the gamedesigninitiative at cornell university

Lecture 14

Geometry & Texture

Graphics Lectures

- Drawing Images
  - Coordinates & Transforms
  - Images & Colors

bare minimum to draw graphics

- Drawing Perspective
  - Camera
  - Projections

side-scroller vs. top down

- **Drawing Primitives**
  - Meshes
  - Shaders

necessary for lighting & shadows

The OpenGL Conundrum

- LibGDX is built on top of **OpenGLES**
  - Mobile version of OpenGL, for targeting Android
  - Supported on desktop (Windows, macOS) also
- LibGDX uses **OpenGLES 2.0**
  - This is an ancient version **deprecated 15 years ago**!
  - LibGDX too much legacy code to support newer versions
- GDIAC extensions support **OpenGLES 3.0**
  - Most recent version of OpenGLES
  - Future platforms are likely moving to **Vulkan**

The OpenGL Conundrum

- LibGDX is built on top of **OpenGLES**
  - Mobile version of OpenGL, for targeting Android
  - Supported on desktop (Windows, macOS) also
- LibGD
  - This **o**!
  - LibG ersions
- GDIAC extensions support **OpenGLES 3.0**
  - Most recent version of OpenGLES
  - Future platforms are likely moving to **Vulkan**

But the GDIAC extensions are backward compatible

Why Does This Matter?

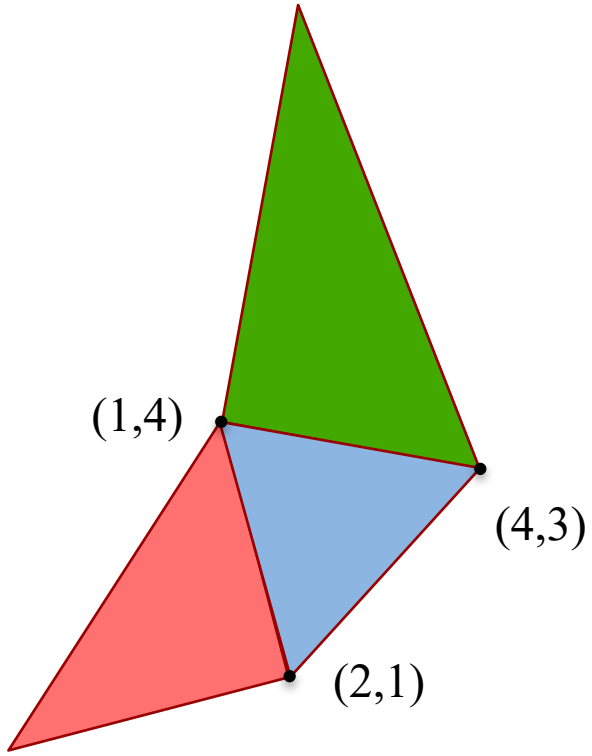
- OpenGL relies on **shader programs**
  - Instruct the graphics card what to do
  - Written in a graphics language like GLSL
  - Loaded when your game first starts
- OpenGLES 2.0 and 3.0 are **not compatible**
  - They use different dialects of GLSL
  - GDIAC supports both kinds of shaders
  - LibGDX only supports OpenGLES 2.0
- This matters if you want your own shaders

Controlling the OpenGL Version

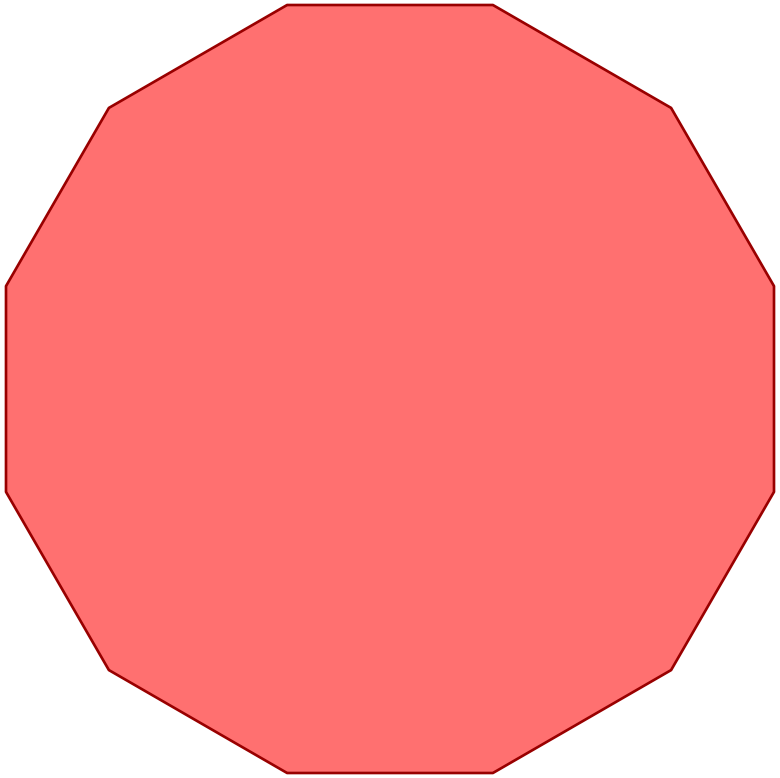
- LibGDX has **two** OpenGLES interfaces
  - `Gdx.gl20` // Never null, even if using 3.0
  - `Gdx.gl30` // Null only if using 2.0
- We set the version in `DesktopLauncher`
  - Option `config.useGL30`
  - Value is `true` by default
- You almost never need to change this
  - Only needed if using legacy LibGDX features
  - **Example:** ShapeRenderer

Drawing In OpenGL

- Everything is 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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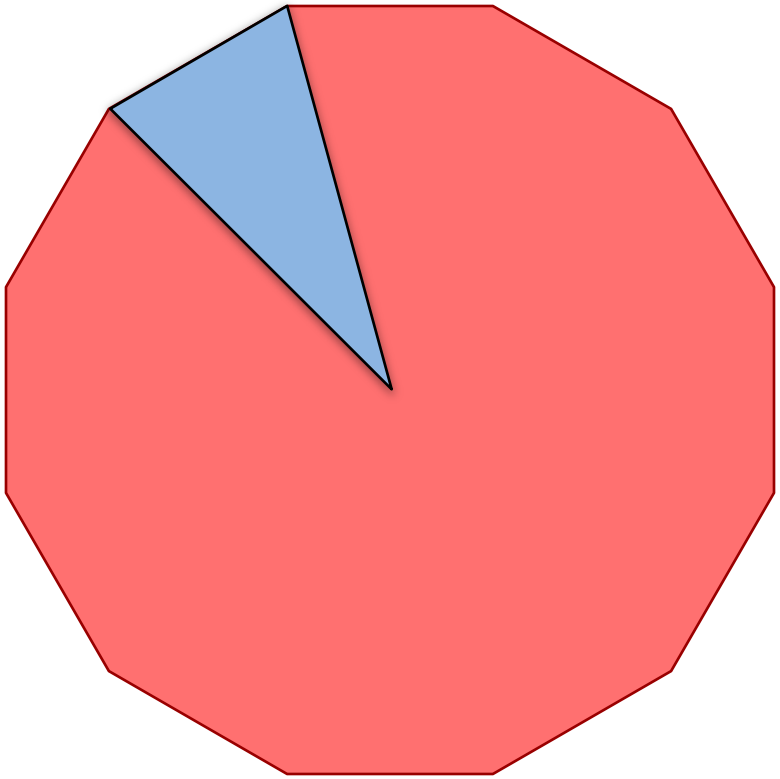

