27 – BLENDING & COMPOSITING

Textbook: 16.4

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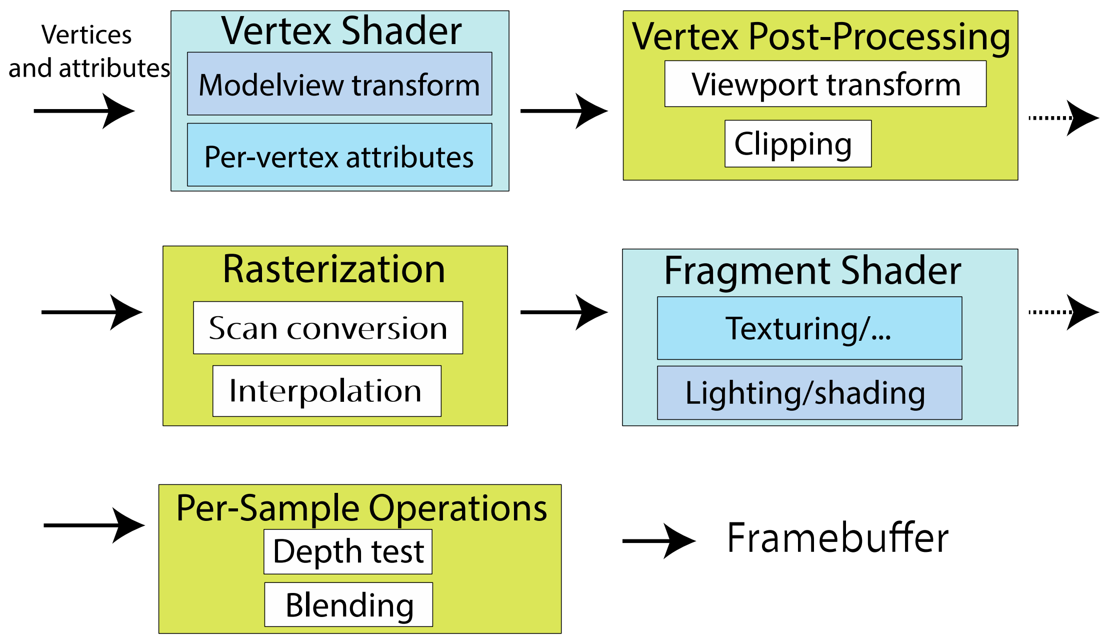
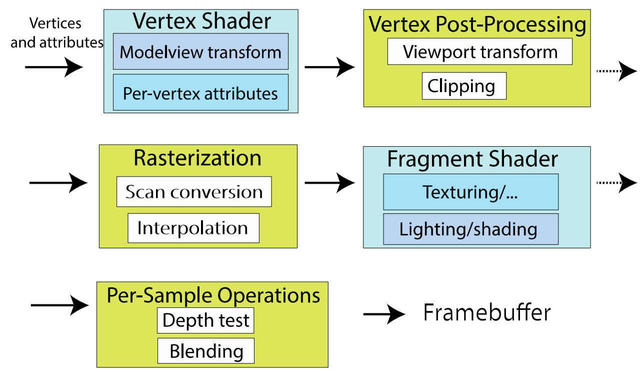
THE RENDERING PIPELINE



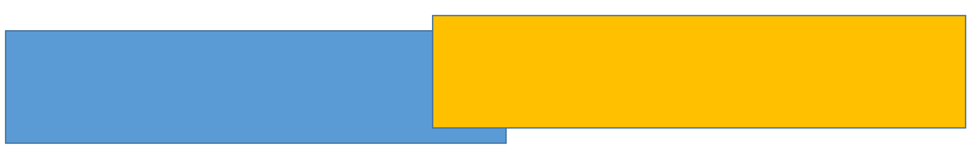
SOME OF YOU WERE WONDERING…

- Why is depth test AFTER the fragment shader?
- Why bother with computing the color if it's behind something?
- The answer is blending.



