the gamedesigninitiative at cornell university

Lecture 16

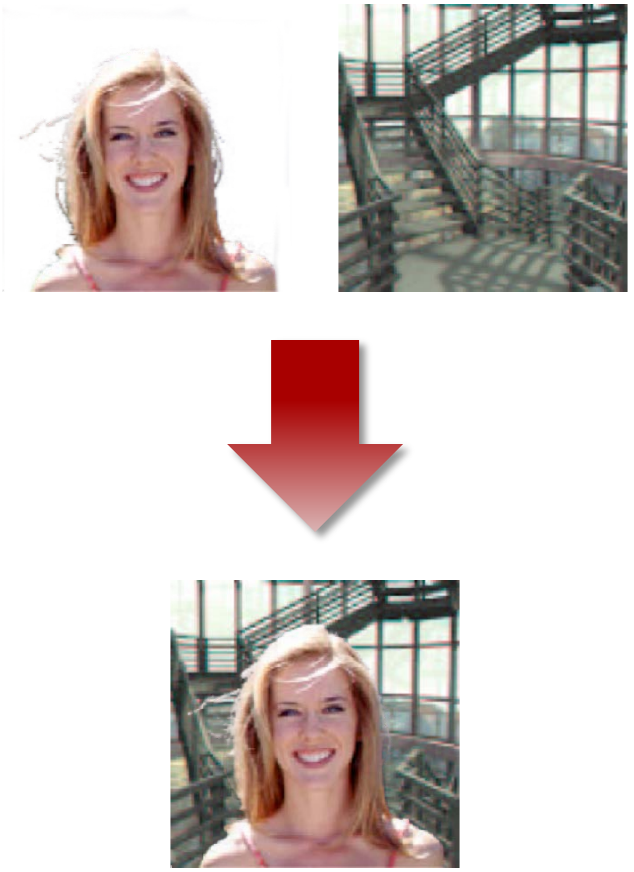
Color and Textures

Take Away For Today

- Image **color** and **composition**
  - What is the RGB model for images?
  - What does alpha represent?
  - How does alpha composition work?
- **Graphics primitives**
  - How do primitives differ from sprites?
  - How does LibGDX support primitives?
  - How do we combine sprites and primitives?

Drawing Multiple Objects

- Objects are on a **stack**
  - Images are *layered*
  - Drawn in order given
- Uses **color composition**
  - Often just draws last image
  - What about **transparency**?
- We need to understand…
  - How color is represented
  - How colors combine



Color Representation

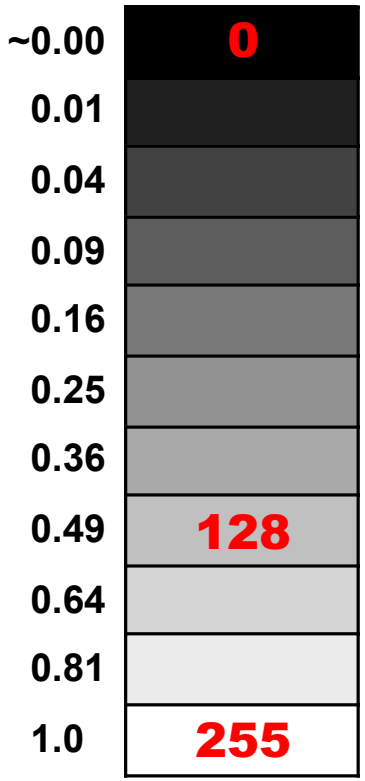
- Humans are **Trichromatic**
  - Any color a blend of three
  - Images from only 3 colors
- Additive Color
  - Each color has an intensity
  - Blend by adding intensities
- Computer displays:
  - Light for each "channel"
  - Red, green and blue
- Aside: Subtractive Color
  - Learned in primary school
  - For pigments, not light

[Cornell CS 465 Slides]

Color Blending Example

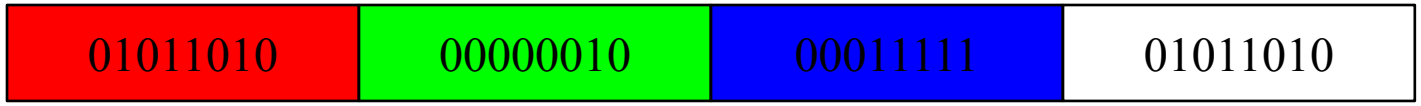
Color Representation

- Each color has an **intensity**
  - Measures amount of light of that color
  - 0 = absent, 1 = maximum intensity
- Real numbers take up a lot of space
  - **Compact representation**: one byte (0-255)
  - As good as human eye can distinguish
- But graphics algorithms require [0,1]
  - Use [0,255] for *storage only*
  - intensity = bits/255.0
  - bits = floor(intensity*255)



Color Representation

- Intensity for three colors: 3 bytes or 24 bits

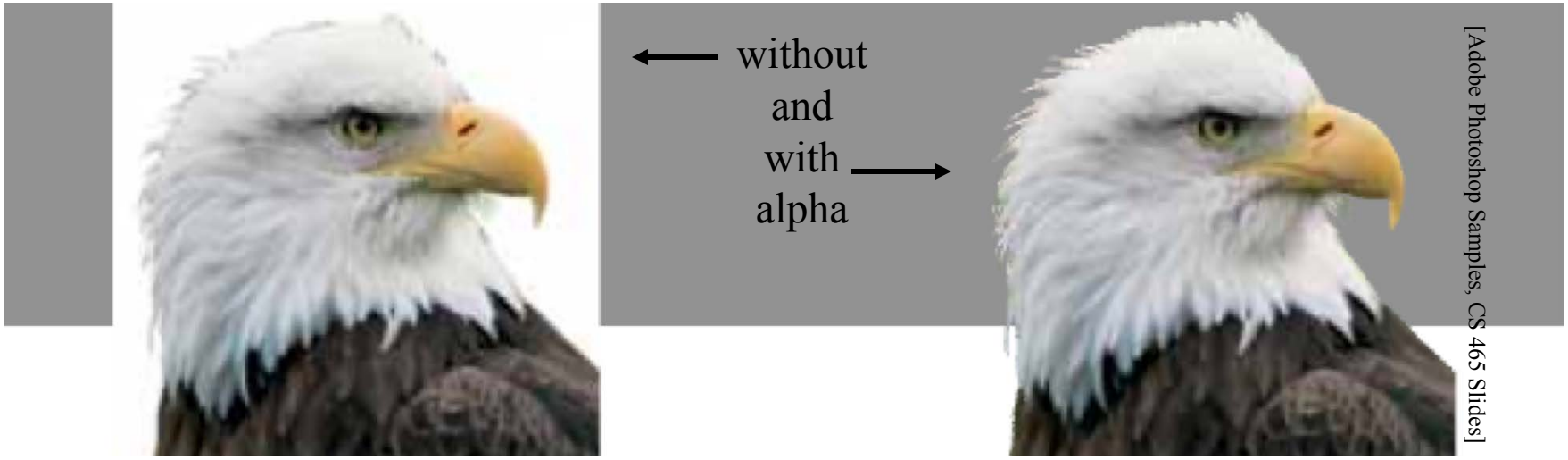


HTML Color	#5A	02	1F	Not Supported

- Store as a 32 bit int; use bit ops to access
  - red: `0x000000FF & integer`
  - green: `0x000000FF & (integer >> 8)`
  - blue: `0x000000FF & (integer >> 16)`
- Most integers are actually 4 bytes; what to do?

The Alpha Channel

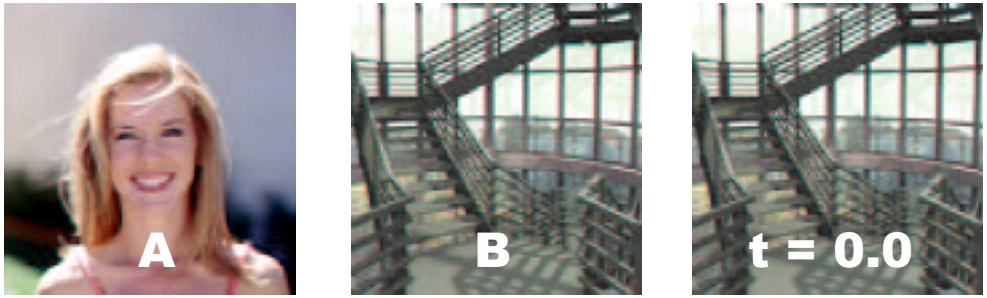
- Only used in **color composition**
- Does *not* correspond to a physical light source
  - Allows for transparency of overlapping objects
  - Without it the colors are written atop another



Color Composition

- Trivial example: Video crossfade
  - Smooth transition from one scene to another.