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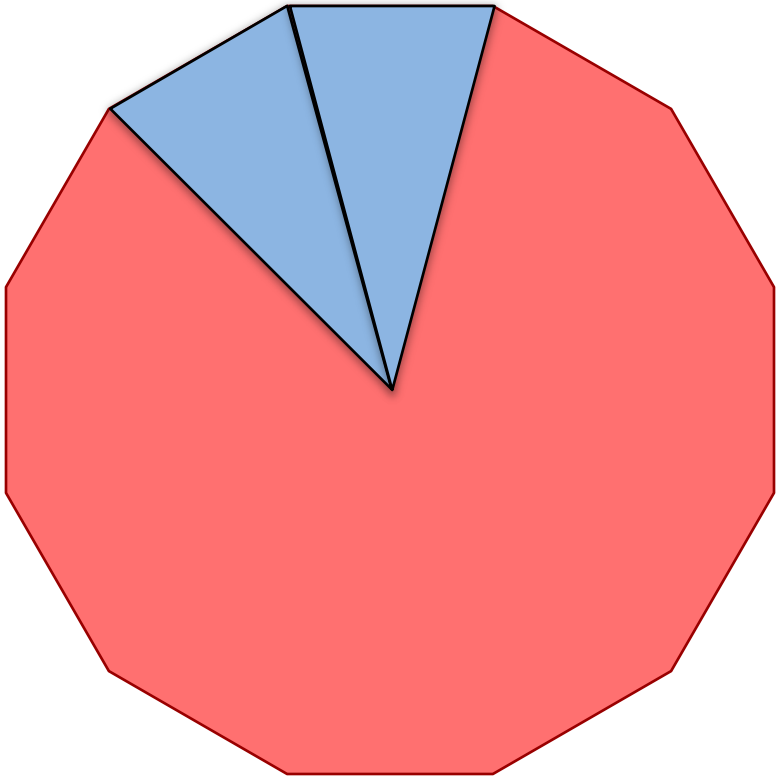

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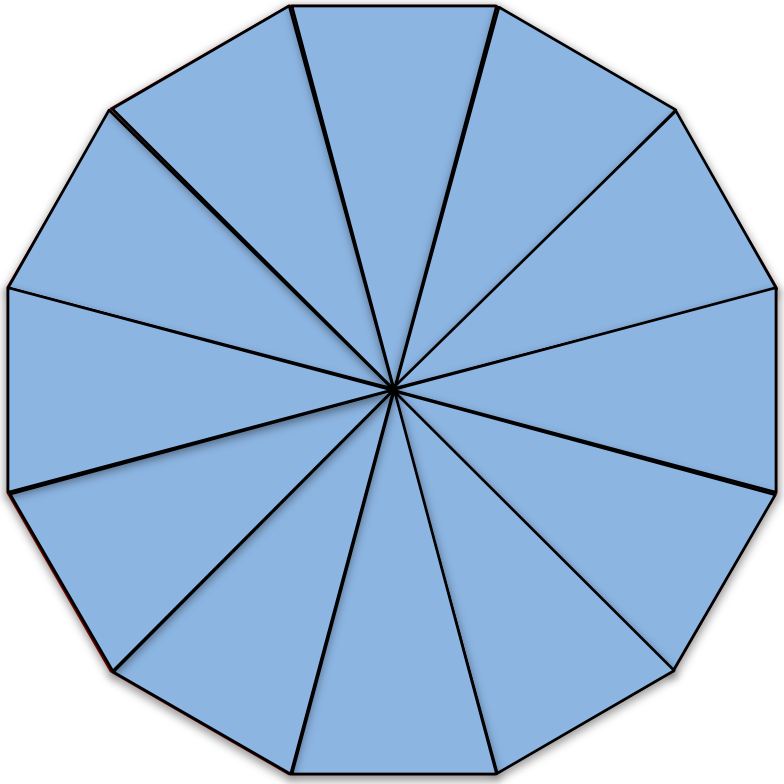
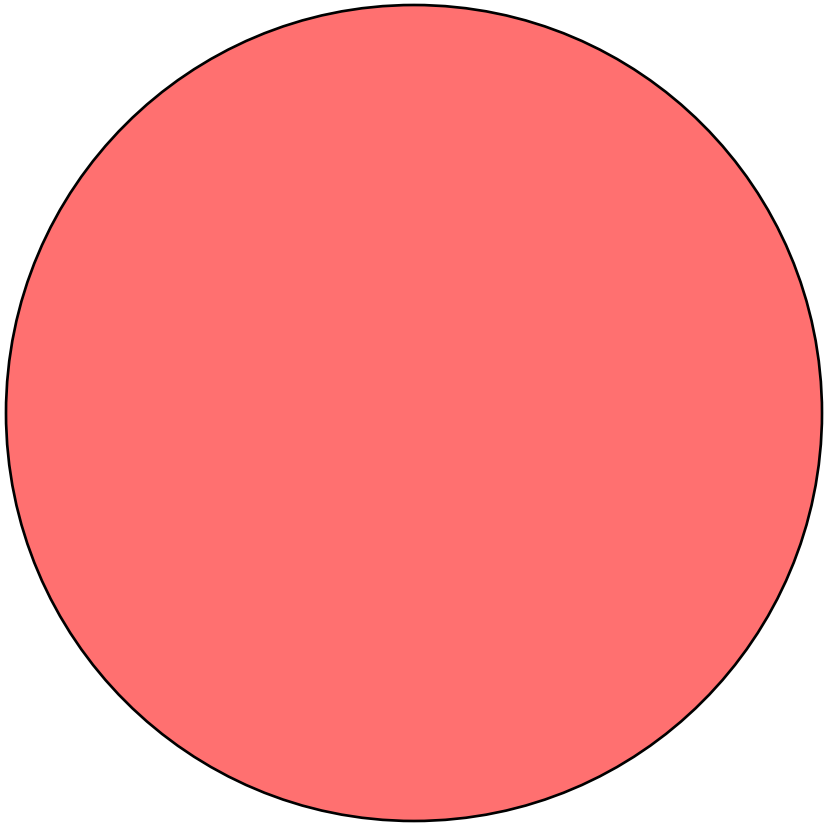


Round Shapes?



