the gamedesigninitiative at cornell university

Lecture 16

Color and Textures

Graphics Lectures

- Drawing Images
  - SpriteBatch interface
  - Coordinates and Transforms
- Drawing Perspective
  - Camera
  - Projections
- **Drawing Primitives**
  - Color and Textures
  - Polygons

bare minimum
to draw graphics

side-scroller vs.
top down

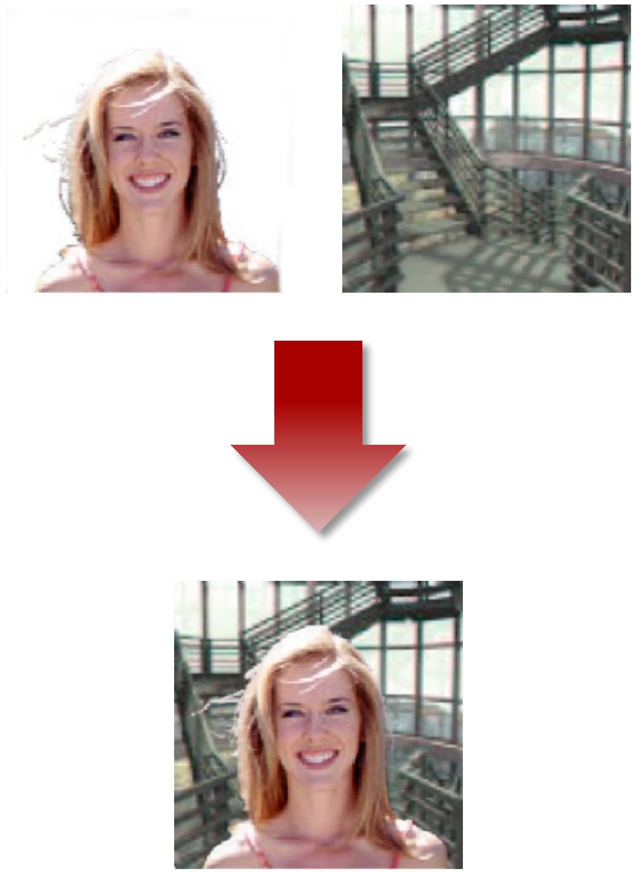
necessary for
lighting & shadows

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?

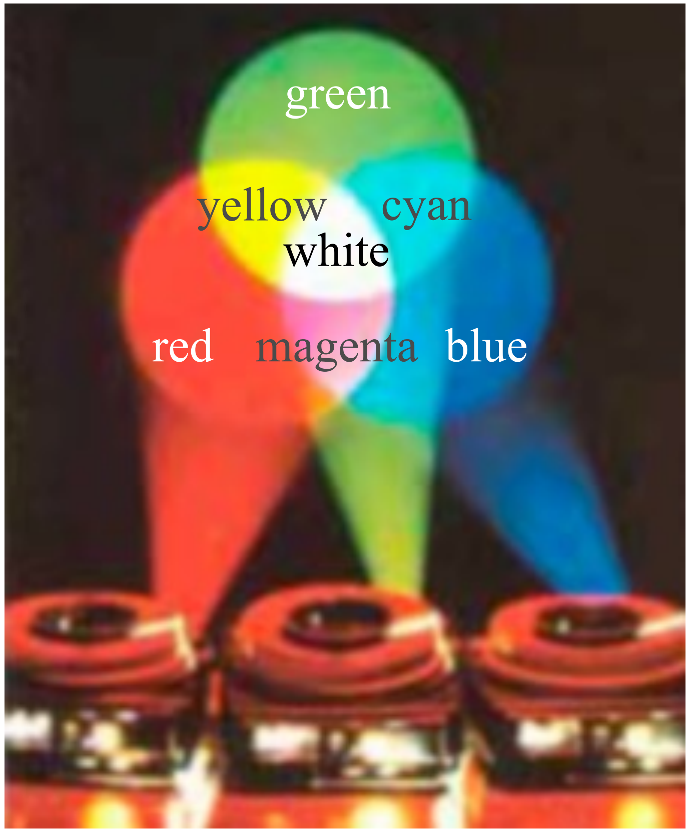
Drawing Multiple Objects

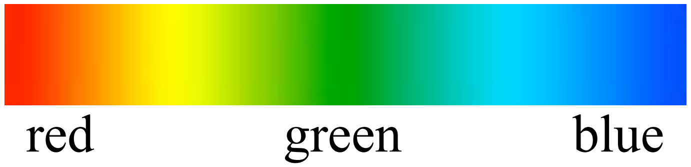
- Objects are on a **stack**
  - Images are *layered*
  - Drawn in order given
- Uses **color composition**
  - Often just draws last image
  - What about **transparency**?
- We need to understand…
  - How color is represented
  - How colors combine



Color Representation

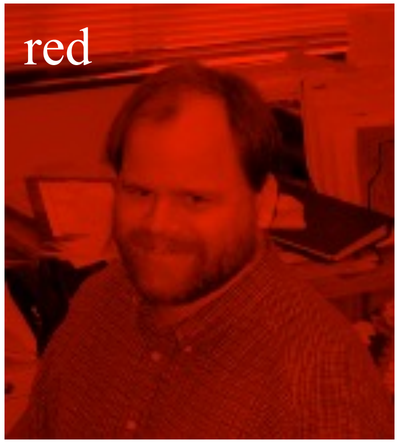
- Humans are **Trichromatic**
  - Any color a blend of three
  - Images from only 3 colors
- Additive Color
  - Each color has an intensity
  - Blend by adding intensities
- Computer displays:
  - Light for each "channel"
  - Red, green and blue
- Aside: Subtractive Color
  - Learned in primary school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

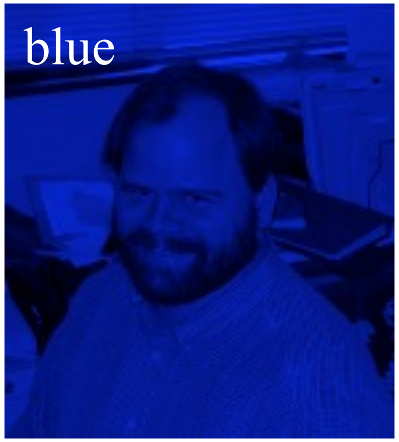


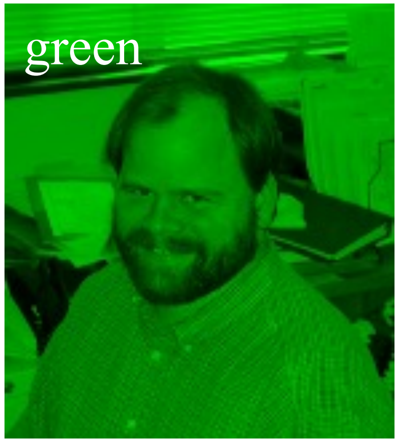


[Cornell CS 465 Slides]