[Chuang et al/ Corel]



$$r_C = tr_A + (1-t)r_B$$
$$g_C = tg_A + (1-t)g_B$$
$$b_C = tb_A + (1-t)b_B$$

per pixel calculation

  - Note sums weight to 1.0
    - No unexpected brightening or darkening
    - No out-of-range results
  - This is an example of **linear interpolation**

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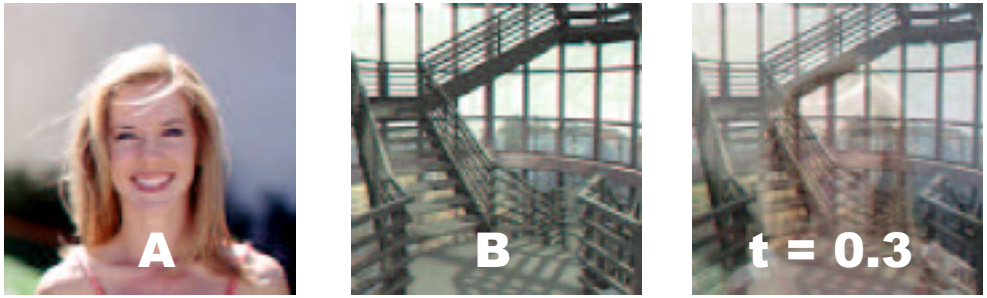

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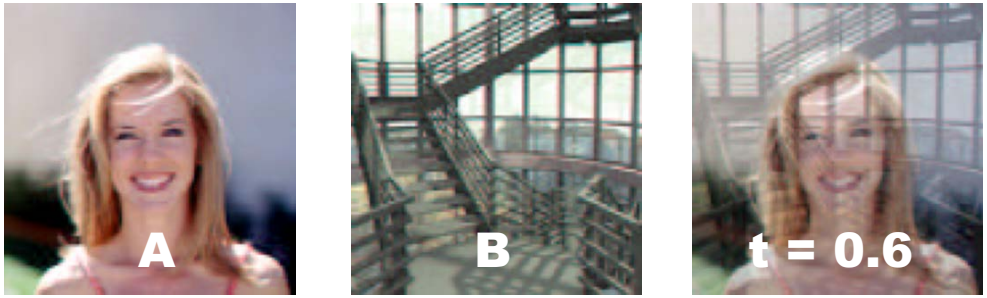

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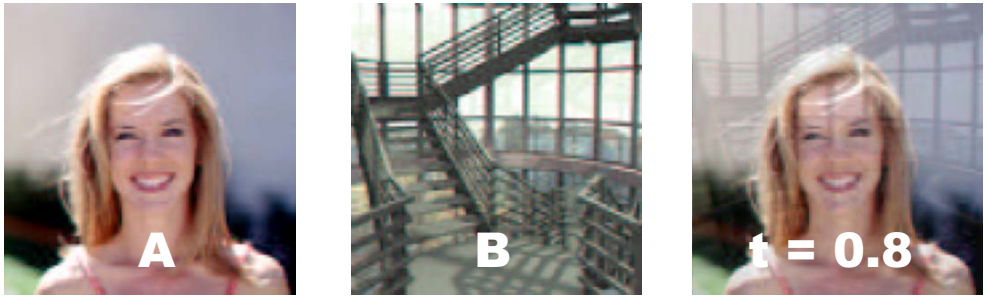

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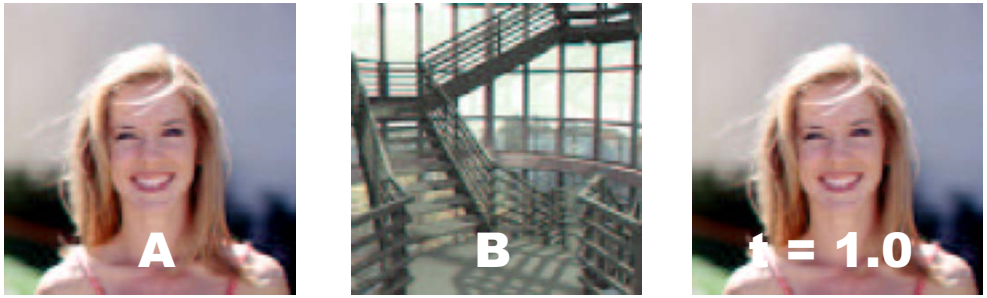

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per pixel calculation

  - Note sums weight to 1.0
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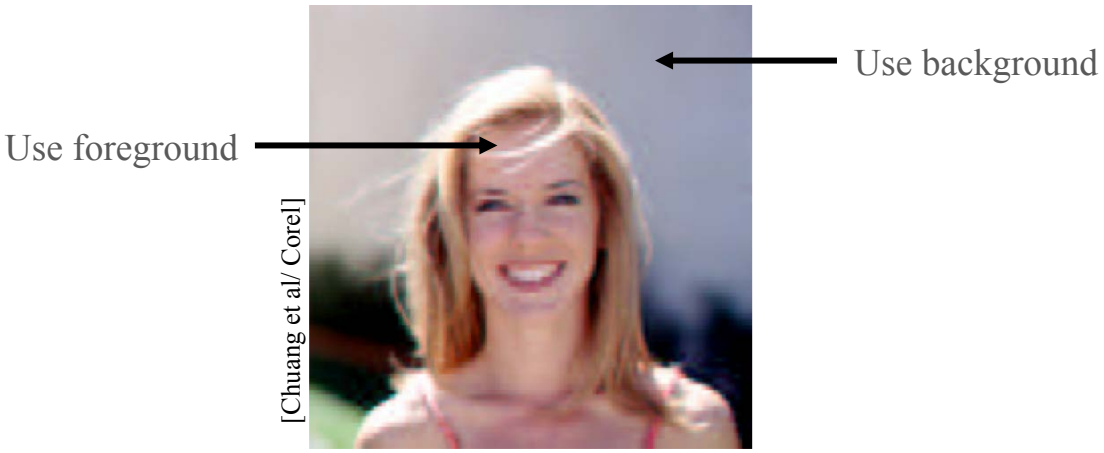
  - This is an example of **linear interpolation**

Foreground and Background

- In many cases, just adding is not enough
  - Want some elements in composite, not others
  - Do not want transparency of crossfade
- How we compute new image varies with position.

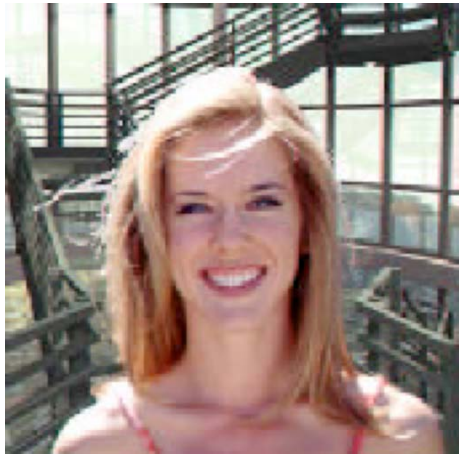


- Need to store a tag indicating parts of interest

Binary Image Mask

- First idea: Store one bit per pixel
  - Answers question "Is this pixel in foreground?"