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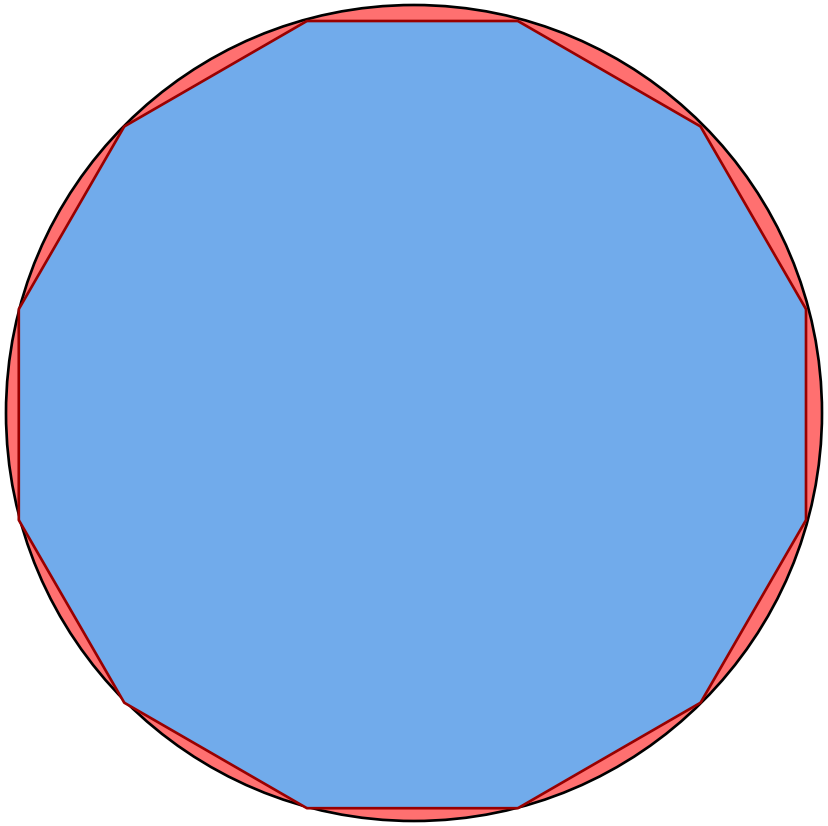
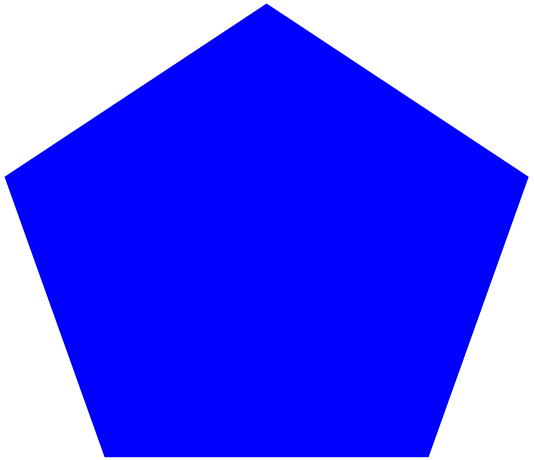


Legacy LibGDX: ShapeRenderer

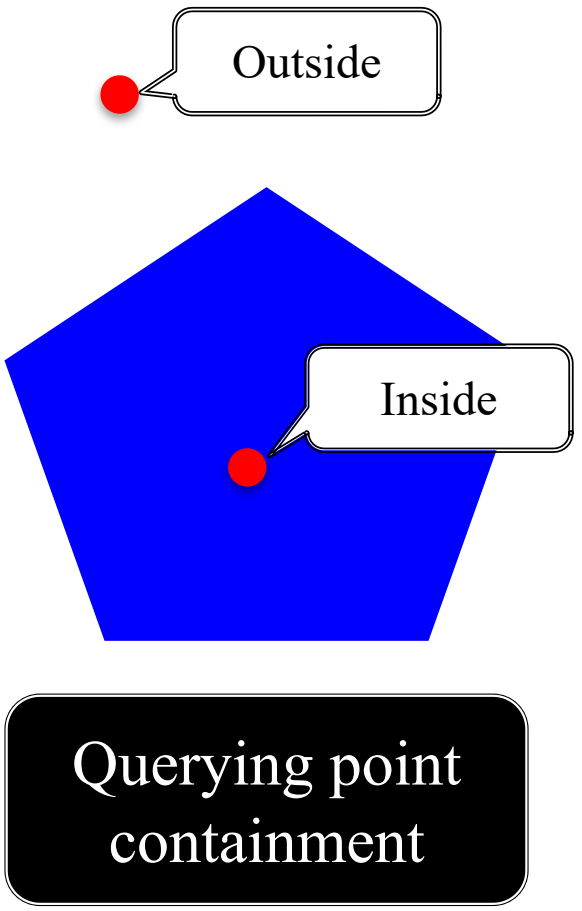
- Tool to draw triangles
  - Specify a general shape
  - Makes the triangles for you
- Works like a SpriteBatch
  - Has a begin/end
  - Several draw commands
- Hard to mix with SpriteBatch
  - Requires a separate **pass**
  - End one before begin other
  - Made our code really messy



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

The Problem with ShapeRenderer

- It is just a drawing tool
  - Only draws shapes on screen
  - Does not keep any **geometry**
- Shapes are very limited
  - Triangles, rectangles, circles
  - Often a lot of manual work
- Conflates two issues
  - Computational geometry
  - Shape rendering
- We need a better solution



Computational Geometry

- Study of the **representation** of geometric shapes
  - Data structures to store complex shapes
  - Algorithms to generate complex shapes
- GDIAC tools allow us to do more than drawing
  - Query point containment
  - Intersect two shapes with each other
  - Break up a shape into triangles
  - Control Bezier splines
- Found in package `edu.cornell.gdiac.math`

Computational Geometry

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  - Qu
  - Int
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GDIAC SpriteBatch makes ShaperRenderer redundant

- Found in package `edu.cornell.gdiac.math`

The Primary Classes

Poly2

- Represents a **solid** shape
- Built from **triangles**
- `PolyFactory` for basic shapes
- Draw with `fill` method
  - Use Affine2 to position
  - Can be colored or textured

Path2

- Represents a shape **outline**
- Built from **line segments**
- `PathFactory` for basic shapes
- Draw with `outline` method
  - Use Affine2 to position
  - Can be colored or textured

These are also useful for physics!

Example Using Factories

```
PathFactory pathTool = new PathFactory();
PolyFactory polyTool = new PolyFactory();

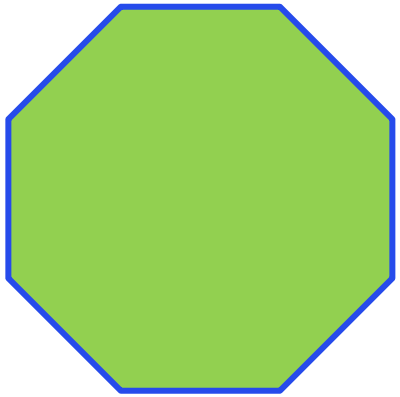
Poly2 interior = polyTool.makeNgon(200, 200, 100, 8);
Path2 border = pathTool.makeNgon(200, 200, 100, 8);

batch.begin(camera);

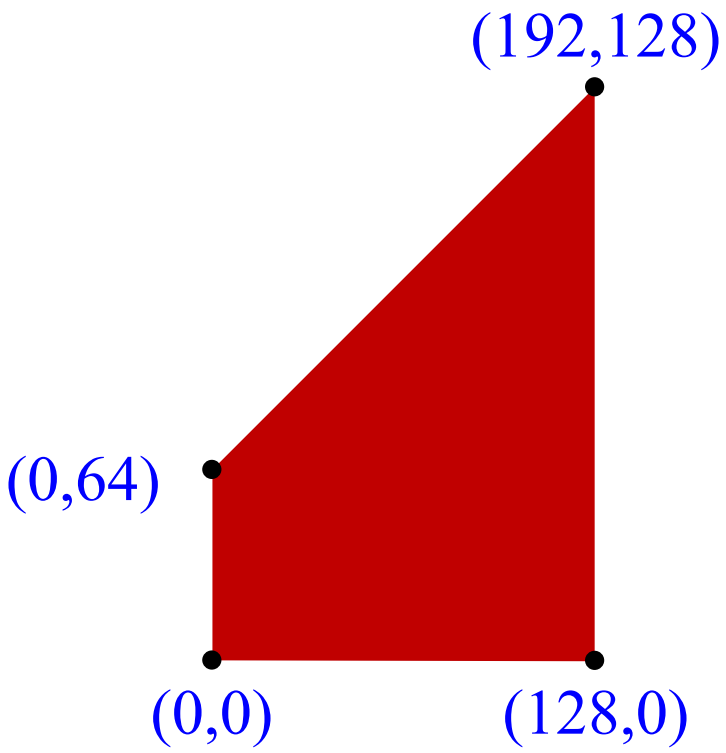
batch.setColor(Color.GREEN);
batch.fill(interior, transform);

batch.setColor(Color.BLUE);
batch.outline(border, transform);

batch.end();
```



