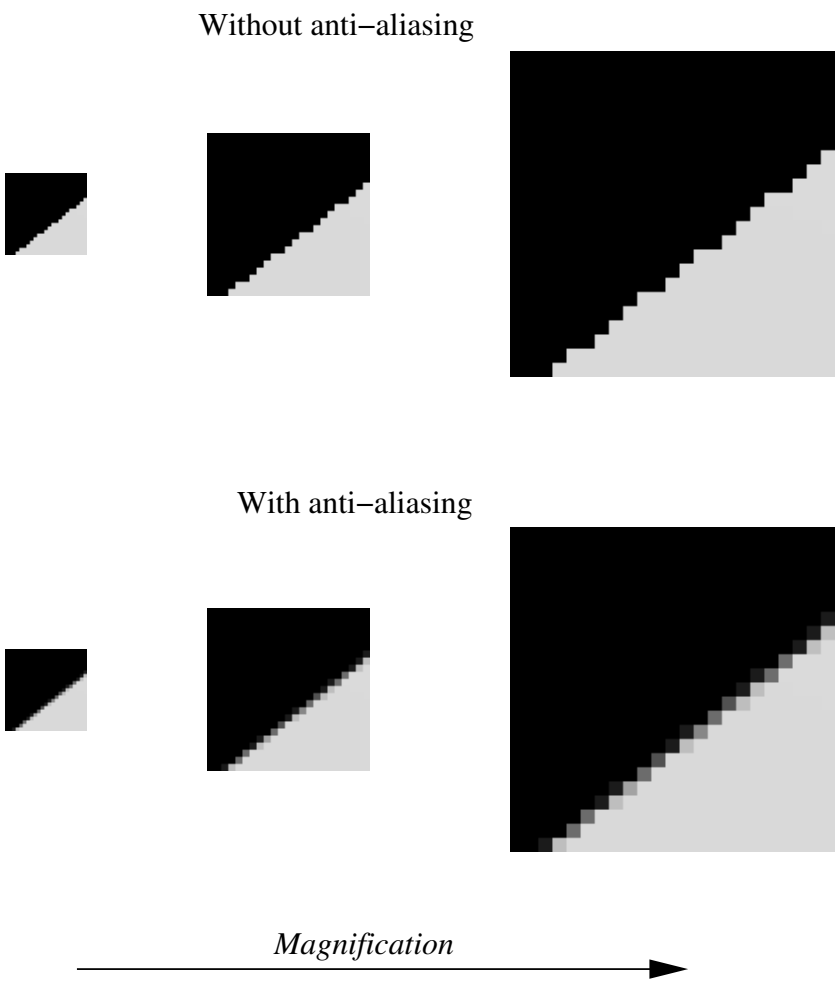
1. Sampling:

2. Filtering:

3. Combination:

Example - polygon revisited:

Polygon anti-aliasing



Q:What about temporal aliasing?

Motivation for image compositing

Often, small programs work better than big ones:

- Example: Unix

The same is true for rendering a picture:

- Want different small programs for different objects
- Small errors should not force "recompilation" of entire image

Motivation, cont.

Therefore, you want to separate an image into "elements":

- Rendered independently
- "Composited" together

Each element has its own "matte" with coverage information.

Goals:

- Do not want to induce aliasing:
  want to retain soft edges in elements
- Want to exploit associativity, allowing composites in any order
- Want to do dissolves and fades

The "alpha" channel

We encode the matte (or coverage) information in a separate channel, called "alpha":

$$\begin{array}{rl} \alpha = 0 & \text{no coverage} \\ \alpha = 1 & \text{full coverage} \\ 0 < \alpha < 1 & \text{partial coverage} \end{array}$$

The alpha will control the linear interpolation of foreground and background colors when one element is placed over another.

Relationship between alpha and RGB:

- Alpha computed at same time
- Alpha resolution needs to be comparable
- Alpha treated in almost exactly the same way

The meaning of alpha

Q: How do we express a pixel that is half covered by a full red object?

Porter-Duff solution: Use *pre-multiplied* value in the color component:

The meaning of alpha, cont.

In general, (r, g, b, α) indicates a pixel that is α covered by the color $(r/\alpha,\ g/\alpha,\ b/\alpha)$.

This convention allows you to draw the (r, g, b) components directly and see antialiased edges.

Q: What is the meaning of the values:

- $(0, 0, 0, 1)$?
- $(0, 0, 0, 0)$?
- $(1, 1, 1, 1/2)$?

The compositing algebra: Assumptions

We now want to start mixing images together, based on alpha.

We do not have exact coverage information in each pixel: just overall alpha.

So we need to make some assumptions.

We'll consider two cases:

1. The overlap of two semi-transparent objects like haze
2. The overlap of two opaque hard-edged elements

Case 1: Semi-transparent objects

Let α_A and α_B be the opacities of A and B.

Suppose we put A and B over a background G.

Questions:

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

- How much of G is blocked by A but passed by B?