[Chuang et al/ Corel] [Cornell PCG]



  - Does not work well near the edges

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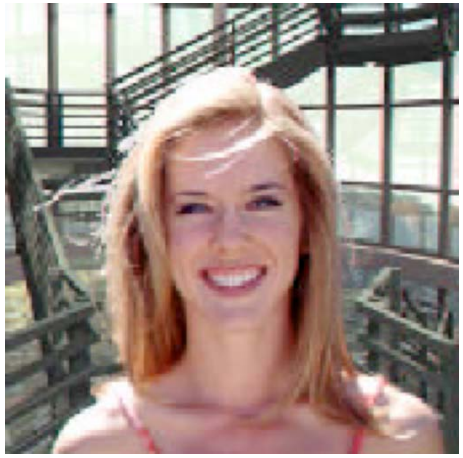

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- First idea: Store one bit per pixel
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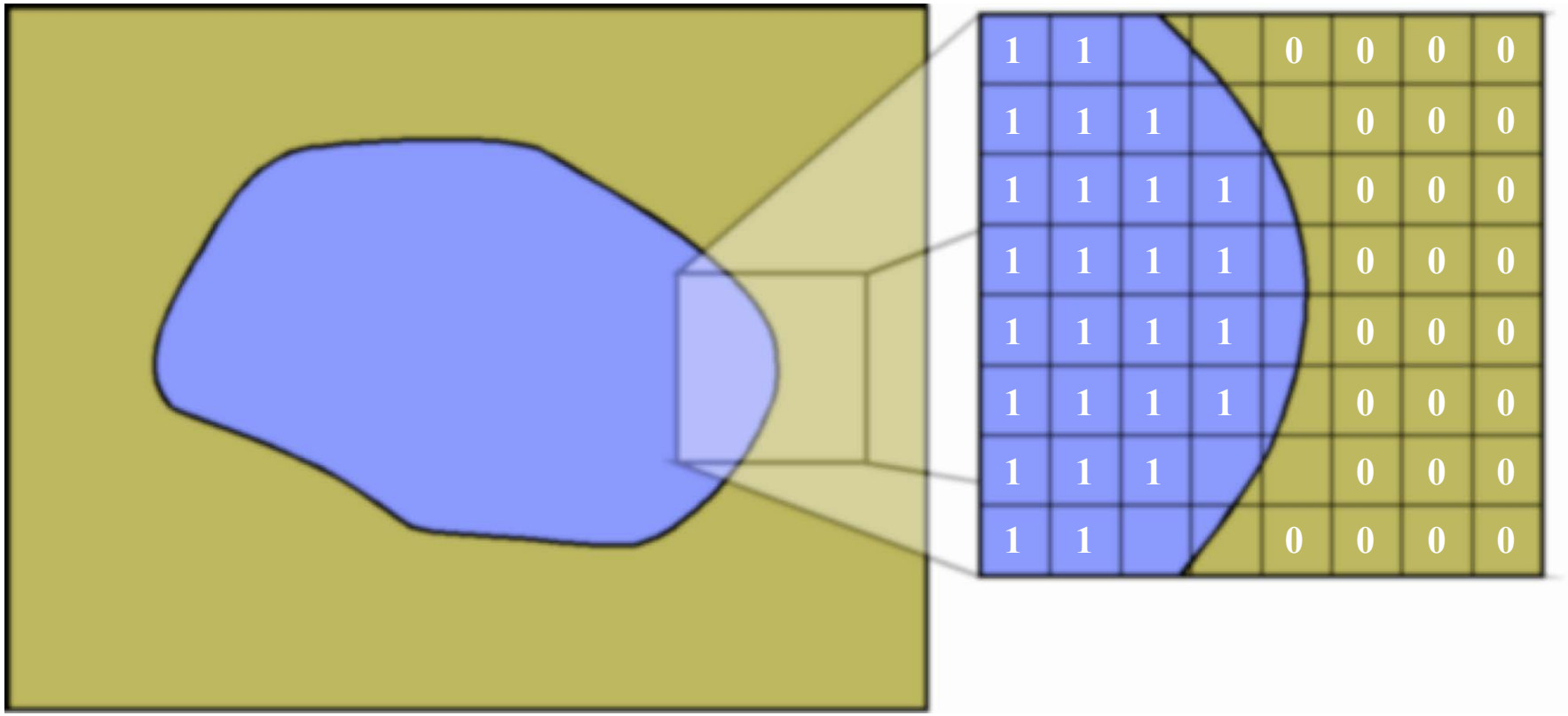
  - Does not work well near the edges

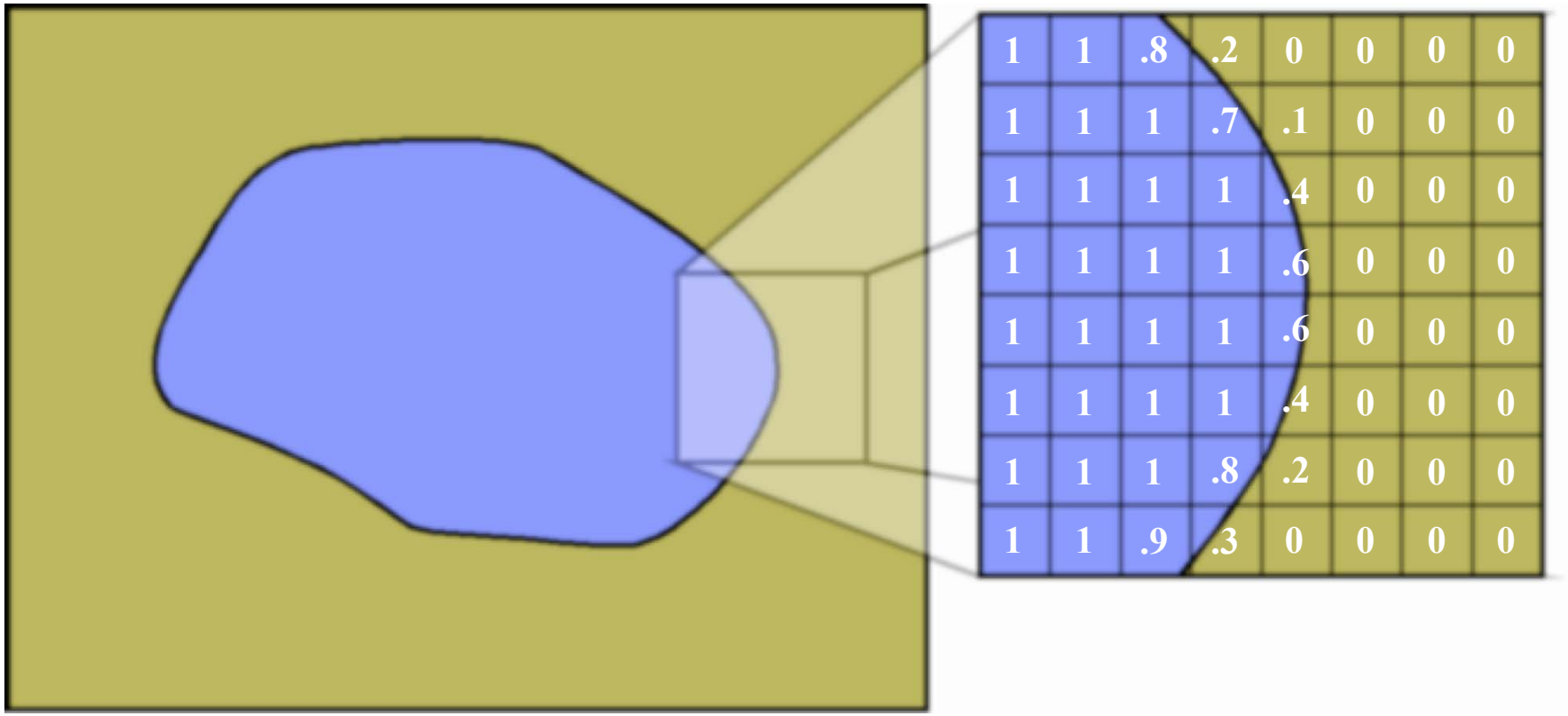
Partial Pixel Coverage

Problem: Boundary neither foreground nor background



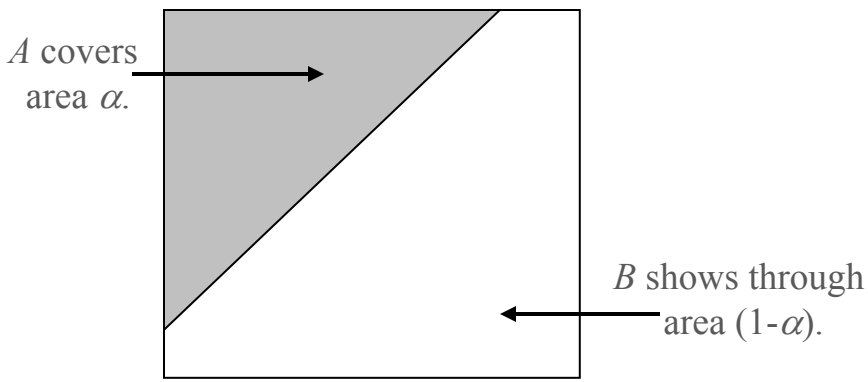
Partial Pixel Coverage

Solution: Interpolate on the border (Not exact, but *fast*)