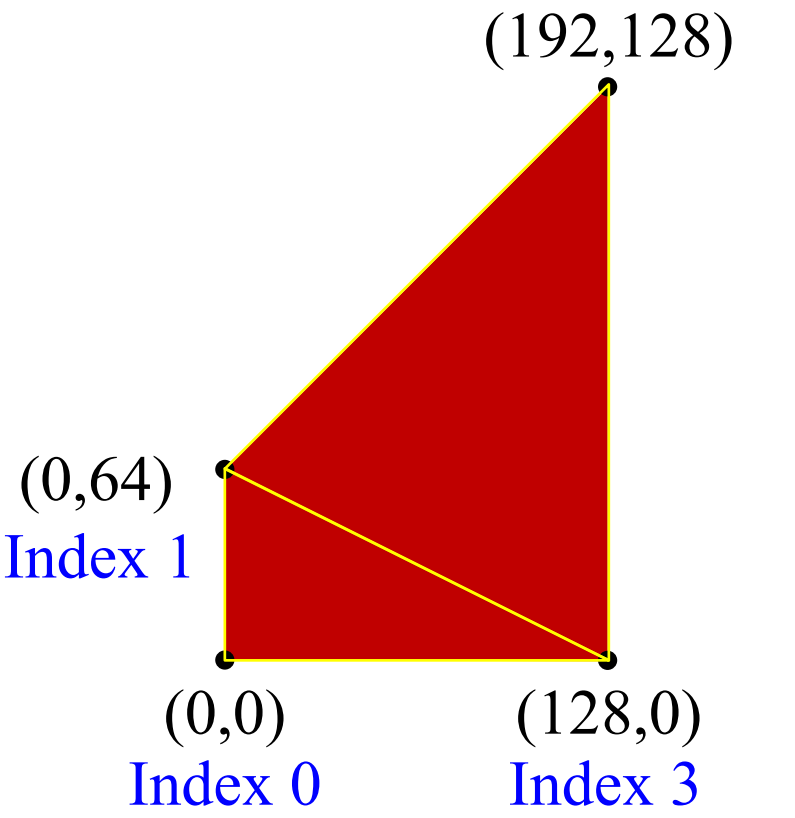
Understanding Poly2




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

- Built up from **vertices**
  - Coordinates in 2d space
  - Stored as an array of floats
  - Transform with Affine2
- Must convert into triangles
  - Each vertex has an index
  - Given by position in array
  - Create array of indices
- `Path2` is much simpler
  - Only vertices in array
  - Connects adjacent vertices

Understanding Poly2



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

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

- Built up from **vertices**
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  - Transform with Affine2
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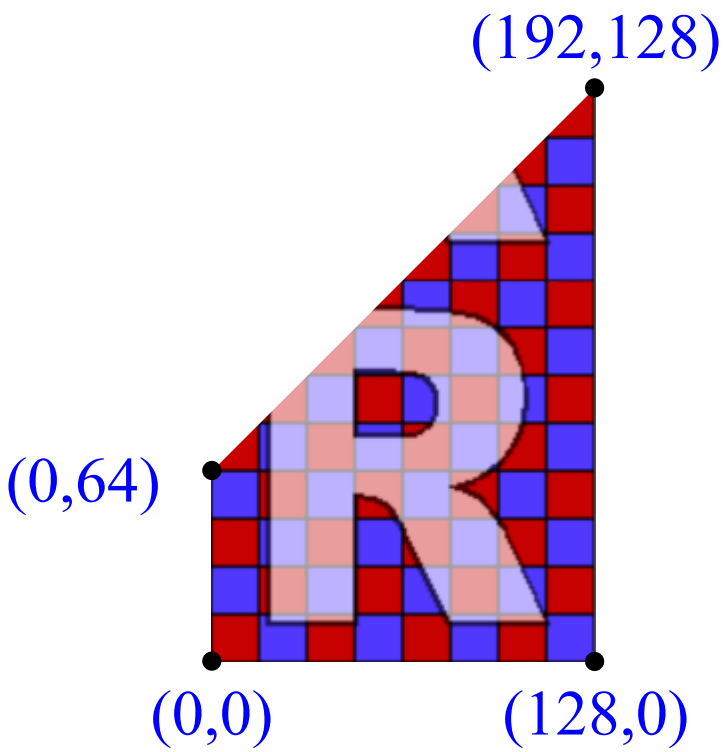
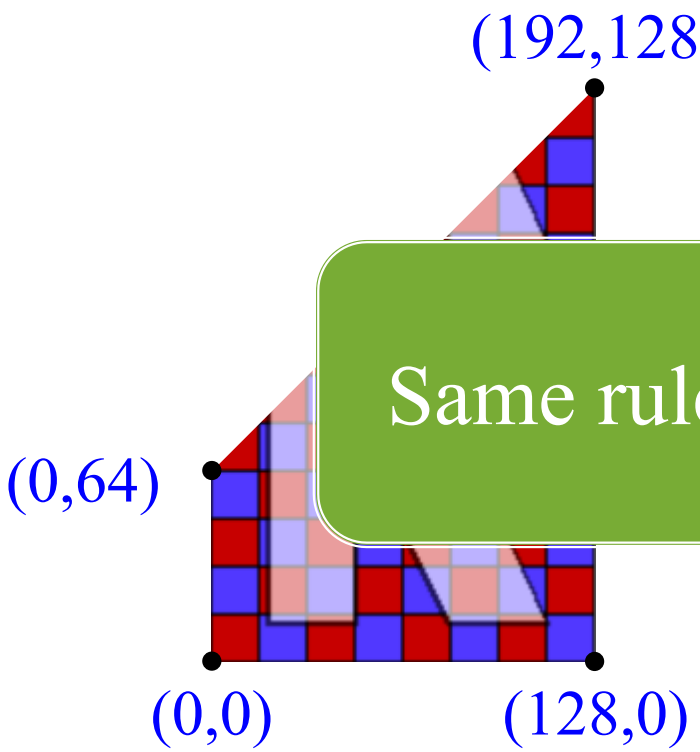
Poly2 and Textures



- Poly2 can be **textured**
  - Fill is an image, not a color
  - Solid colors use null texture
- Works like a **cookie cutter**
  - Treat as object coordinates
  - Vertices are pixel locations
  - Uses image inside of shape
- What if goes out of bounds?
  - Example texture is 128x128
  - Depends on texture settings
  - Options: **repeat** or **clamp**