Color Blending Example

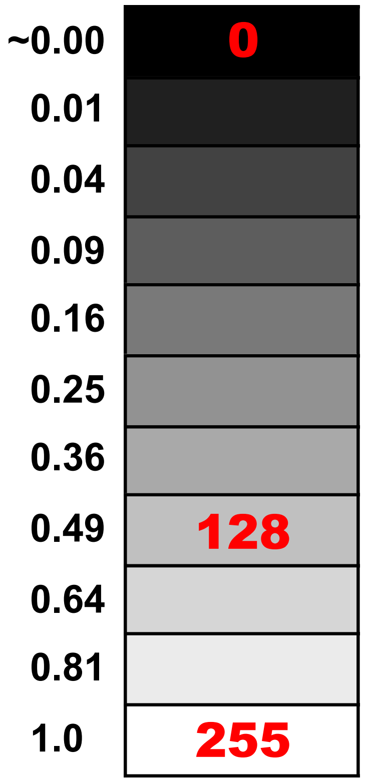






Color Representation

- 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

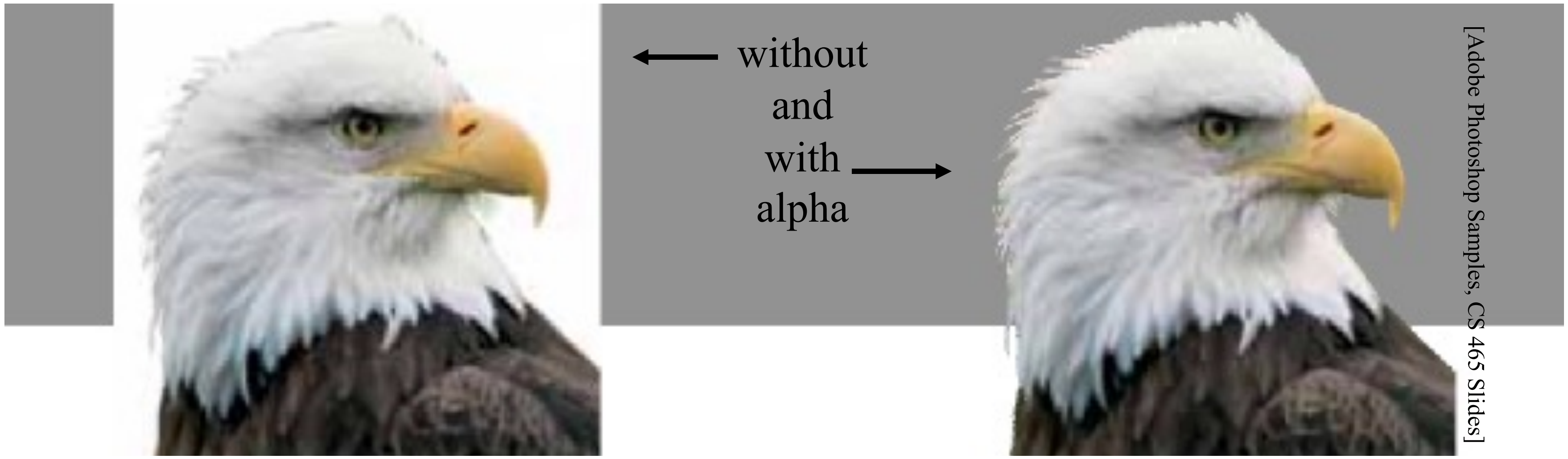
- Intensity for three colors: 3 bytes or 24 bits

	01011010	00000010	00011111	01011010
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

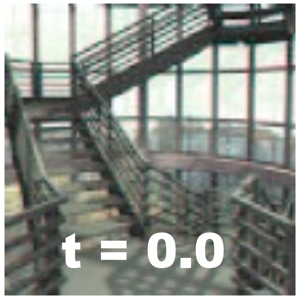
- Only used in **color composition**
- Does *not* correspond to a physical light source
  - Allows for transparency of overlapping objects
  - Without it the colors are written atop another



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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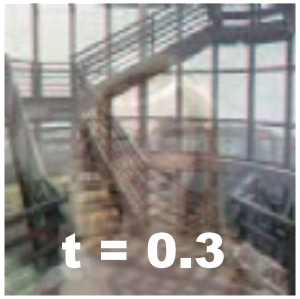

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$$b_C = t b_A + (1-t) b_B$$

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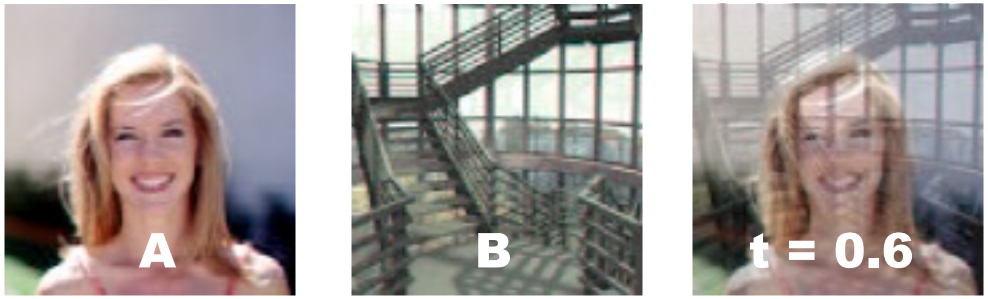

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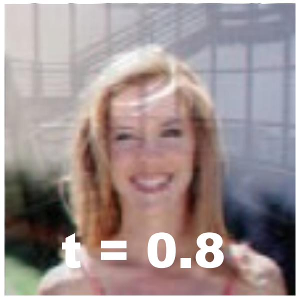

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per pixel calculation

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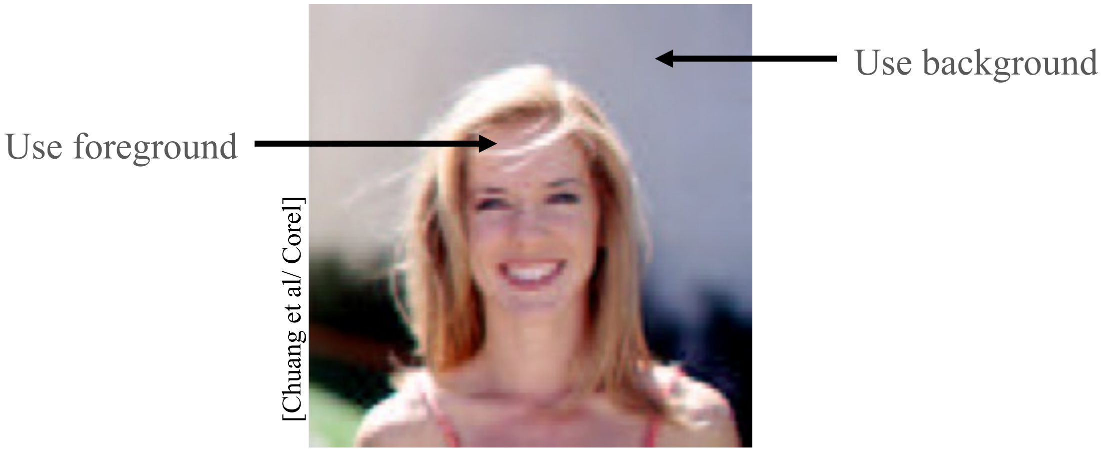
  - This is an example of **linear interpolation**

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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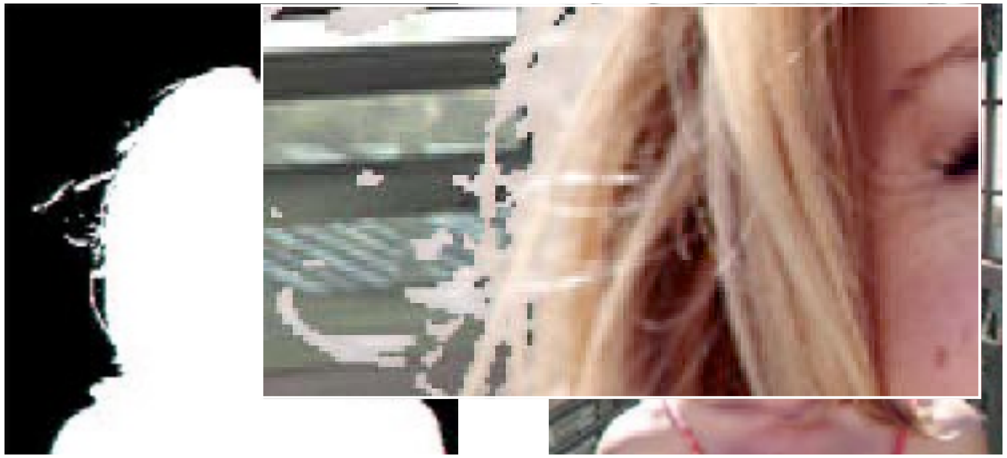
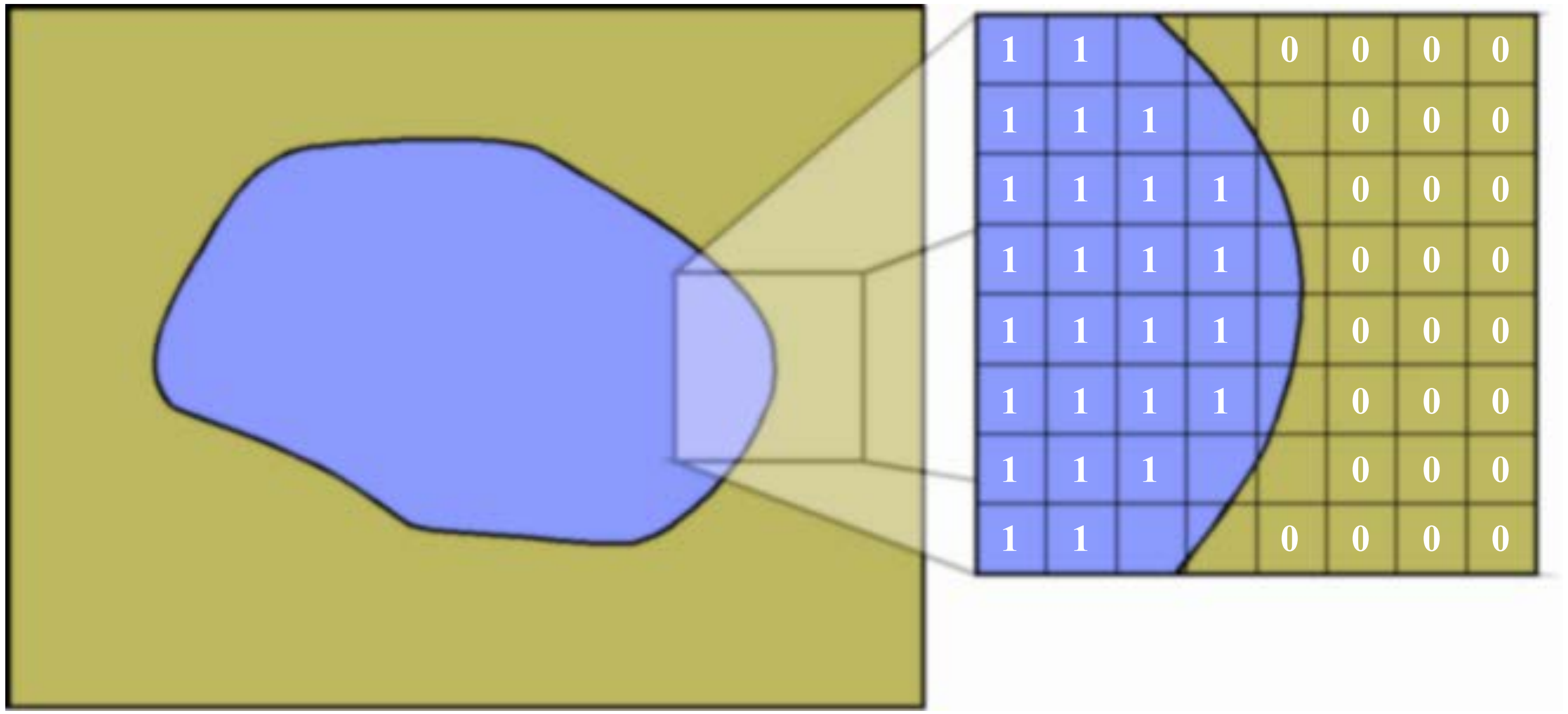