Alpha Compositing

- Formalized in 1984 by Porter & Duff
- **Store fraction of pixel covered**; call it α



$$C = A \textbf{ over } B$$

$$r_C = \alpha_A r_A + (1 - \alpha_A) r_B$$

$$g_C = \alpha_A g_A + (1 - \alpha_A) g_B$$

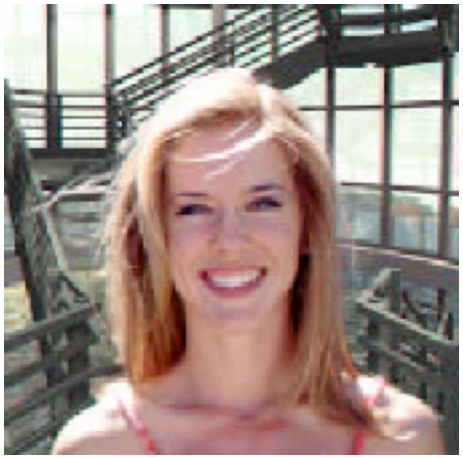
$$b_C = \alpha_A b_A + (1 - \alpha_A) b_B$$

- Clean implementation; 8 more bits makes 32
  - 2 multiplies + 1 add for compositing

Alpha Compositing Example

- Repeat previous with grey scale mask
  - Edges are much better now

[Chuang et al/ Corel] [Cornell PCG]



Alpha Compositing Example

- Repeat previous with grey scale mask
  - Edges are much better now

[Chuang et al/ Corel] [Cornell PCG]

Compositing in LibGDX

- spriteBatch.setBlendFunction(src, dst);

  OpenGL Constants

  - **General Formula**: $c_C = (\text{src})c_A + (\text{dst})c_B$

- **Alpha Blending**
  - src = GL20.GL_SRC_ALPHA (a_A)
  - dst = GL20.GL_ONE_MINUS_SRC_ALPHA $(1\text{-}a_A)$
- Colors may be **premultiplied**: $c' = ca$
  - src = GL20.GL_ONE
  - dst = GL20.GL_ONE_MINUS_SRC_ALPHA

Compositing in LibGDX

- `spriteBatch.setBlendFunction(src, dst);`

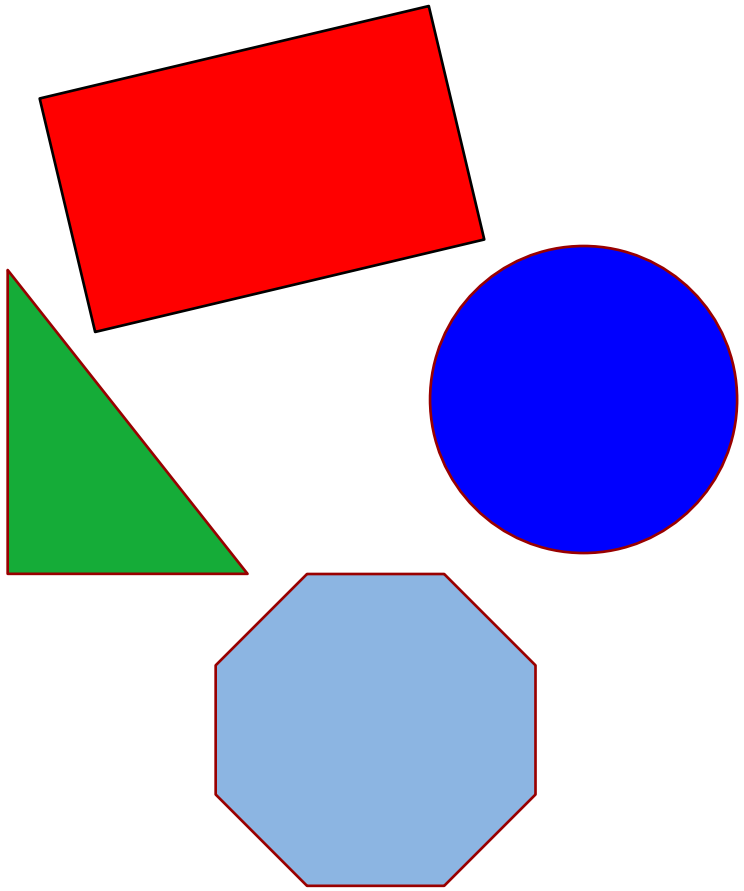
  OpenGL Constants

  - **General Formula**: $c_C = (\texttt{src})c_A + (\texttt{dst})c_B$

- **Additive Blending** (not premultiplied)
  - `src` = `GL20.GL_SRC_ALPHA`
  - `dst` = `GL20.GL_ONE`
- **Opaque** (no blending at all)
  - `src` = `GL20.GL_ONE`
  - `dst` = `GL20.GL_ZERO`

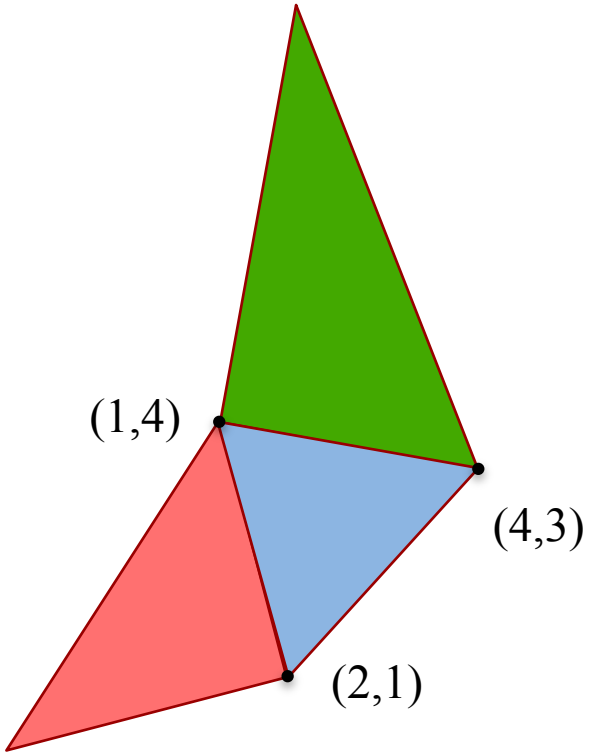
The Problem with Sprites

- Sprites drawn by artist
  - Distort with transforms
  - Major changes require new art from artist
  - Inefficient collaboration
- Sprite-free graphics?
  - Simple geometries
  - Particle effects
  - Dynamic shapes