Poly2 and Textures

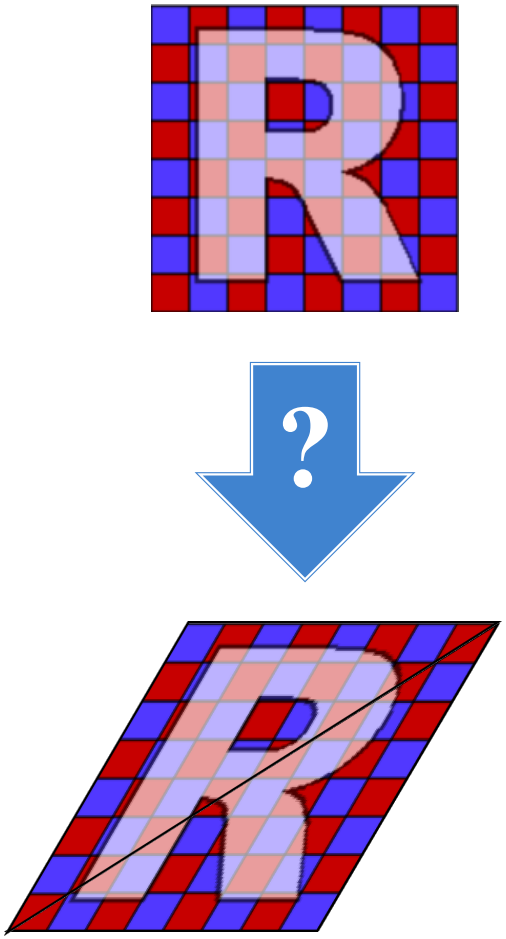


Same rules apply to Path2

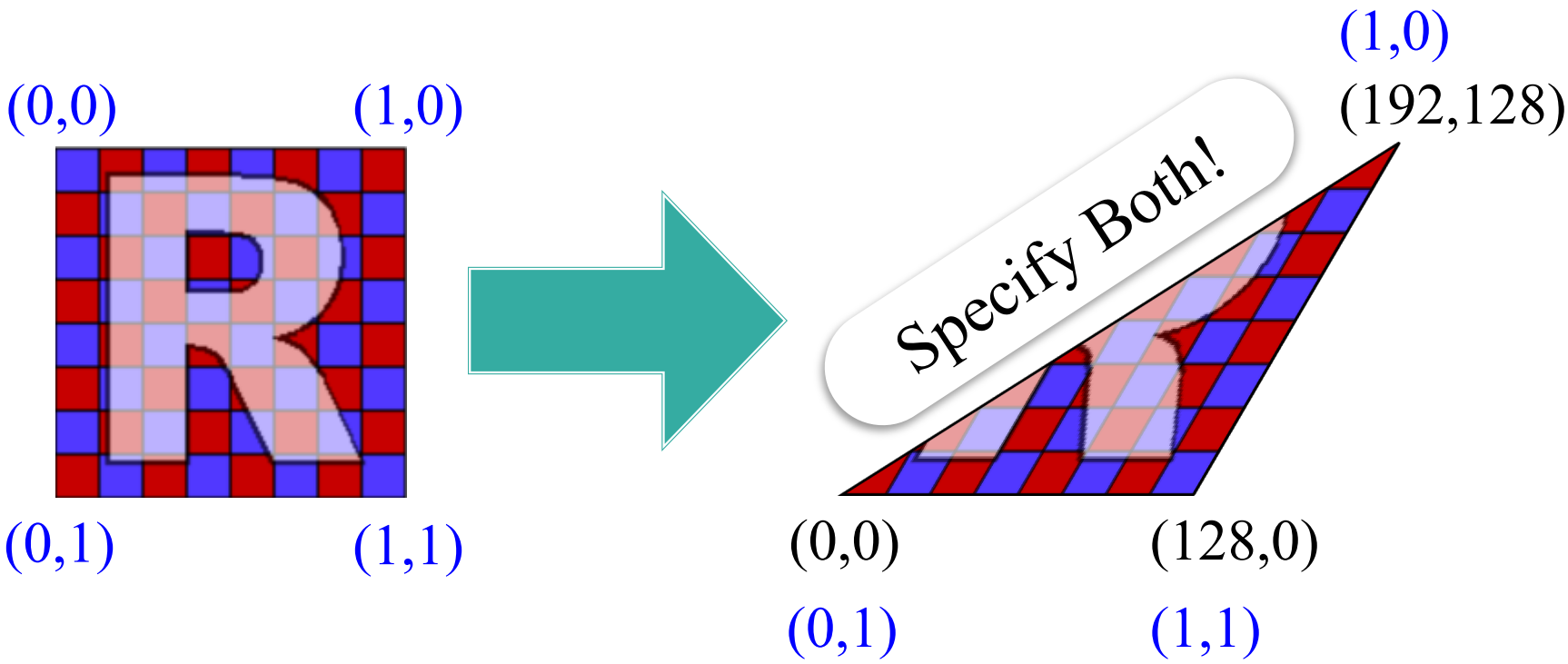
- Poly2 can be **textured**
  - Fill is an image, not a color
  - Solid colors use null texture
- Works like a **cookie cutter**
  - t coordinates
  - xel locations
  - side of shape
- What if goes out of bounds?
  - Example texture is 128x128
  - Depends on texture settings
  - Options: **repeat** or **clamp**

Limitation of Poly2

- Texturing is by **cookie cutter**
  - Stretching shape changes area
  - Does **not** stretch the image
  - Also depends on image **size**
- Want more design flexibility
  - Want to "pin" image to shape
  - Image moves with vertices
- **Idea**: Two sets of vertices
  - One to represent the Poly2
  - Another for the image pixels
  - Must support texture swapping



Texture Coordinates are Percentages



Texture Coordinates
(even if not square)