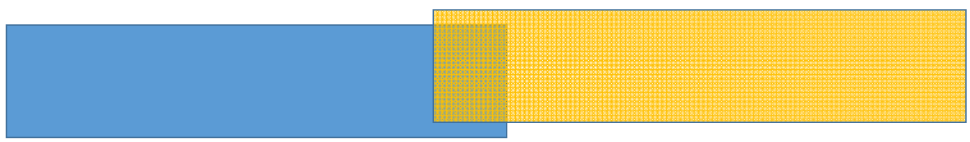
OPAQUE VS. TRASPARENT

- If all objects are opaque, no blending is needed
- As before, simply overwrite the color in framebuffer
- Then depth test can be done BEFORE fragment shader
  - *(if, of course, fragment shader does not modify z)*



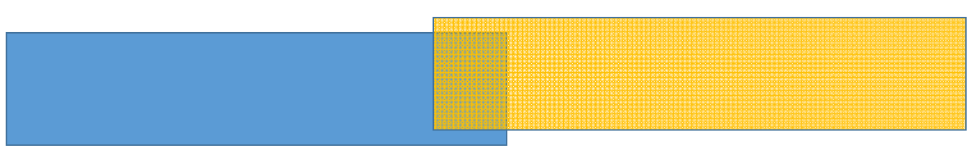
OPAQUE VS. TRASPARENT

- For transparent objects, every time we're writing into a fragment buffer, we need to consider what there is already



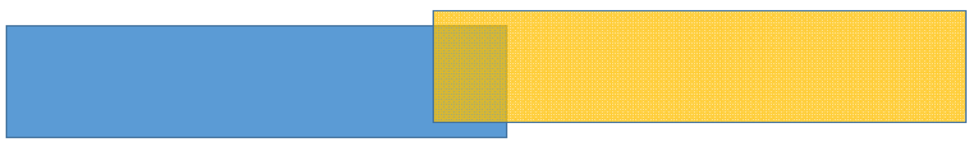
OPAQUE VS. TRASPARENT

- For transparent objects, every time we're writing into a fragment buffer, we need to consider what there is already
- Per fragment:
  - Fragment's color: **source** color
  - What's in framebuffer: **destination** color



OPAQUE VS. TRASPARENT

- For transparent objects, every time we're writing into a fragment buffer, we need to consider what there is already
- Per fragment:
  - Fragment's color: **source** color
  - What's in framebuffer: **destination** color
- Same idea as layers in Photoshop



How to combine those
2 colors into some new color?

BLENDING: THERE ARE MANY WAYS.

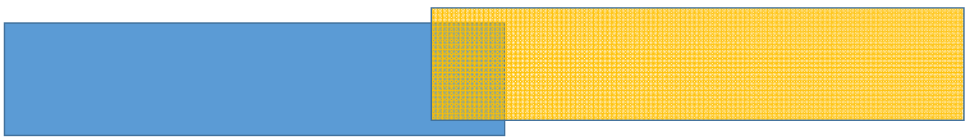
- Cool effects: http://threejs.org/examples/webgl_materials_blending.html

BLENDING EQUATIONS

- $D = (r, g, b, \alpha)_D$ - destination color (what's already in framebuffer)
- $S = (r, g, b, \alpha)_S$ - source color (current fragment)
- $Out = (r, g, b, \alpha)_{Out}$ - output color (result of blending)

Blending equations:

$$Out.rgb = f_1(D.rgb, S.rgb)$$
$$Out.\alpha = f_2(D.\alpha, S.\alpha)$$



$\boldsymbol{\alpha = 1.0}$ (opaque) $\boldsymbol{\alpha = 0.7}$ (semi-transparent)

BLENDING EQUATIONS

Blending equations:

$$Out.rgb = f_1(D.rgb, S.rgb)$$
$$Out.\alpha = f_2(D.\alpha, S.\alpha)$$

A user chooses both f_1 and f_2 out of those options:

$$f(D, S) = d \cdot D + s \cdot S$$
$$f(D, S) = d \cdot D - s \cdot S$$
$$f(D, S) = s \cdot S - d \cdot D$$
$$f(D, S) = \min(D, S)$$
$$f(D, S) = \max(D, S)$$

d,s – some parameters

D (S) – either D.rgb (S.rgb) or $D.\alpha$ ($S.\alpha$)