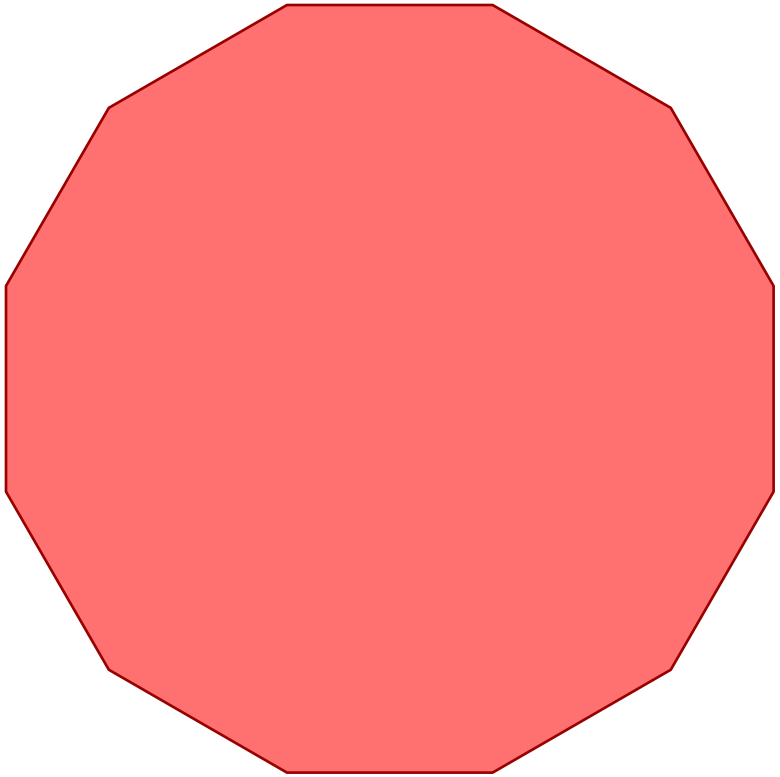


Triangles in Computer Graphics

- Everything made of **triangles**
  - Mathematically "nice"
  - Hardware support (GPUs)
- Specify with **three vertices**
  - Coordinates of corners
- Composite for complex shapes
  - Array of vertex objects
  - Each 3 vertices = triangle



Triangulation of Polygons



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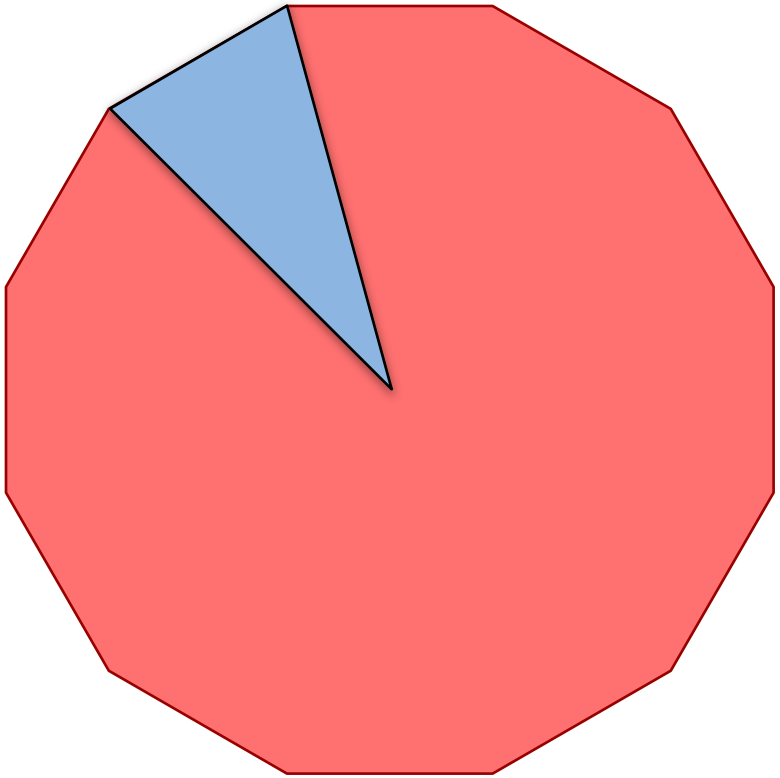

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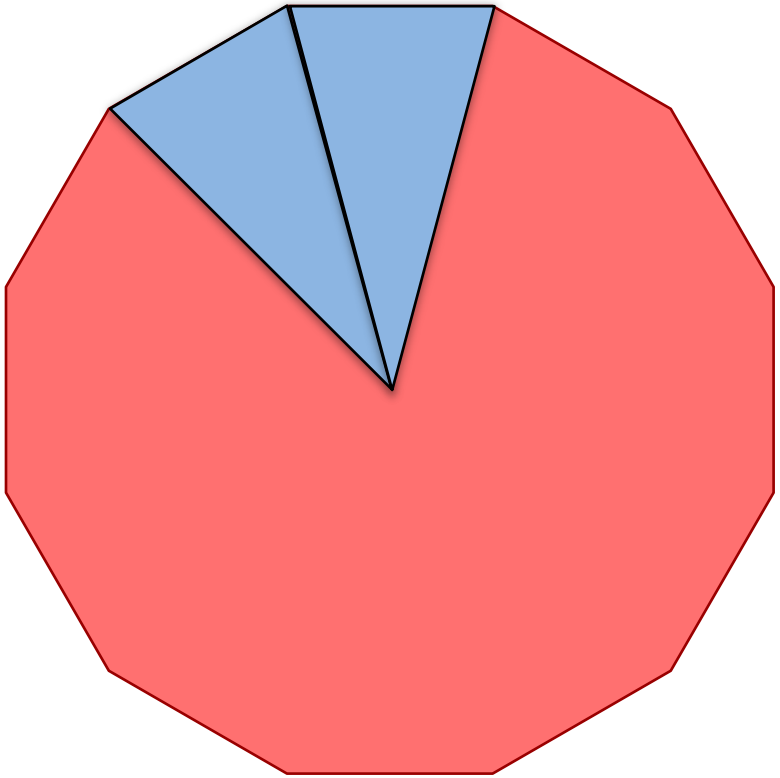

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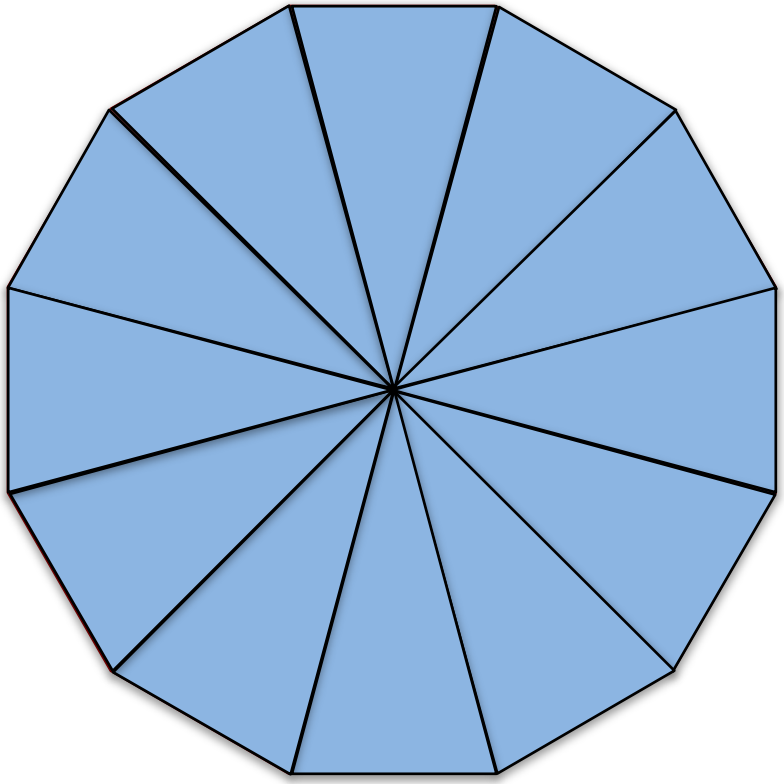
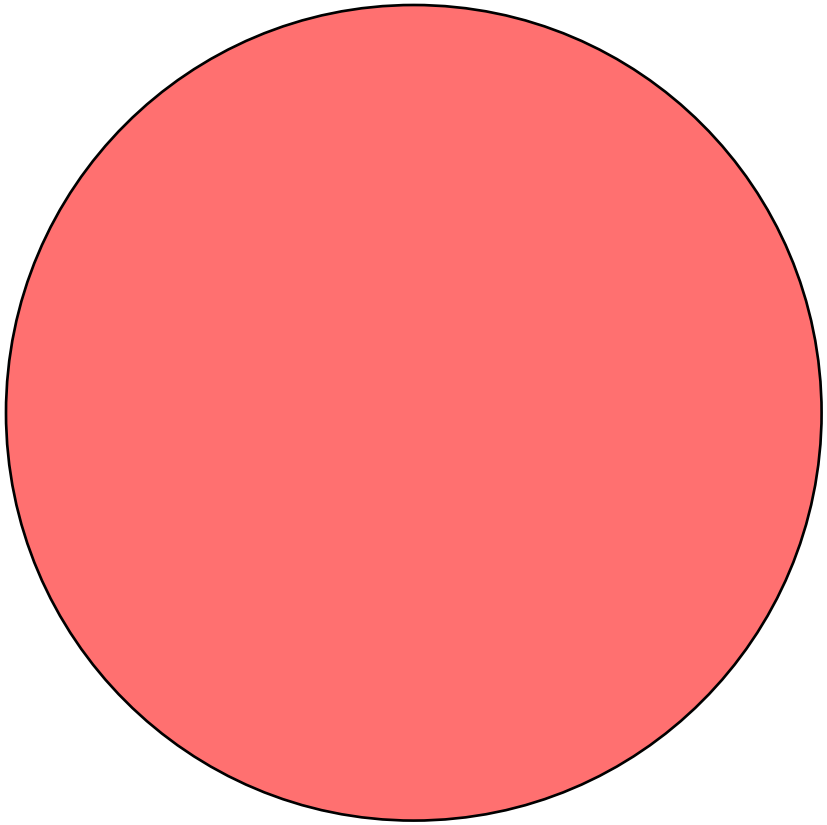


Round Shapes?