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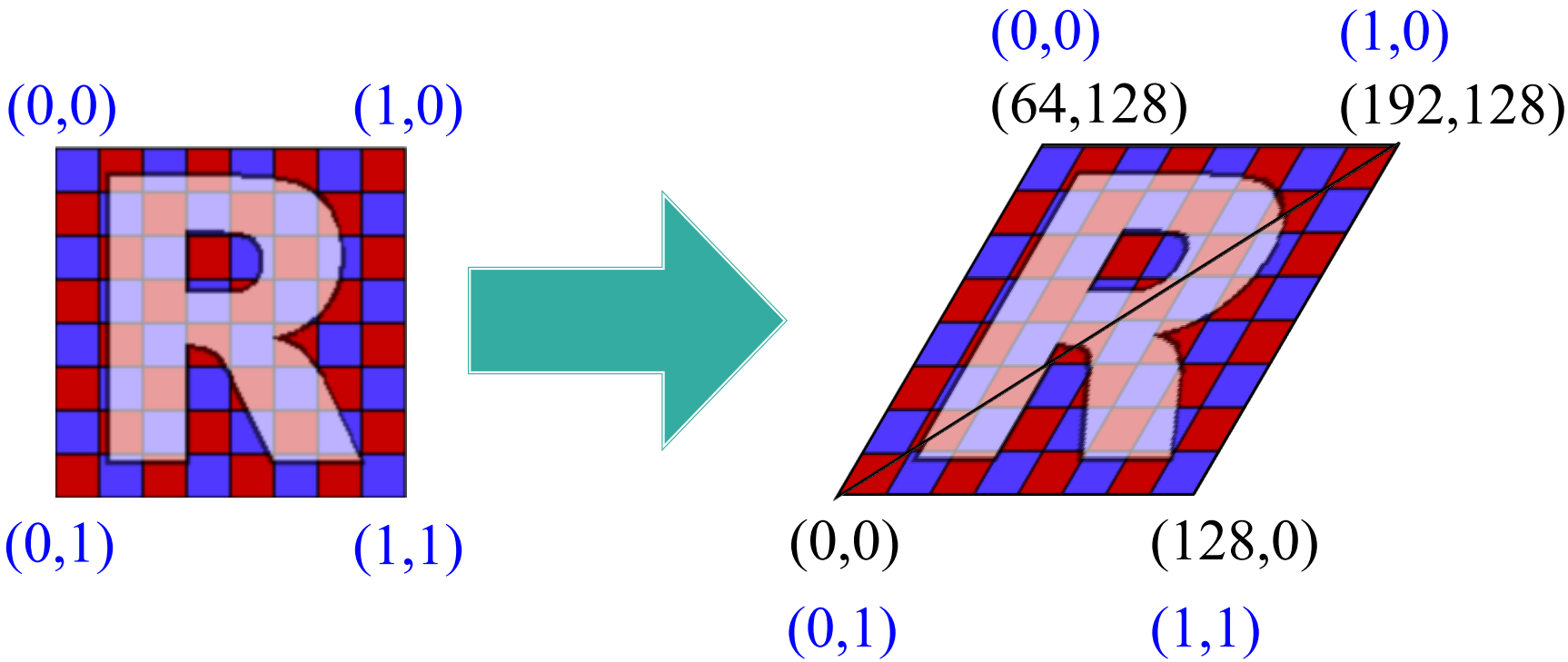
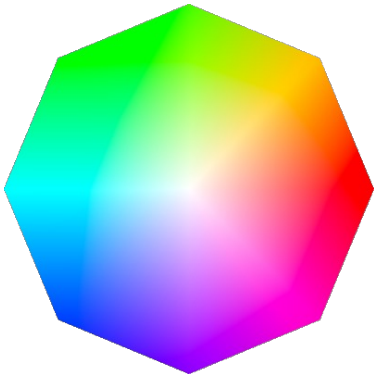


Texture Coordinates
(even if not square)

Triangle Coordinates
(more than one triangle)

GDIAC Support: SpriteMesh

- Very similar to `Poly2`
  - Specify individual vertices
  - Specify triangles as indices
  - Constructor takes a `Poly2`
- But for each vertex can add
  - Individual color
  - Texture coordinates
  - Gradient coordinates (?)
- Used heavily in **Lab 4**
  - Build Poly2 for box2d
  - Then define a `SpriteMesh`

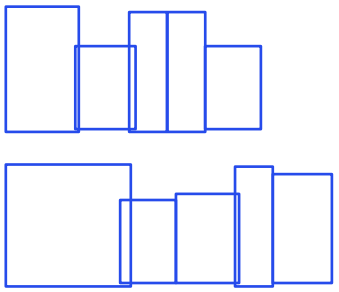


SpriteBatch Revisited

- `SpriteMesh` objects are **composable**
  - Each mesh has two arrays: vertices, indices
  - Concatenating vertices makes a new mesh
  - Indices are added and concatentated
- `SpriteBatch` makes one large `SpriteMesh`
  - Each draw command adds to the mesh
  - The final `end()` draws the mesh to the screen
  - **Exception:** Also draws if mesh gets too large
- Very efficient for sending to graphics card

SpriteBatch and Text

- Each `Font` has a texture
  - Image with letters pre-drawn
  - Reason you specify font size
- `TextLayout` makes a **mesh**
  - Positions from font metrics
  - Includes *kerning*, *alignments*
  - Vertices include texture cords
- This makes text **very fast**
  - Generating vertices is quick
  - Actual font cached in texture



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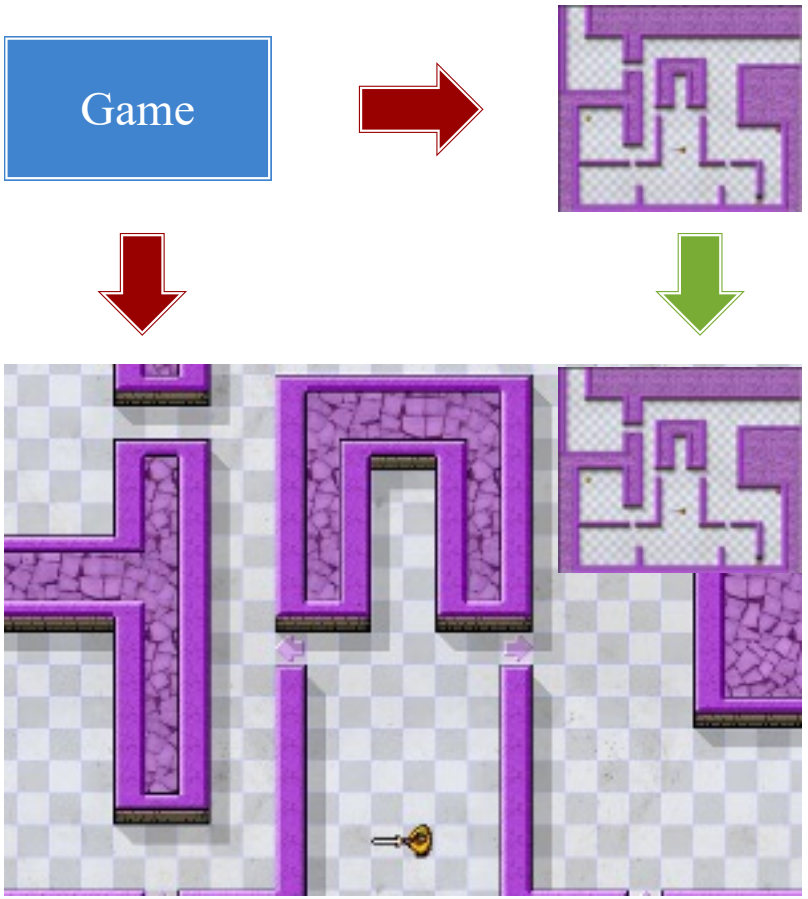
Offscreen Rendering

- Can create *dynamic* textures
  - Draw an image to a texture
  - Draw that texture to screen
  - Called *offscreen rendering*
- Applications
  - Mini-maps
  - Scene Transitions
  - Light & Shadow
- Made easy in GDIAC
  - Class `RenderTarget`
  - Uses begin/end pattern