- How much of G is blocked by B but passed by A?

- How much of G is blocked by A and B?

Case 2: Opaque objects

Let α_A and α_B be the coverages of two opaque objects A and B within a pixel.

So A divides pixel into subpixels areas of ratio $\alpha_A : 1 - \alpha_A$.

Compositing assumption:

No correlation between A and B.

So A divides B into areas of ratio:

Case 2, cont.

Q: What are the resulting areas of:

- $\not{A} \cap \not{B}$:
- $A \cap \not{B}$:
- $\not{A} \cap B$:
- $A \cap B$:

Q: When do these assumptions break down?

Compositing operators

Two pictures divide a pixel into 4 subareas:

Name	*Description*	*Choices*
0	$\not A \cap \not B$	0
A	$A \cap \not B$	$0, A$
B	$\not A \cap B$	$0, B$
AB	$A \cap B$	$0, A, B$

Each of these areas can be filled in with different choices, listed above.

Q: How many choices in all?

Compositing operators, cont.

Let's look at the 12 choices for filling in regions 0, A, B, and AB:

1. $(0, 0, 0, 0)$:
2. $(0, A, 0, A)$:
3. $(0, 0, B, B)$:
4. $(0, A, B, A)$:
5. $(0, A, B, B)$:
6. $(0, 0, 0, A)$:
7. $(0, 0, 0, B)$:
8. $(0, A, 0, 0)$:
9. $(0, 0, B, 0)$:
10. $(0, 0, B, A)$:
11. $(0, A, 0, B)$:
12. $(0, A, B, 0)$:

Blending alphas

Let F_A and F_B be the fractions of the original mattes of A and B that prevail in the composite.

Q: What is the alpha value of the composite?

Blending color components

Let C_A, C_B, C_O be the "true" color components of A, B, and the composite, and let c_A, c_B, c_O be the pre-multiplied versions (which we want to compute).

So:

$$\begin{aligned} c_O &= \alpha_O C_O \\ &= \alpha_O \text{———————} \end{aligned}$$

Finding the fractions

Now we just need to find F_A and F_B.

These are easily found by inspection, from the compositing diagrams.

Examples:

Operation	F_A	F_B
clear		
A		
B		
A **over** B		
A **in** B		
A **"plus"** B		

Unary operators

A couple of unary operators are also useful:

$$darken(A, \phi) \equiv$$

$$dissolve(A, \delta) \equiv$$

Example

(*FFire* **plus** (*BFire* **out** *Planet*)
over darken (*Planet*, 0.8) **over** *Stars*

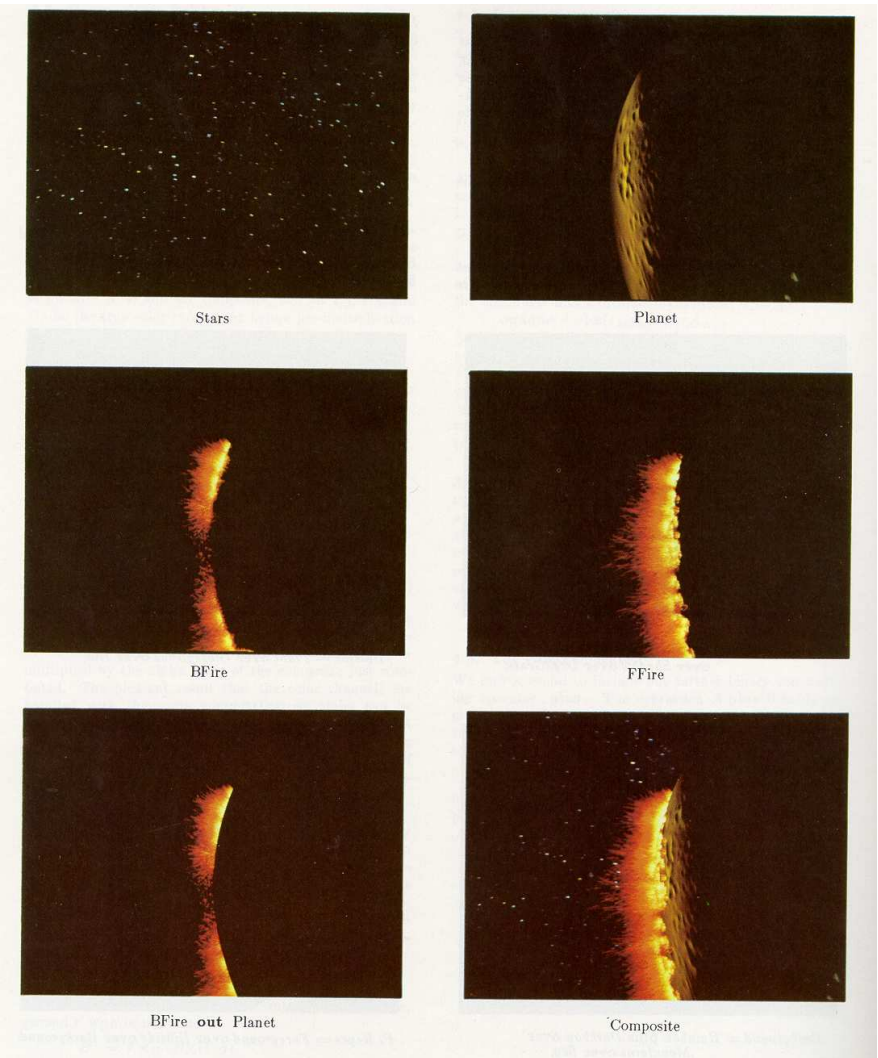


Image composite for the "Genesis Effect" (Porter and Duff, Figure 2)

For completeness...