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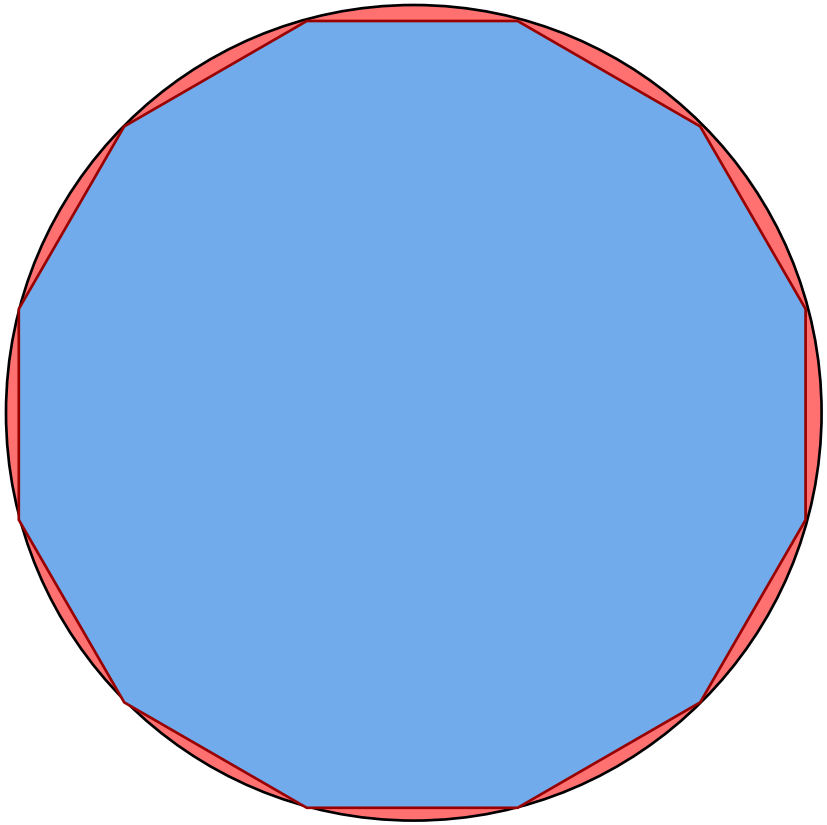
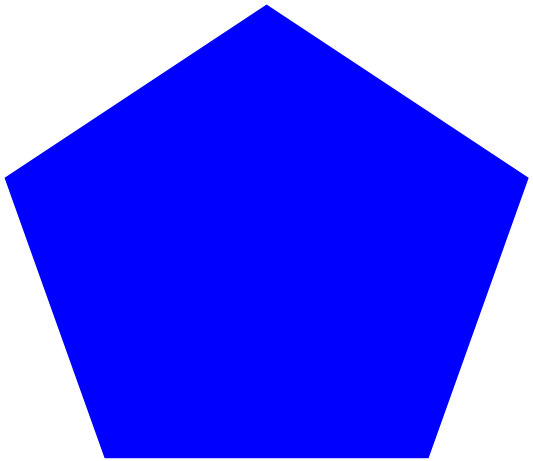


ShapeRenderer in LibGDX

- Tool to draw triangles
  - Specify a general shape
  - Makes the triangles for you
- Works like a SpriteBatch
  - Has a begin/end
  - Can set default color
  - Several draw commands
- Can mix with SpriteBatch
  - But not at the same time!
  - End one before begin other



```
render.circle(200, 200, 100, 5);
```

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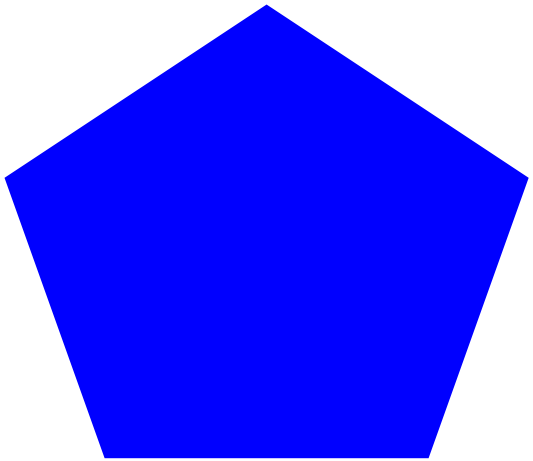

```
render.circle(200, 200, 100, 5);
```

Number of triangles

ShapeRenderer Example

```
render.begin(ShapeRenderer.ShapeType.Filled);
render.setColor(Color.BLUE);
render.circle(200, 200, 100, 8);
render.end();

render.begin(ShapeRenderer.ShapeType.Line);
render.setColor(Color.RED);
render.circle(200, 200, 100, 8);
render.end();
```

ShapeRenderer Example

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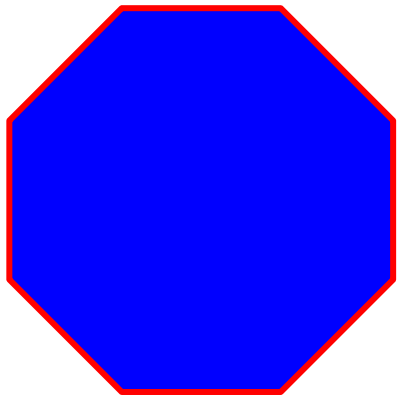