Using RenderTarget

```
// Set the resolution of the texture
RenderTarget target = new RenderTarget(width, height)

target.begin();

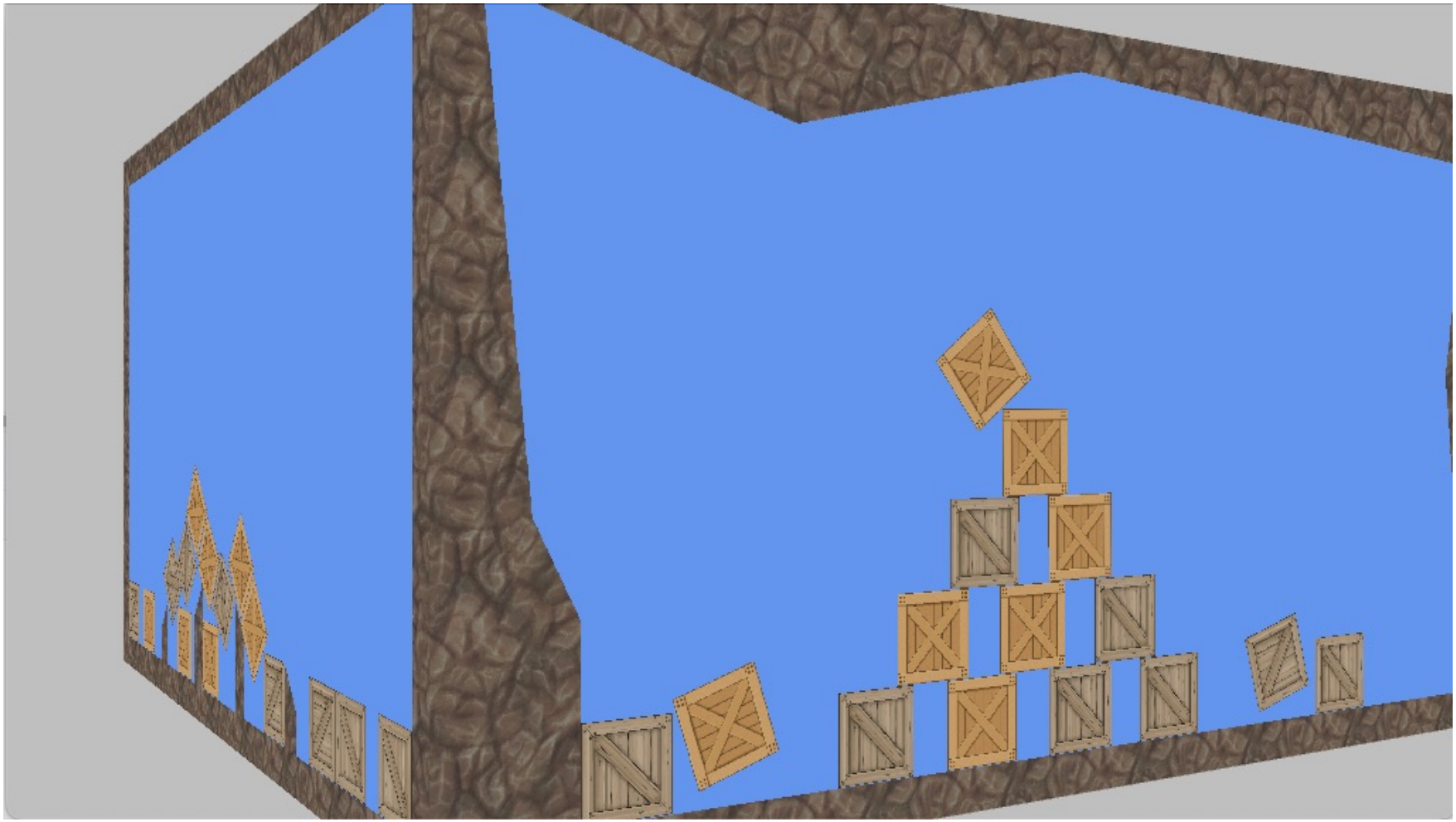
// All drawing here is done offscreen
batch.begin(camera);  // Camera must match width/height
...
batch.end();

target.end();

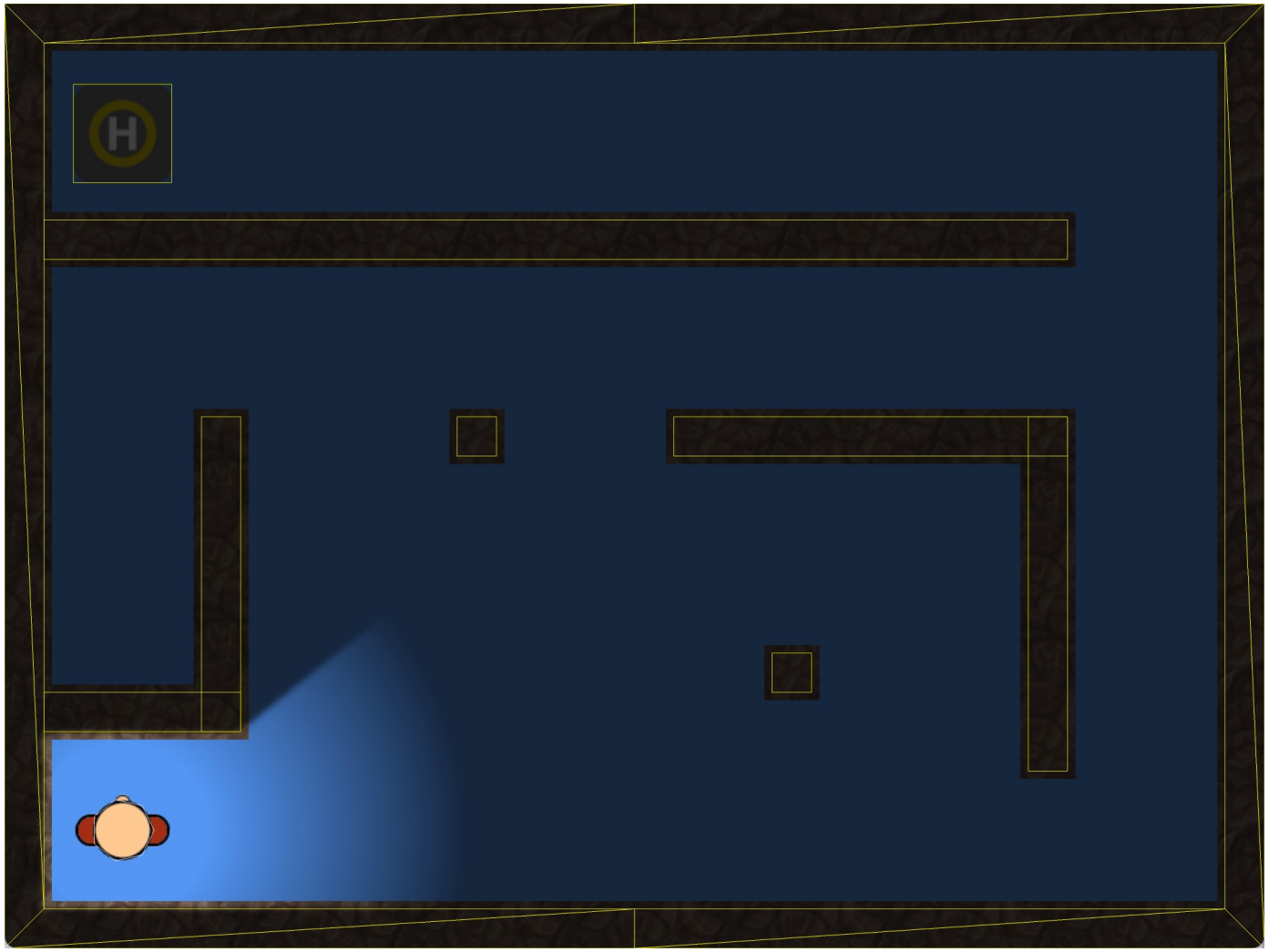
Texture texture = target.getTexture();

// Now use texture to draw to screen
```