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D (S) – either D.rgb (S.rgb) or $D.\alpha$ $(S.\alpha)$

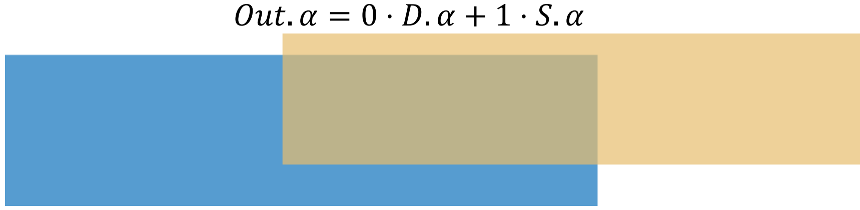
And d,s out of those:

$$d, s \in \{D.rgb, 1 - D.rgb, \\ S.rgb, 1 - S.rgb, \\ D.\alpha, 1 - D.\alpha \\ S.\alpha, 1 - S.\alpha \\ \text{constant}\}$$

WHAT CAN WE DO WITH THOSE?

- Simple transparency ("over operator"):
  - $f_1 = ADD$, $f_2 = ADD$
  - $d_1 = 1 - S.\alpha$
  - $s_1 = S.\alpha$
  - $d_2 = 0$
  - $s_2 = 1$

$$Out.rgb = (1 - S.\alpha) \cdot D.rgb + S.\alpha \cdot S.rgb$$
$$Out.\alpha = 0 \cdot D.\alpha + 1 \cdot S.\alpha$$



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  - $f_1 = ADD$, $f_2 = ADD$
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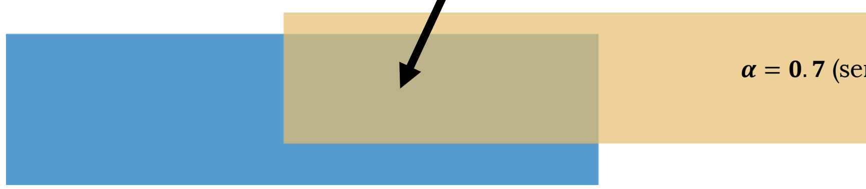
rgb: $(1 - 0.7) \cdot (0,0,1) + 0.7 \cdot (1,1,0)$
= (0,0,0.3) + (0.7, 0.7,0)=(0.7,0.7,0.3)

$$Out.rgb = (1 - S.\alpha) \cdot D.rgb + S.\alpha \cdot S.rgb$$
$$Out.\alpha = 0 \cdot D.\alpha + 1 \cdot S.\alpha$$

$\boldsymbol{\alpha = 1.0}$ (opaque)

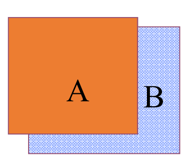


$\boldsymbol{\alpha = 0.7}$ (semi-transparent)

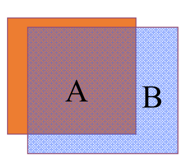
OVER OPERATOR

$$Out.rgb = (1 - S.\alpha) \cdot D.rgb + S.\alpha \cdot S.rgb$$

- Examples: $A.\alpha = 1, B.\alpha = 0.4$



A over B:
$Out.rgb = (1) \cdot A.rgb + (1 - 1) \cdot B.rgb$

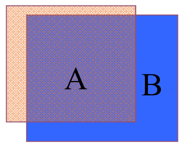


B over A:
$Out.rgb = (0.4) \cdot A.rgb + (1 - 0.4) \cdot B.rgb$

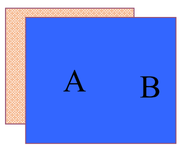
OVER OPERATOR

$$Out.rgb = (1 - S.\alpha) \cdot D.rgb + S.\alpha \cdot S.rgb$$

- Examples: $A.\alpha = 0.4, B.\alpha = 1$



A over B:
$$Out.rgb = (1 - 0.4) \cdot A.rgb + (0.4) \cdot B.rgb$$

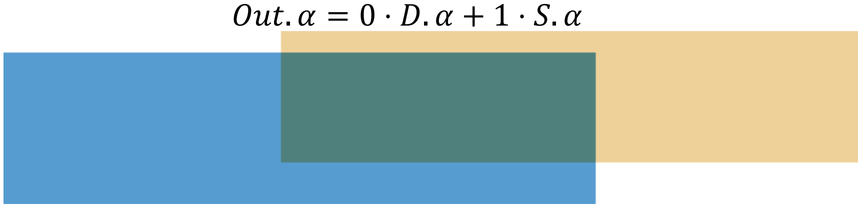


B over A:
$$Out.rgb = (0) \cdot A.rgb + (1) \cdot B.rgb$$

WHAT CAN WE DO WITH THOSE?

