Lecture 17

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
Color Blending Example

- blue
- red
- green

Color & Texture
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

<table>
<thead>
<tr>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>01011010</td>
<td>00000010</td>
<td>00011111</td>
</tr>
<tr>
<td>01011010</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

![Image showing the difference between images with and without alpha channel](Adobe Photoshop Samples, CS 465 Slides)
Color Composition

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

  ![Images of A and B with t = 0.0]

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

  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**
Color Composition

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

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  • This is an example of linear interpolation

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\end{align*}
\] per pixel calculation
Color Composition

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

  ![Trivial example: Video crossfade](image)

  ▪ Note sums weight to 1.0
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  ▪ No out-of-range results
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]\]  

per pixel calculation
Color Composition

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  ![Images of A, B, and a blend at t = 0.8](images)

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per pixel calculation

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- This is an example of **linear interpolation**
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?”
  - Does not work well near the edges
Binary Image Mask

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Binary Image Mask

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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 $\alpha$

  \[ C = A \text{ over } B \]

  \[ r_C = \alpha_A r_A + (1 - \alpha_A) r_B \]

  \[ g_C = \alpha_A g_A + (1 - \alpha_A) g_B \]

  \[ b_C = \alpha_A b_A + (1 - \alpha_A) b_B \]

- 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]
[Chuang et al./Cornell PCG]
Alpha Compositing Example

- Repeat previous with grey scale mask
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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` \( (1-a_A) \)

- 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**: \( c_C = (src)c_A + (dst)c_B \)

- **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
Triangulation of Polygons
Triangulation of Polygons
Triangulation of Polygons
Round Shapes?
Round Shapes?

Color & Texture
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

```java
render.circle(200, 200, 100, 5);
```
ShapeRenderer in LibGDX

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```java
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```

Number of triangles
ShapeRenderer Example

```java
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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Note separate pass for filled, outline
Textures

2D Image File

Mapped On To Polygonal Shape

Color & Texture
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 PolygonObject in Lab 4
PolygonRegion Example

- 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

verts = \{0,0,0,64,192,128,128,0\}
PolygonRegion Example

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- Construct PolygonRegion
  - Specify texture
  - Specify vertices+triangles

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
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- 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

```python
vertices = [0, 0, 0, 64, 192, 128, 128, 0]
triangles = [0, 1, 3, 3, 1, 2]

new PolygonRegion(img, 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
  - Not supported by 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

Texture Coordinates (even if not square)

(0,0)   (1,0)

(0,1)   (1,1)

Interpolates

(0,4)   (3,4)

(0,1)   (1,1)

Specify Both!

Triangle Coordinates

(1,0)   (4,0)
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