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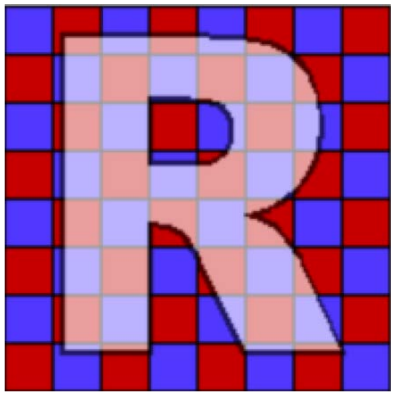
re[illegible]peType.Line);
rende[illegible]olor(Color.RED);
render.circle(200, 200, 100, 8);
render.end();
```

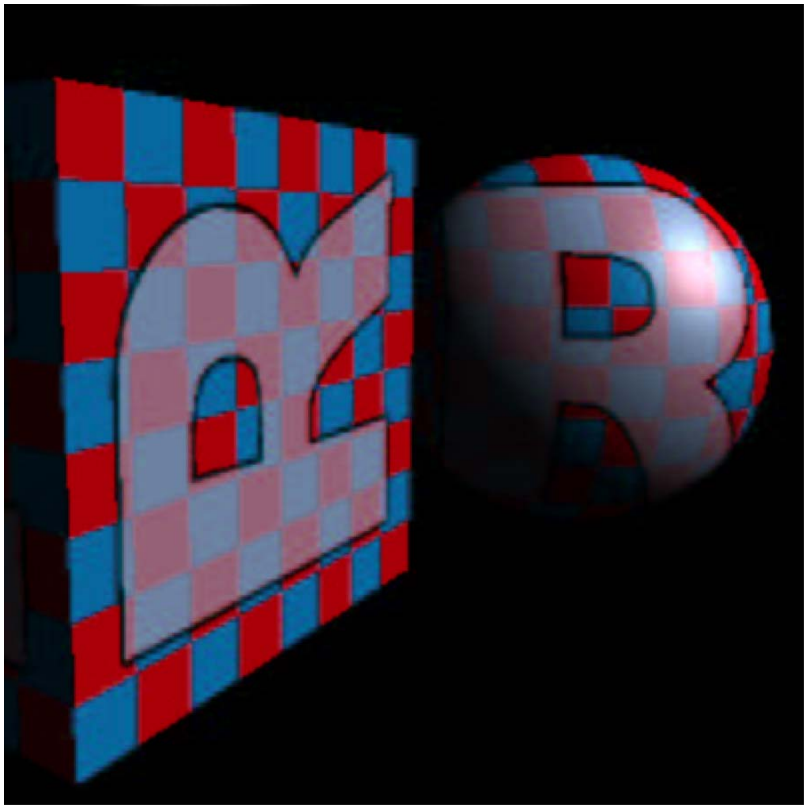
Note separate pass for filled, outline

Textures

2D Image File



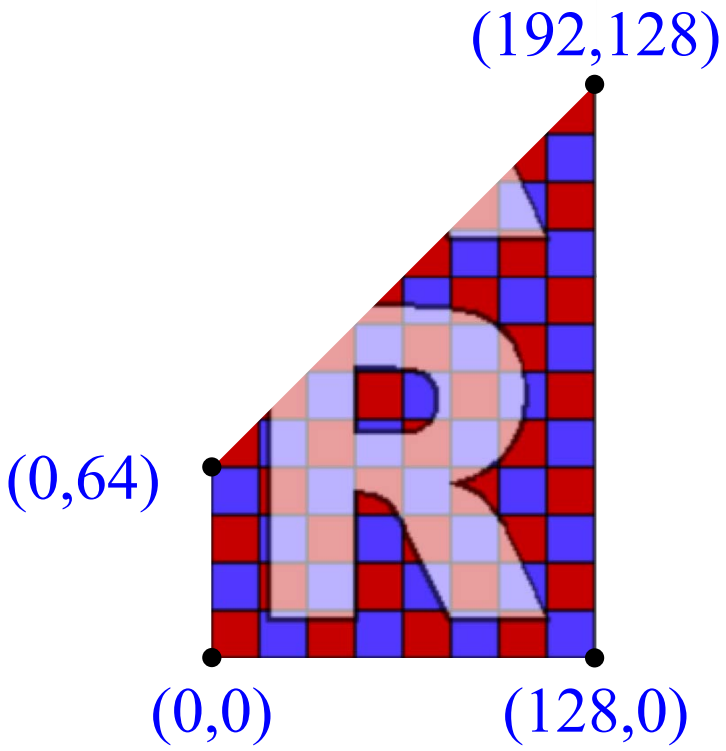
Mapped On To
Polygonal Shape



Simple Texturing in LibGDX

- **PolygonSpriteBatch** handles 90% of all cases
  - Works like a normal `SpriteBatch`
  - But now specify image and polygon
  - Entirely replaced SpriteBatch in **Lab 4**
- Uses the **PolygonRegion** class
  - Way to specify what part of image to use
  - Specify as a collection of vertices
  - Specify using **pixel positions**, not **texture coords**
  - See `PolygonObstacle` in Lab 4

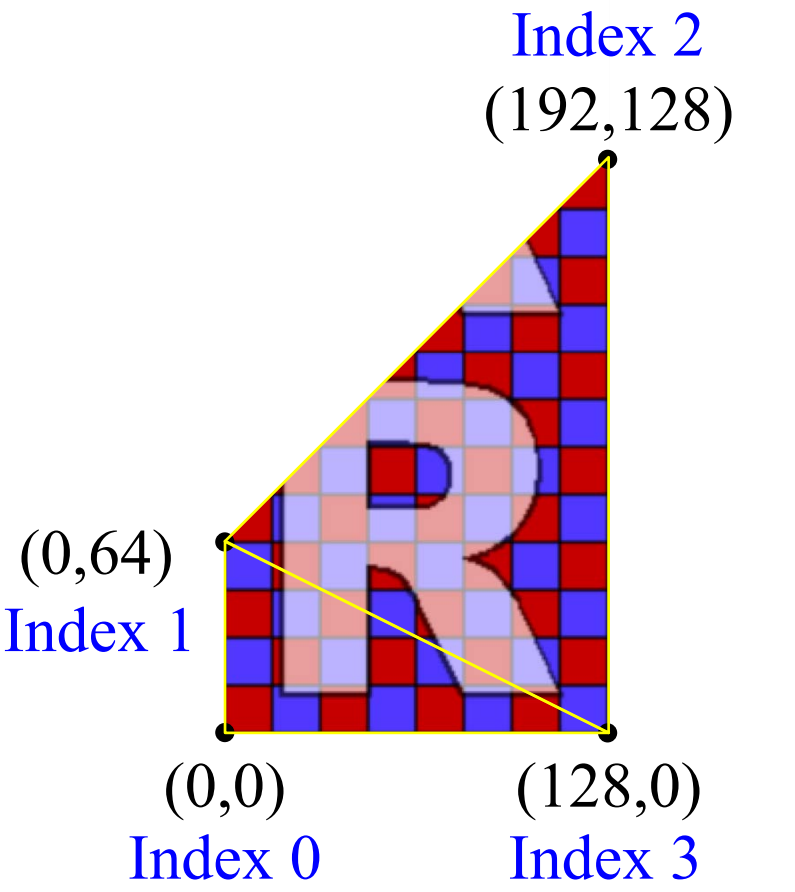
PolygonRegion Example




```
verts = {0,0,0,64,192,128,128,0}
```

- Create vertices by **pixel pos**
  - Example texture is 124x124
  - Preferences set to wrap
  - Store as an array of floats
- Must convert into triangles
  - Each vertex has an index
  - Given by position in array
  - Create array of indices
- Construct PolygonRegion
  - Specify texture
  - Specify vertices+triangles

PolygonRegion Example

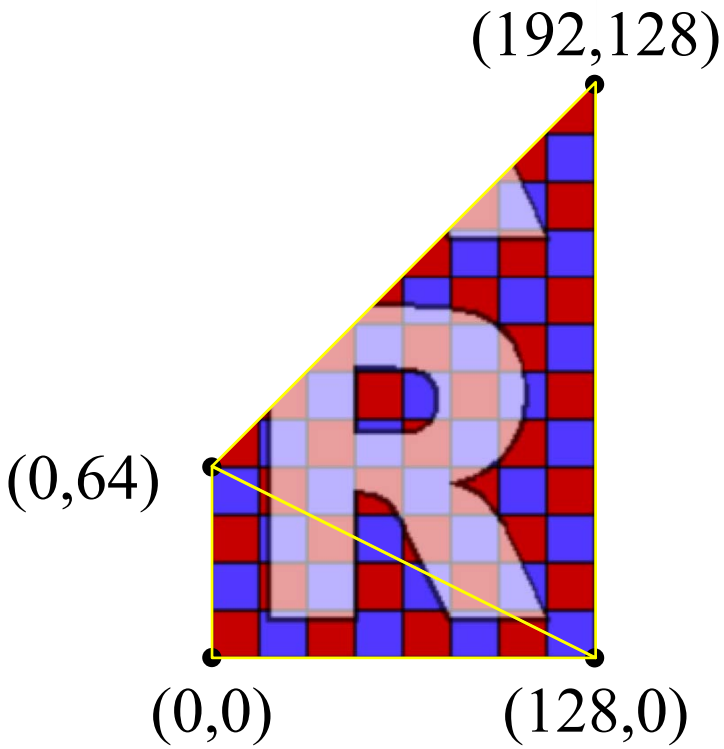