  - Does not work well near the edges

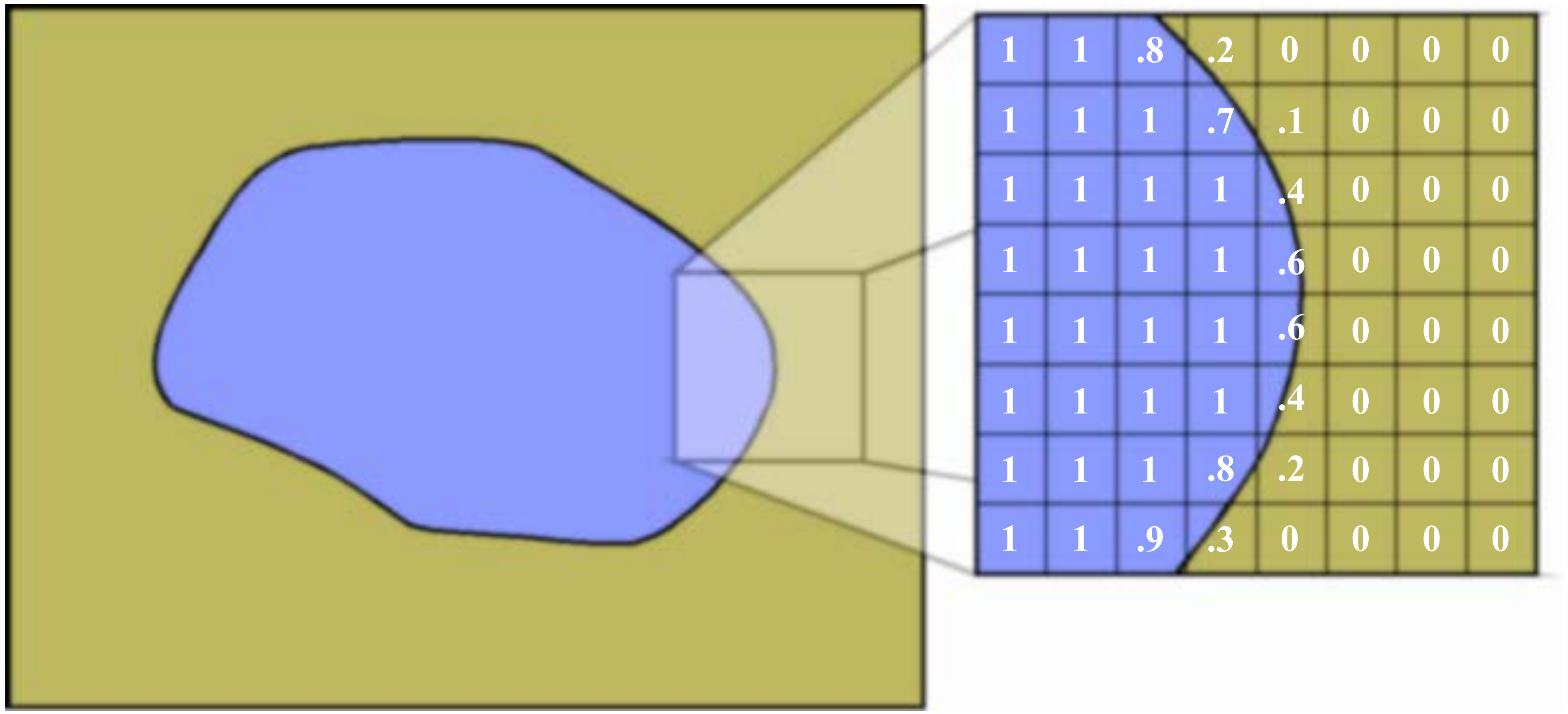
Partial Pixel Coverage

Problem: Boundary neither foreground nor background



Partial Pixel Coverage

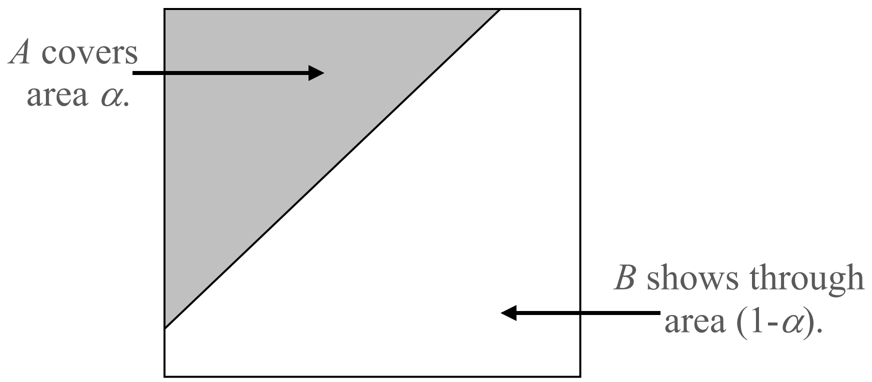
Solution: Interpolate on the border (Not exact, but *fast*)



1	1	.8	.2	0	0	0	0
1	1	1	.7	.1	0	0	0
1	1	1	1	.4	0	0	0
1	1	1	1	.6	0	0	0
1	1	1	1	.6	0	0	0
1	1	1	1	.4	0	0	0
1	1	1	.8	.2	0	0	0
1	1	.9	.3	0	0	0	0

Alpha Compositing

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


A covers area α.
B shows through area (1-α).