- "Multiply"
  - $f_1 = ADD, f_2 = ADD$
  - $\boldsymbol{d_1 = S.rgb}$
  - $\boldsymbol{s_1 = 0}$
  - $d_2 = 0$
  - $s_2 = 1$

$$Out.rgb = S.rgb \cdot D.rgb$$
$$Out.\alpha = 0 \cdot D.\alpha + 1 \cdot S.\alpha$$

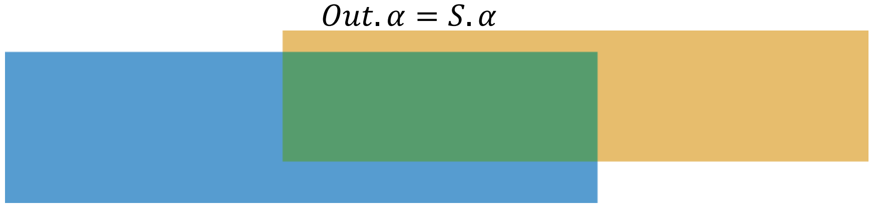


$\boldsymbol{\alpha = 1.0}$ (opaque) $\boldsymbol{\alpha = 0.7}$ (semi-transparent)

WHAT CAN WE DO WITH THOSE?

- "Darken"
  - $f_1 = MIN, f_2 = ADD$
  - $\boldsymbol{d_1 = 1}$
  - $\boldsymbol{s_1 = 1}$
  - $d_2 = 0$
  - $s_2 = 1$

$$Out.rgb = \min(S.rgb, D.rgb)$$
$$Out.\alpha = S.\alpha$$



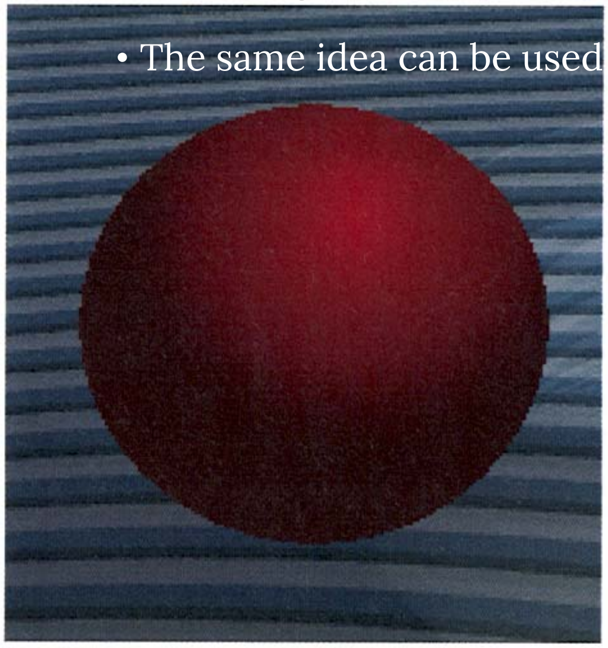
$\boldsymbol{\alpha = 1.0}$ (opaque) $\boldsymbol{\alpha = 1.0}$ (opaque)