```
verts = {0,0,0,64,192,128,128,0}
tris = {0,1,3,3,1,2}
```

- Create vertices by pixel pos
  - Example texture is 124x124
  - Preferences set to wrap
  - Store as an array of floats
- Must **convert into triangles**
  - Each vertex has an index
  - Given by position in array
  - Create array of indices
- Construct PolygonRegion
  - Specify texture
  - Specify vertices+triangles

PolygonRegion Example

new PolygonRegion(img,verts,tris)



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tris = {0,1,3,3,1,2}

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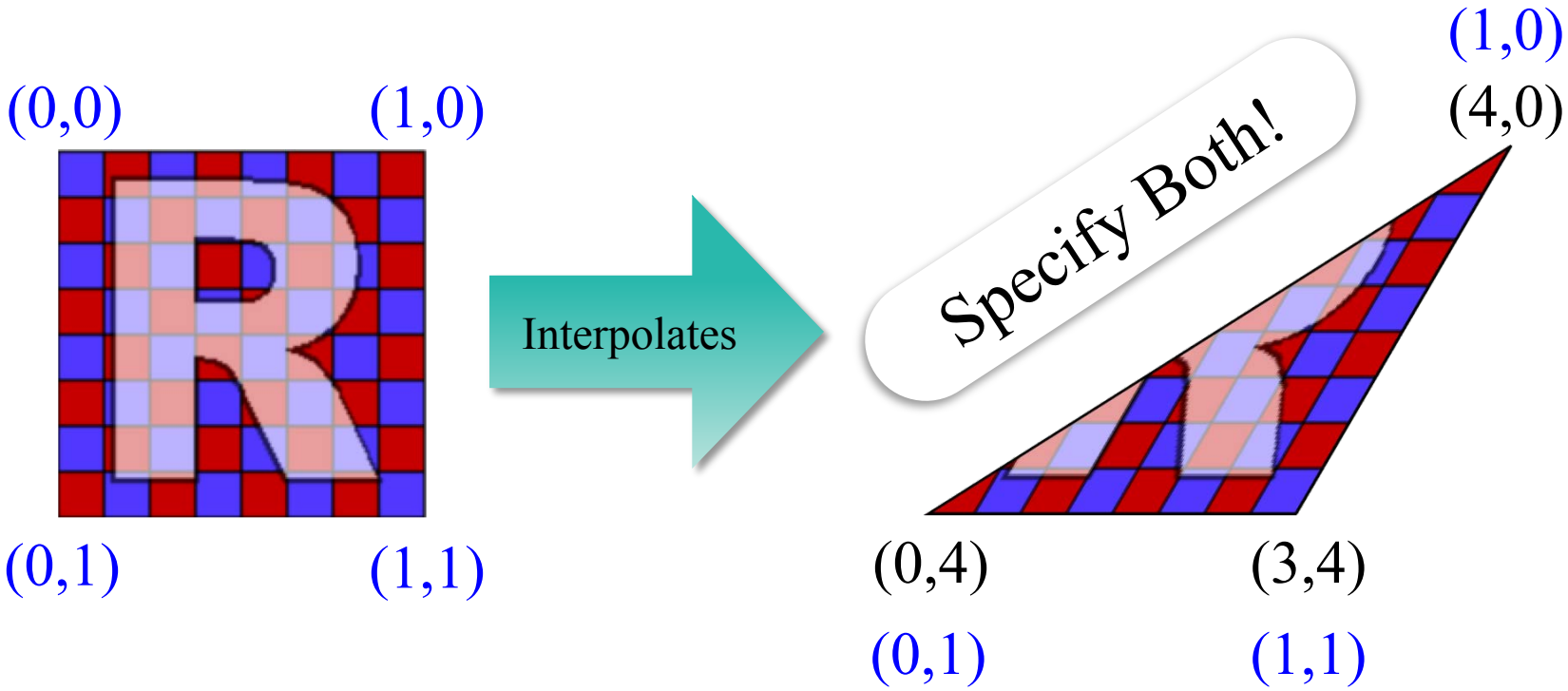
  - Preferences set to wrap
  - Store as an array of floats
- Must convert into triangles
  - Each vertex has an index
  - Given by position in array
  - Create array of indices
- **Construct PolygonRegion**
  - Specify texture
  - Specify vertices+triangles

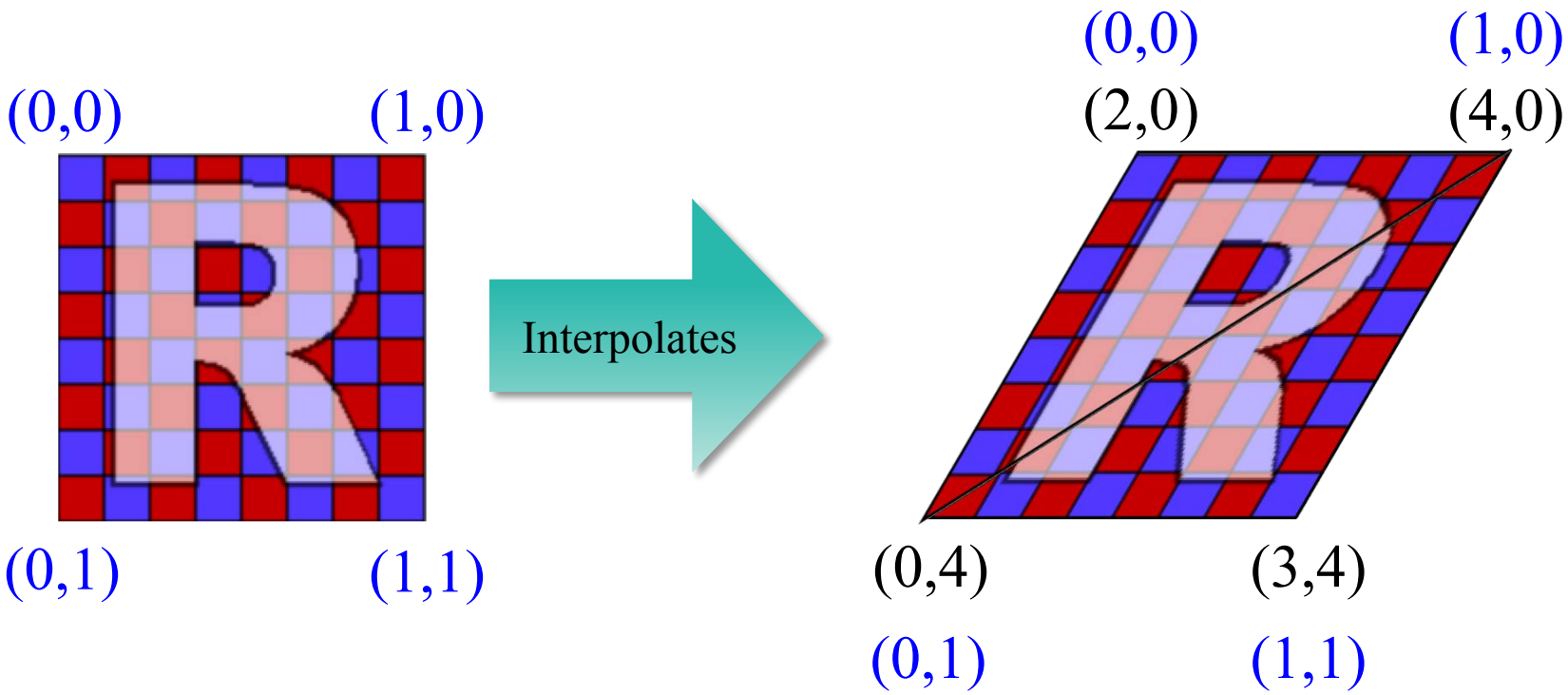
What If I Know OpenGL?

- Use the **GL20** (OpenGLES 2.0) object
  - Standard OpenGL functions are its methods
  - Standard OpenGL values are its constants
- There is a **GL30** (OpenGLES 3.0), but
  - Flakey support for Mac Java or mobile devices
  - Not really necessary for this class
- See **Programming Lab 2** for examples
  - Uses a custom OpenGL shader
  - Also advanced LibGDX classes like Mesh

OpenGL Texturing



OpenGL Texturing



Texture Coordinates
(even if not square)

Triangle Coordinates
(more than one triangle)

Summary

- Computer images defined by **color channels**
  - Three visible channels: red, green, blue
- Sprites combined via **compositing**
  - Alpha = percentage color in foreground
- Can use **triangles** instead of sprites
  - Complex shapes defined by arrays of triangles
- **Textures** generalize the notion of color
  - 2D image that is used to "color" triangle
  - Need triangle coordinates **and** texture coordinates