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

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

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

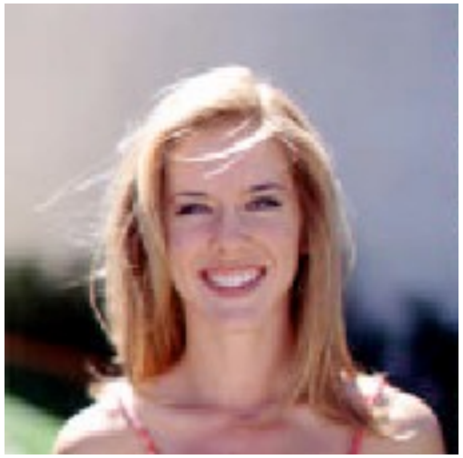
$$b_C = \alpha_A b_A + (1-\alpha_A) b_B$$

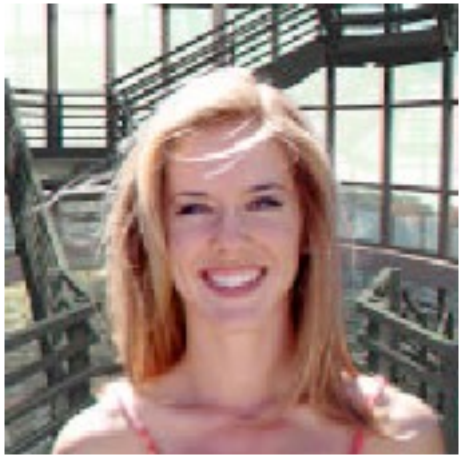
- Clean implementation; 8 more bits makes 32
  - 2 multiplies + 1 add for compositing

Alpha Compositing Example

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

[Chuang et al/ Corel] [Cornell PCG]





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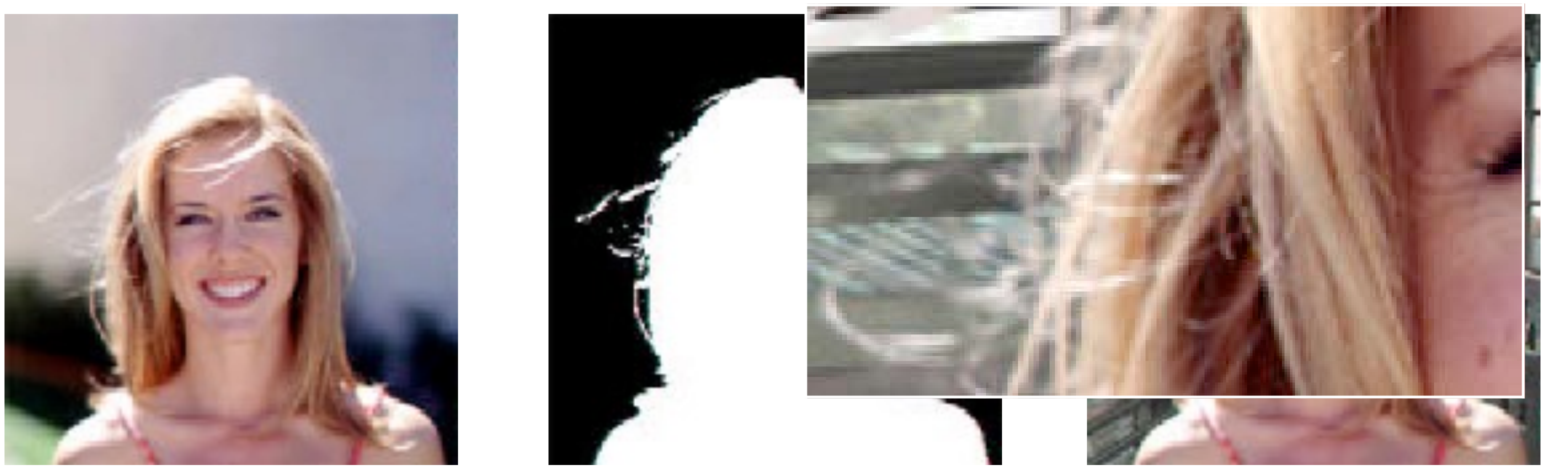


Compositing in LibGDX

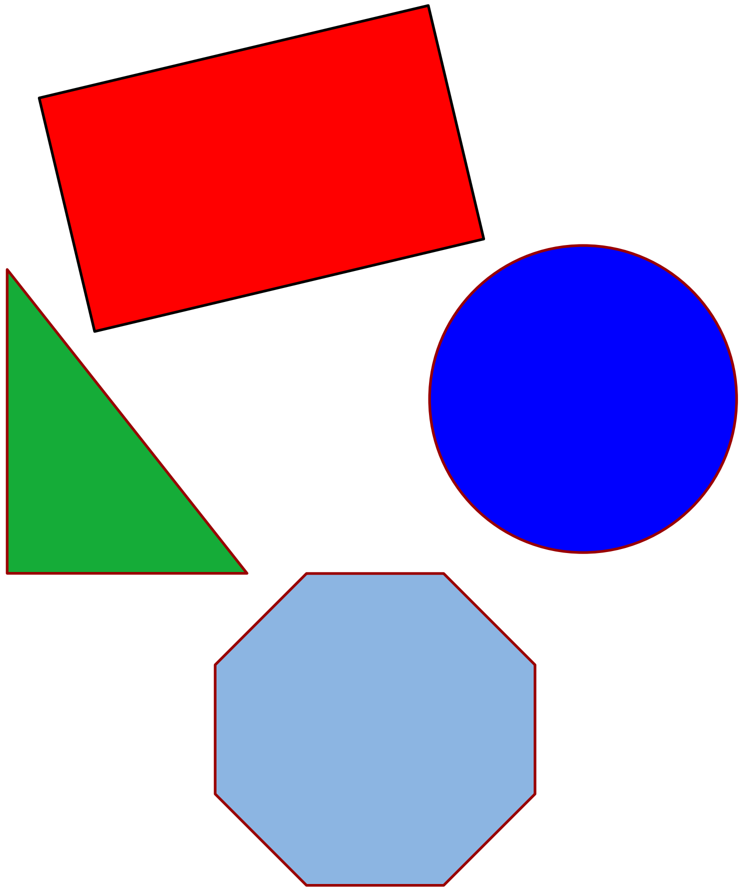
- $\underbrace{\texttt{spriteBatch.setBlendFunction(src, dst);}}_{\text{OpenGL Constants}}$
  - **General Formula**: $c_C = (\texttt{src})c_A + (\texttt{dst})c_B$
- **Alpha Blending**
  - `src = GL20.GL_SRC_ALPHA` (a_A)
  - `dst = GL20.GL_ONE_MINUS_SRC_ALPHA` $(1\text{-}a_A)$
- Colors may be **premultiplied**: $c' = ca$
  - `src = GL20.GL_ONE`
  - `dst = GL20.GL_ONE_MINUS_SRC_ALPHA`

Compositing in LibGDX

- `spriteBatch.setBlendFunction(`$\underbrace{\texttt{src, dst}}_{\text{OpenGL Constants}}$`);`
  - **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`