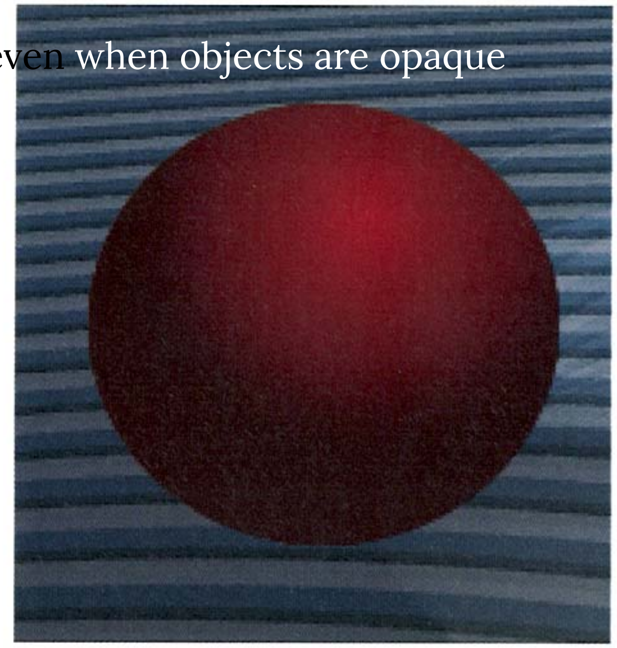
OPENGL BLENDING

- Caveats:
  - Note: alpha blending is an **order-dependent** operation!
    - It matters which object is drawn first AND
    - Which surface is in front
  - For 3D scenes, this makes it necessary to keep track of rendering order explicitly
    - E.g. always draw "back" surface first

BLENDING EXAMPLE

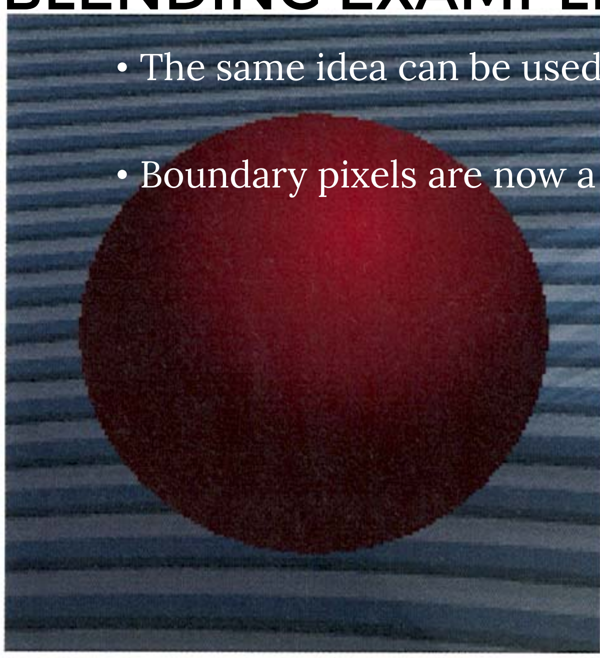
- The same idea can be used even when objects are opaque

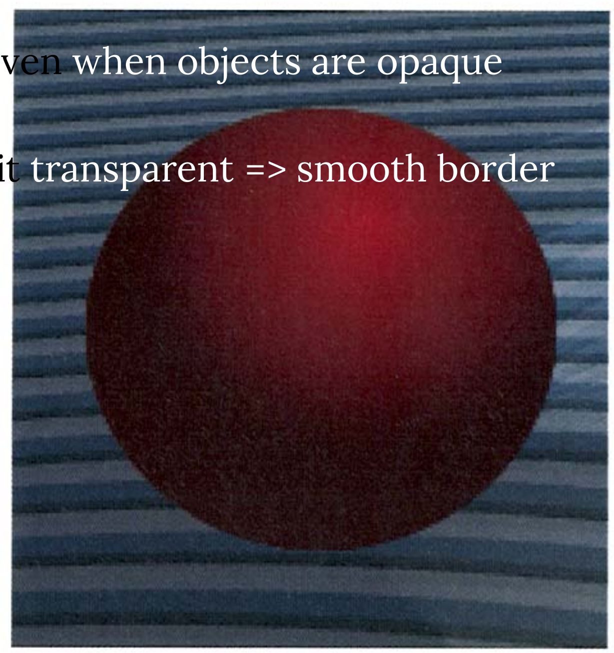




BLENDING EXAMPLE

- The same idea can be used even when objects are opaque
- Boundary pixels are now a bit transparent => smooth border





BLENDING/COMPOSITING IN VFX

- e.g. https://www.youtube.com/watch?v=63o0QJ3CjtY