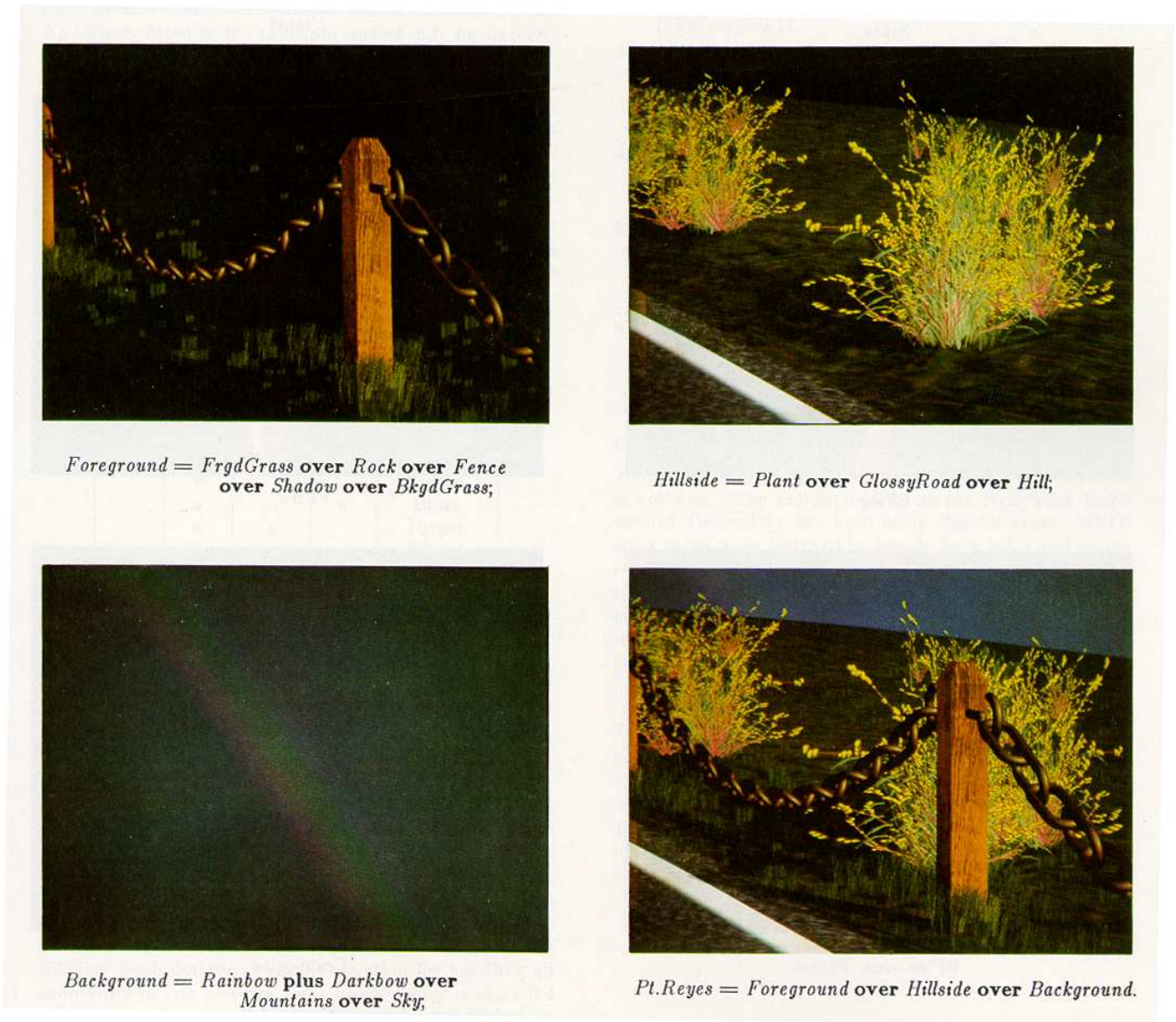


Image composite for "Road to Pt. Reyes" (Porter and Duff, Figure 1)

Summary

What to take away from this lecture:

- Intuitions for aliasing and anti-aliasing
- The reasons for doing compositing
- The meaning of alpha
- How the various compositing operations are defined
- The definition and implications of the "compositing assumption"
- How compositing operations are computed
- How to use compositing in practice