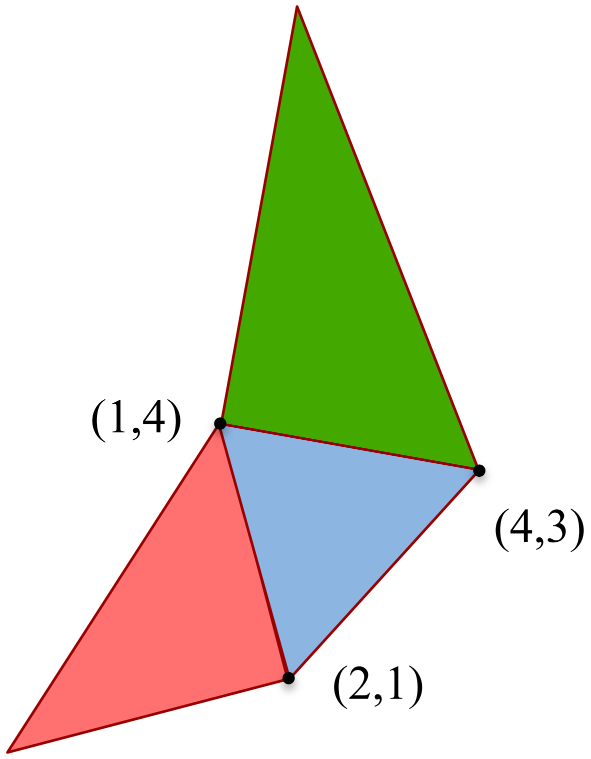
The Problem with Sprites

- 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

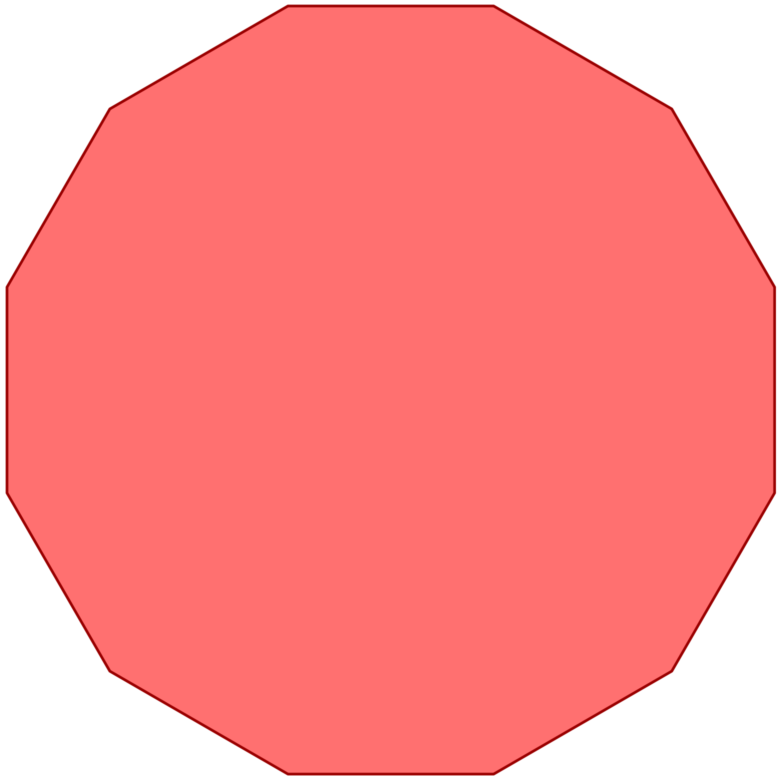


Triangles in Computer Graphics

- 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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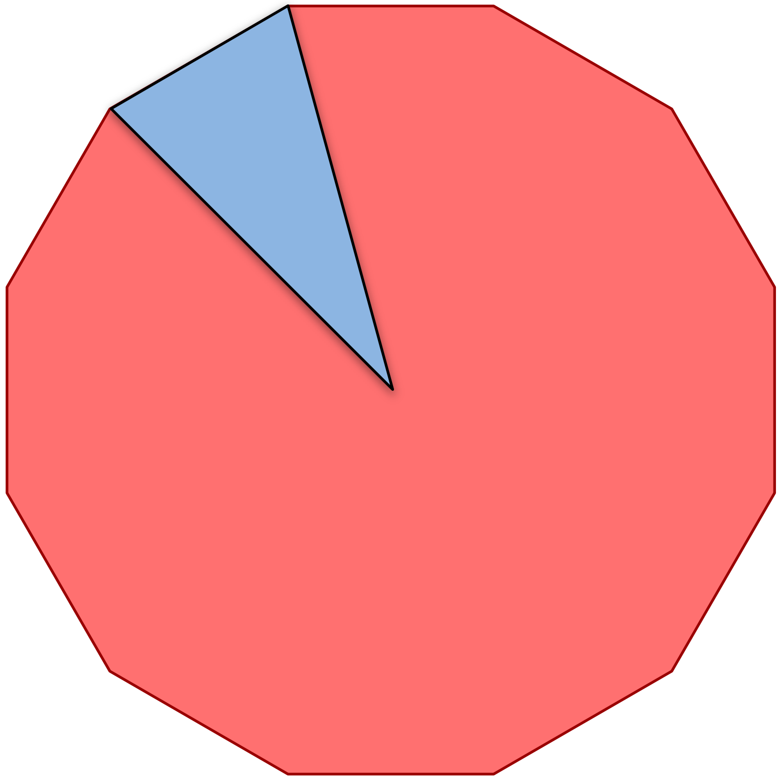

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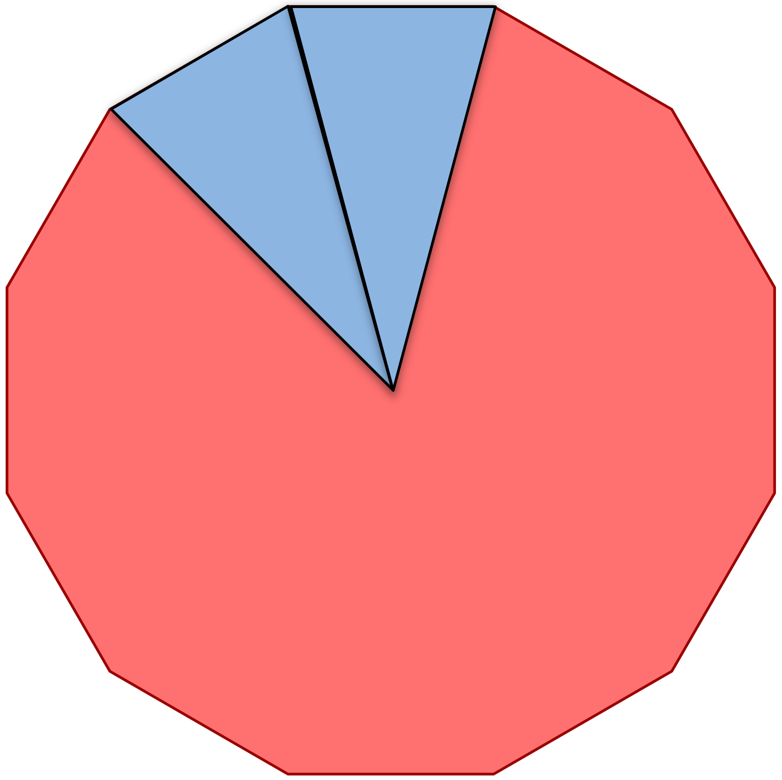

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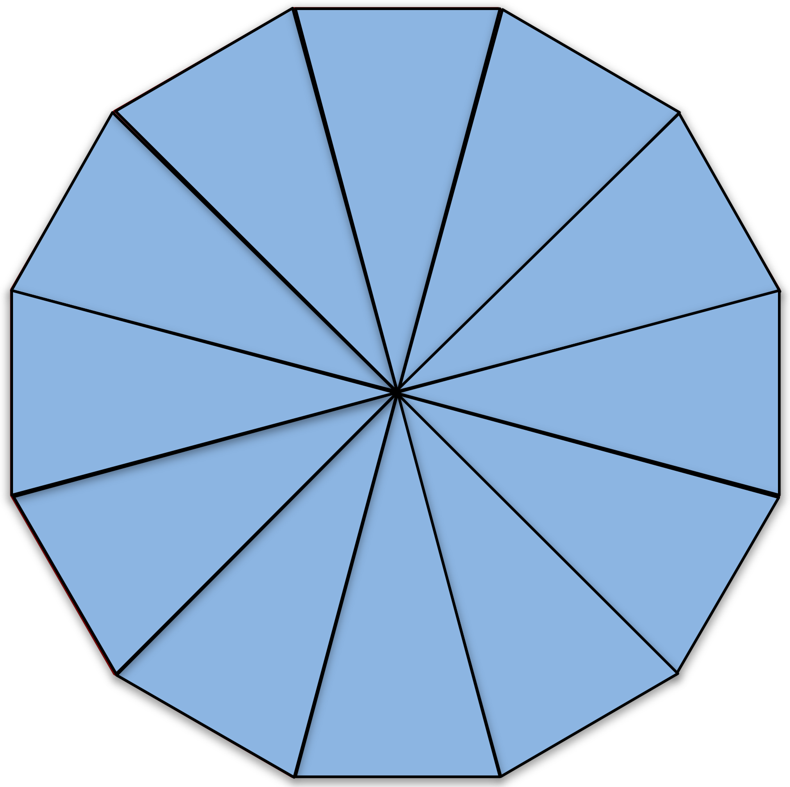
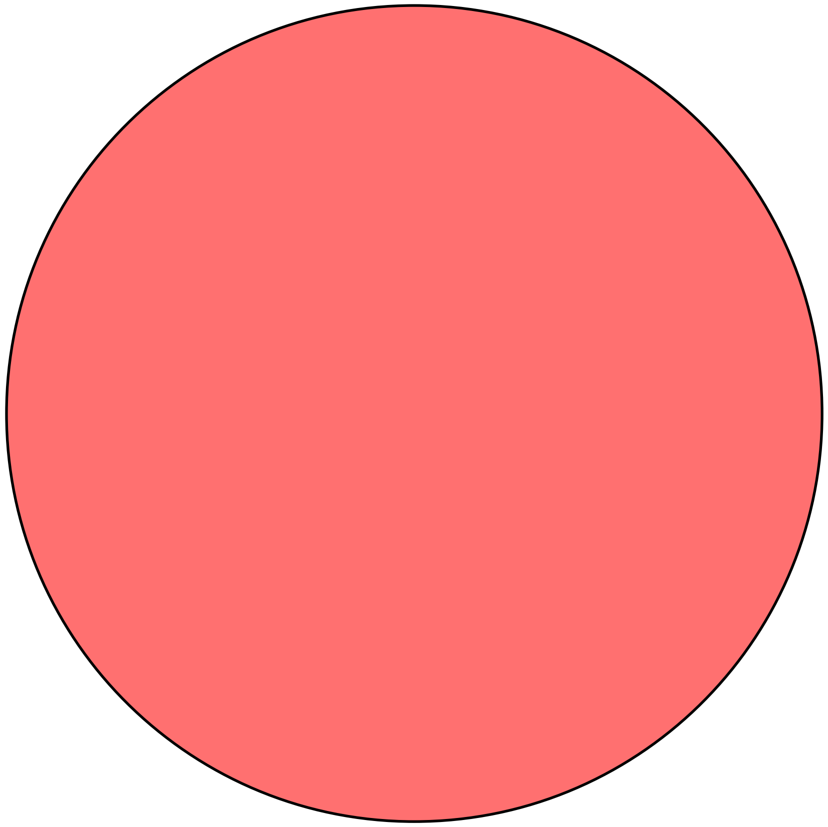


Round Shapes?



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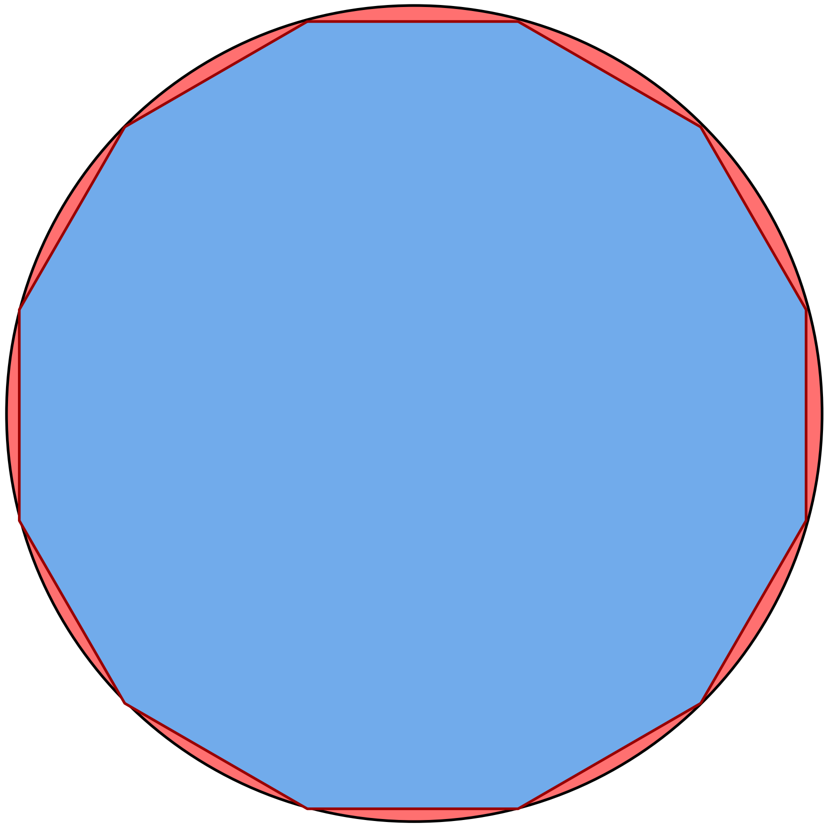
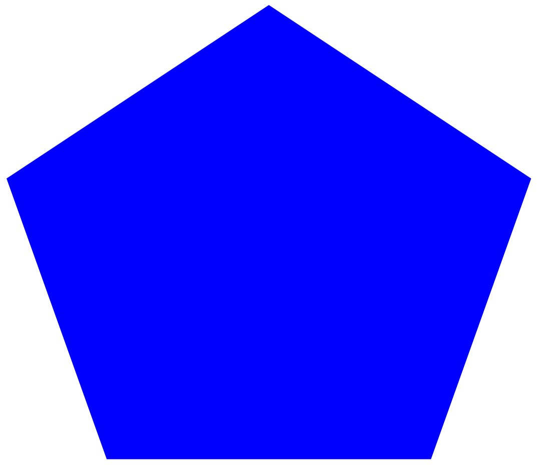


ShapeRenderer in LibGDX

- 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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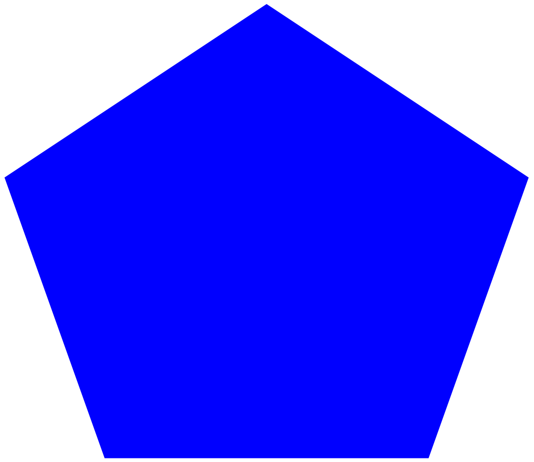

```
render.circle(200, 200, 100, 5);
```

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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render.begin(ShapeRenderer.ShapeType.Filled);
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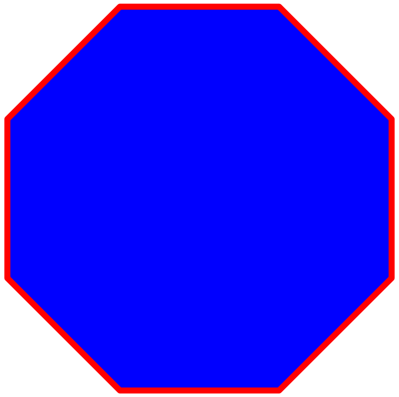

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re                                    peType.Line);
rende     olor(Color.RED);
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render.end();
```

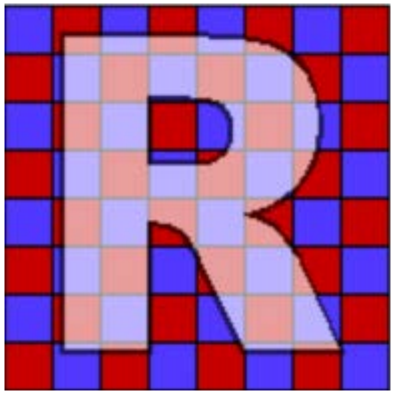
Note separate pass for filled, outline

Why Can’t We Use SpriteBatch?

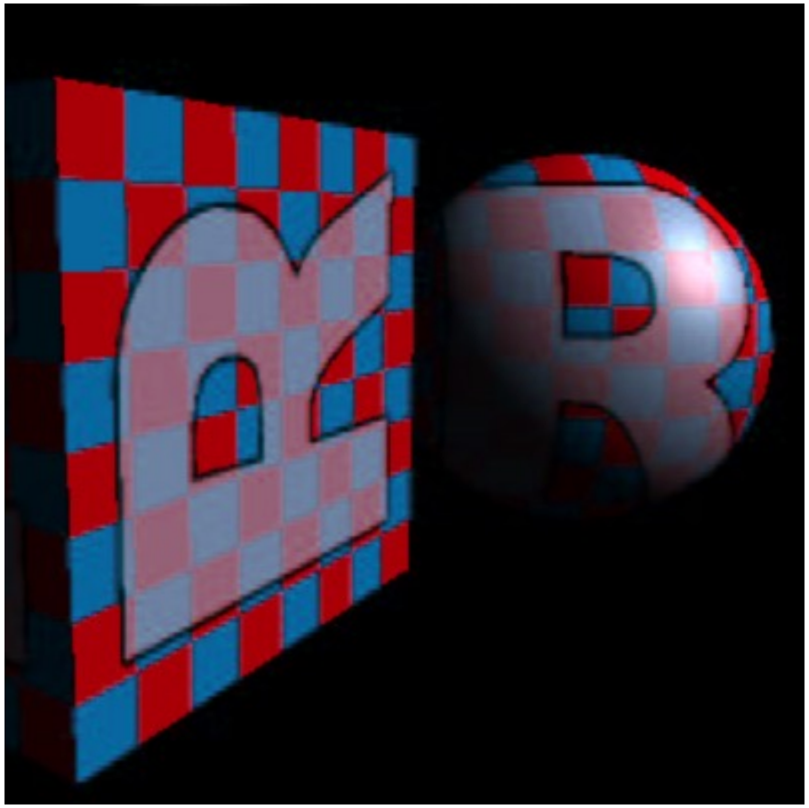
- SpriteBatch needs to have a texture to draw
  - These shapes are just solid colors
  - **But what if we have a white texture?**
- SpriteBatch can only draw solids, not lines
  - But lines have a width to them
  - **So aren’t lines actually just solids?**
- So the real question is…
  - **How do we draw non-rectangular textures?**

Textures

2D Image File



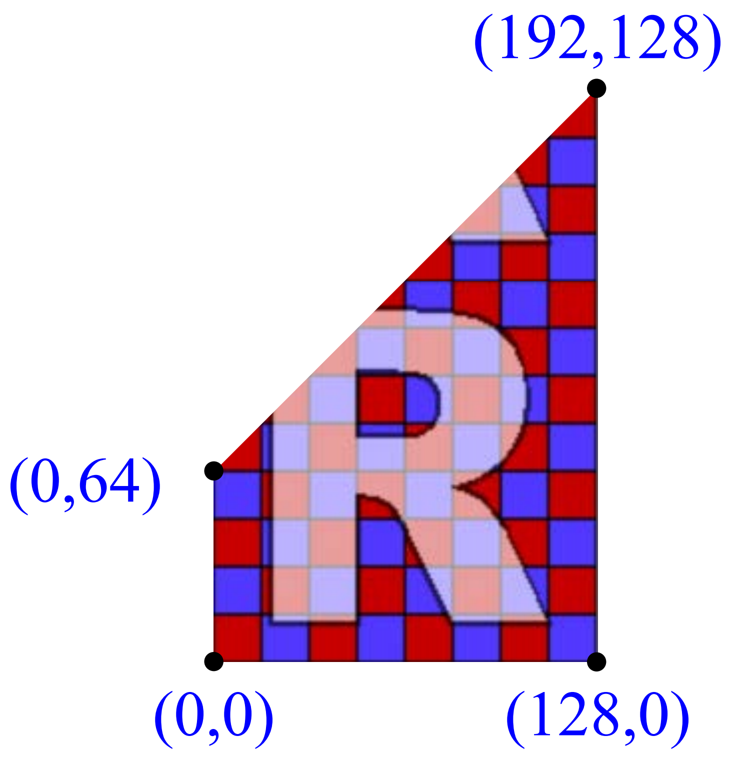
Mapped On To
Polygonal Shape



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

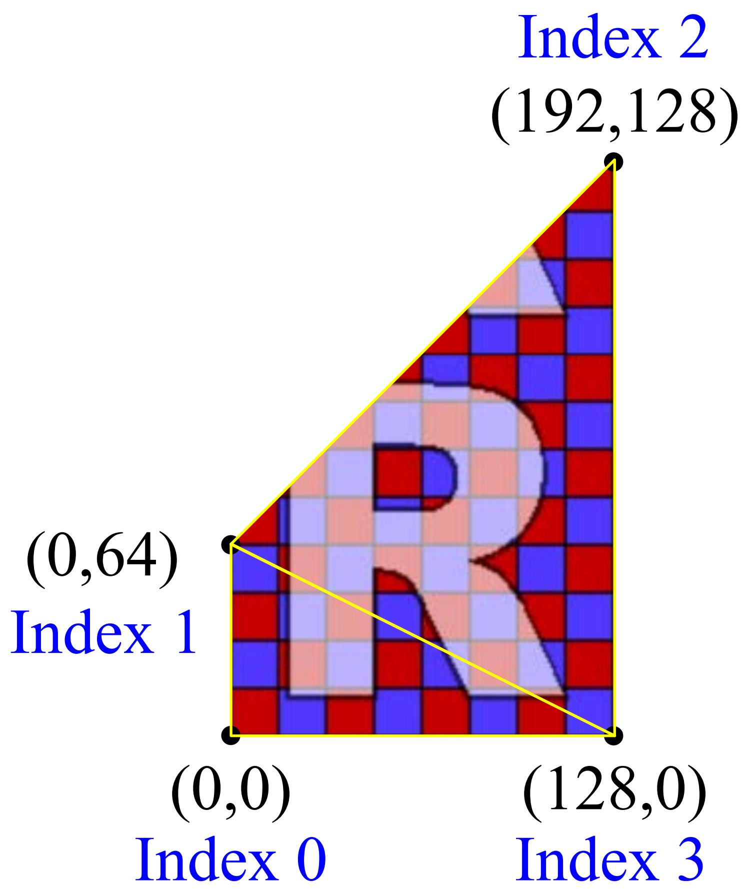
PolygonRegion Example



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

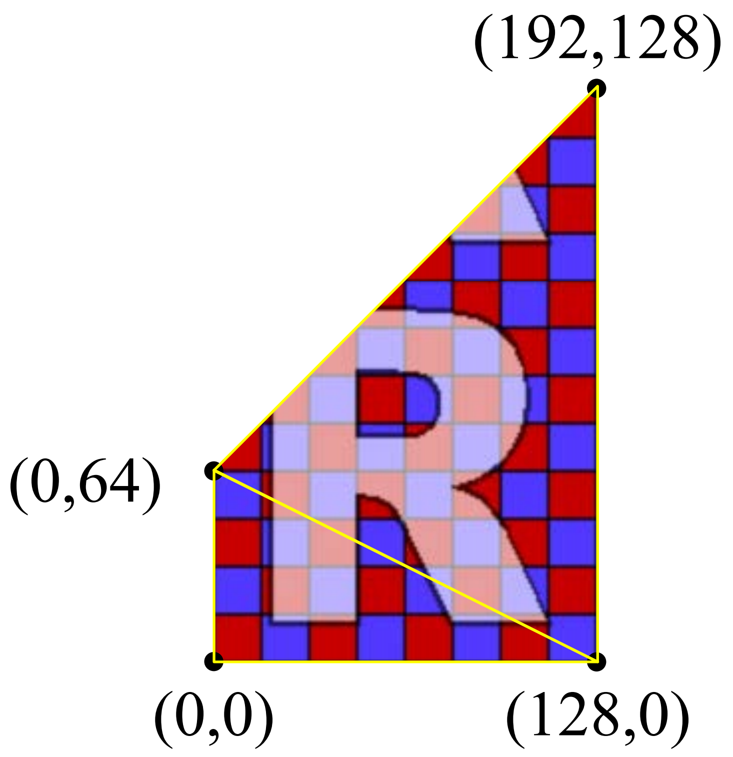


```
verts = {0,0,0,64,192,128,128,0}
tris = {0,1,3,3,1,2}
```

- 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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verts = {0,0,0,64,192,128,128,0}
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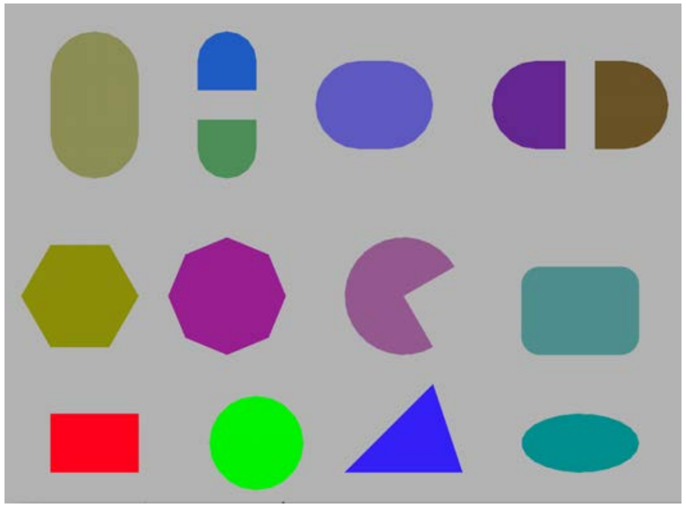
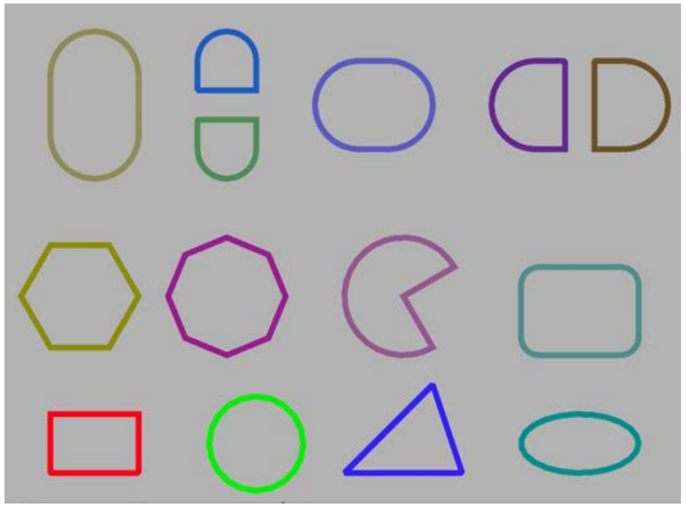
- Create vertices by pixel pos
  - Example texture is 124x124
  - Preferences set to wrap
  - Store as an array of floats
- Must convert into triangles
  - Each vertex has an index
  - Given by position in array
  - Create array of indices
- **Construct `PolygonRegion`**
  - Specify texture
  - Specify vertices+triangles

Replacing ShapeRenderer

- GDIAC has the class Poly2
  - Is a 2D (solid) Polygon
  - Used extensively in CUGL
- Comes with several tools
  - **Triangulation**
  - **Extrusion**
  - **Smoothing**
- Can make a PolygonRegion
  - Just give it a texture
  - Pass to PolygonSpriteBatch

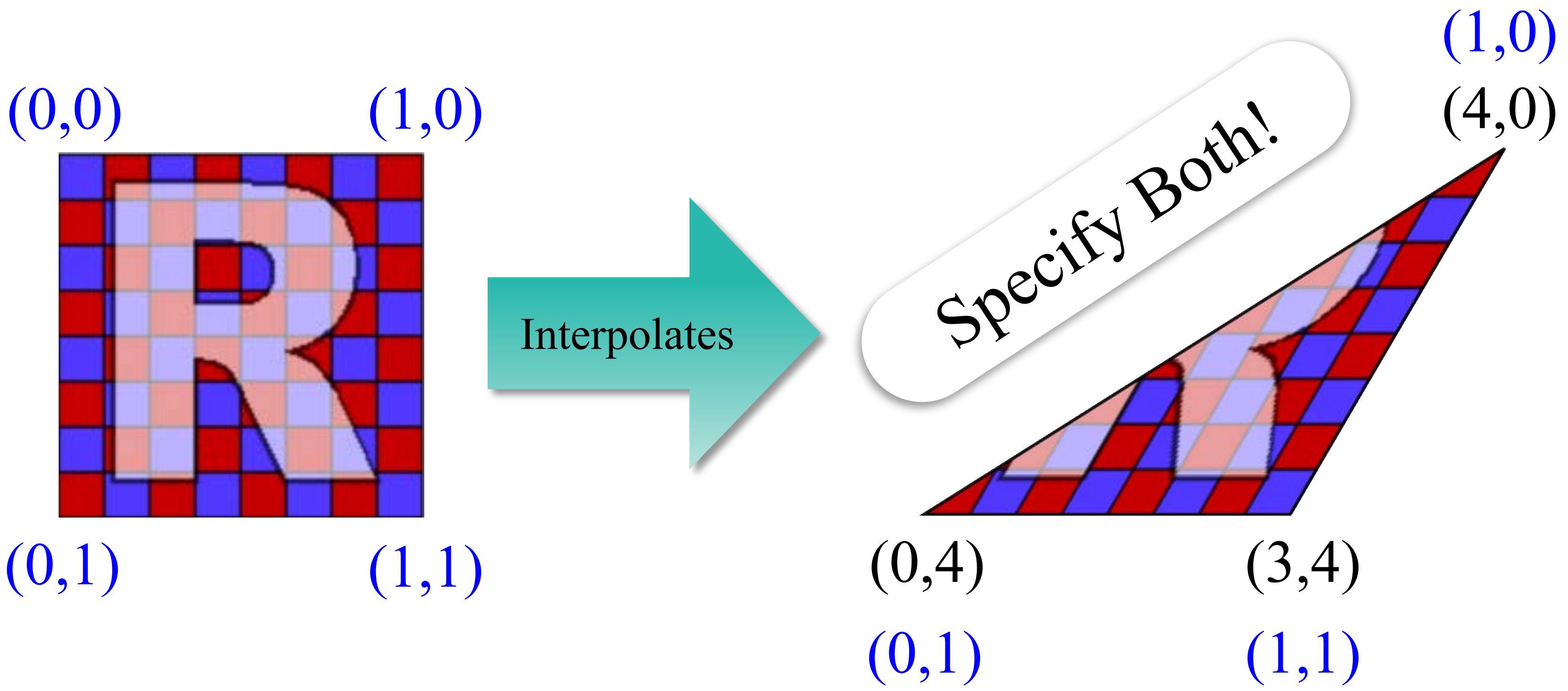




What If I Know OpenGL?

- 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
  - It is not the default OpenGL in LibGDX
  - Requires special DesktopLauncher settings
- See **Programming Lab 2** for examples
  - Uses a custom OpenGL shader
  - Also advanced LibGDX classes like Mesh

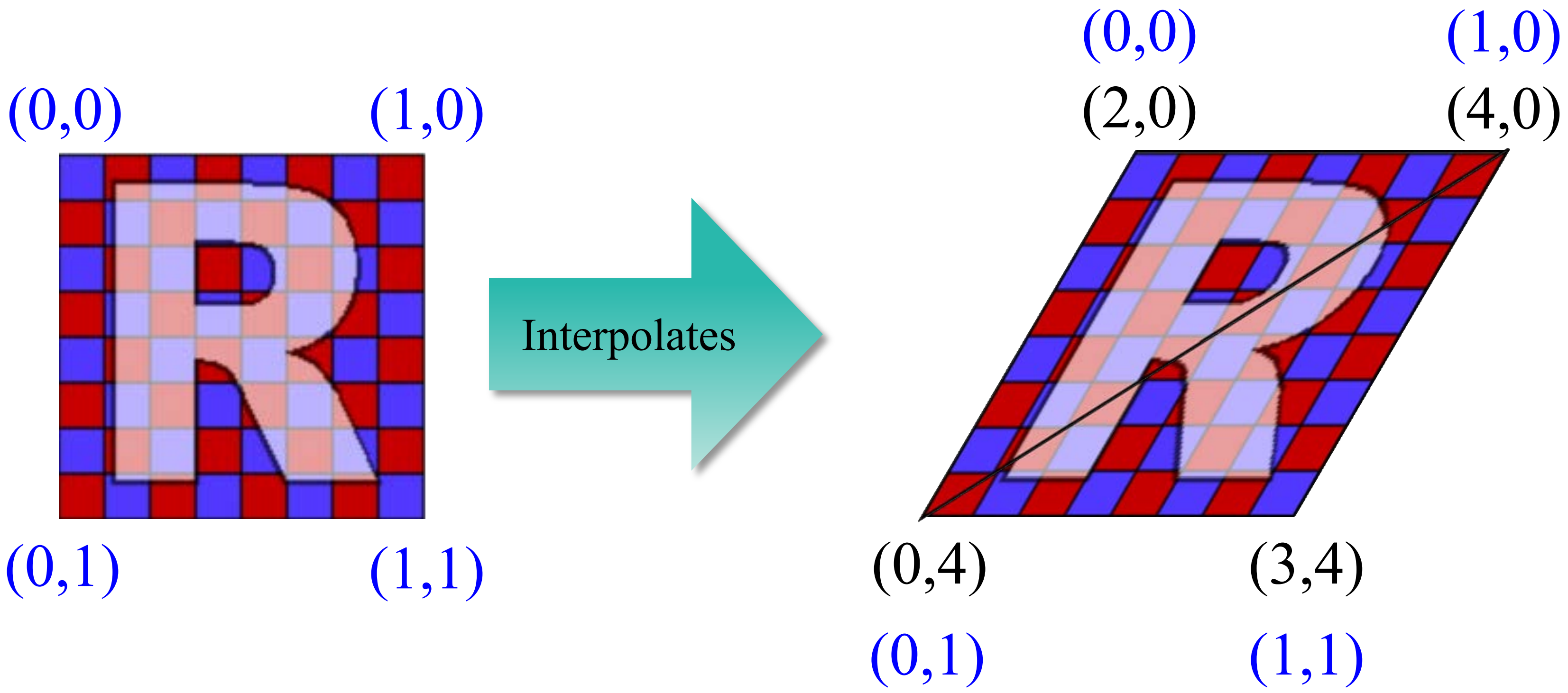
OpenGL Texturing



Texture Coordinates
(even if not square)

Triangle Coordinates

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