Example: Cube Transitions



Example: box2d Lights



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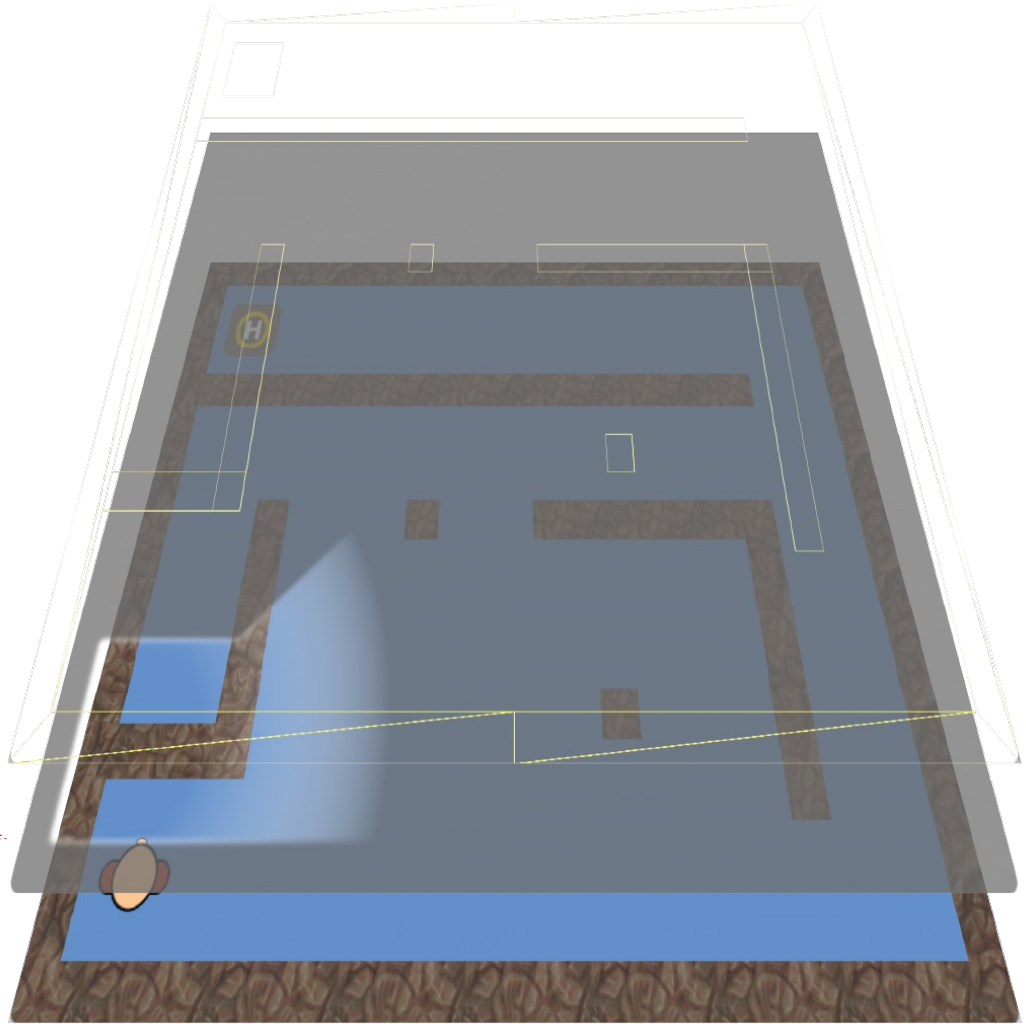


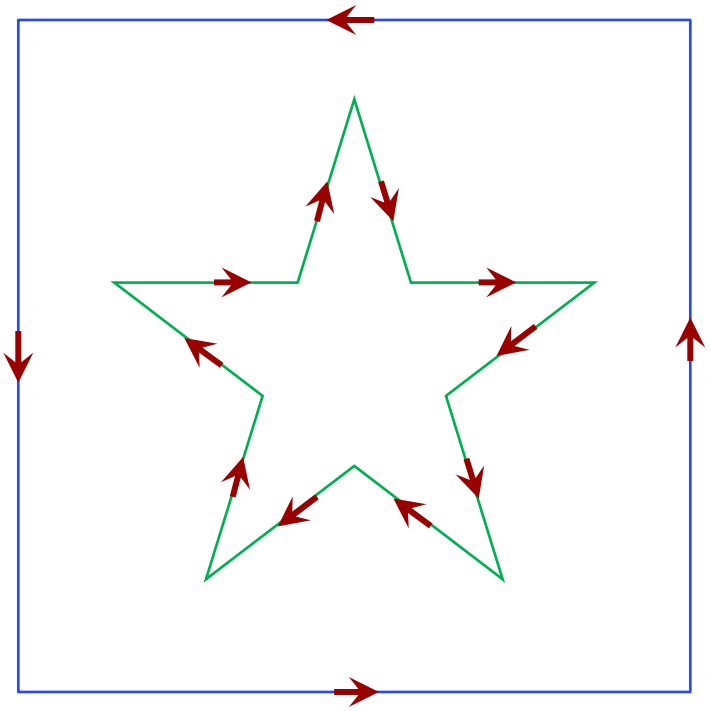
Drawn to texture

Drawn to screen

Drawn to screen

Additional Techniques: Triangulation

- **Goal:** Convert `Path2` to `Poly2`
  - Fill insides with triangles
  - Avoid adding new vertices
- Requirements for `Path2`
  - Lines cannot cross
  - Must be counter-clockwise
  - Clockwise paths are "holes"
- Class `PolyTriangulator`
  - Uses **ear-clipping** algorithm
  - Simple and fast enough
  - But triangles are not optimal



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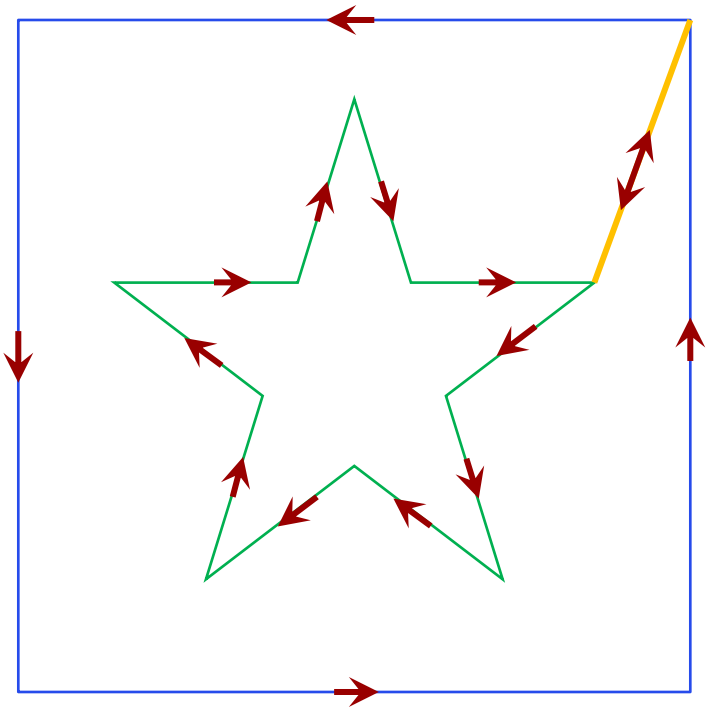

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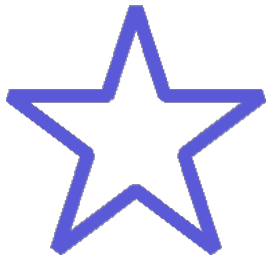
  - [illegible]
  - [illegible]
  - [illegible]

Alternative algorithms are a student project

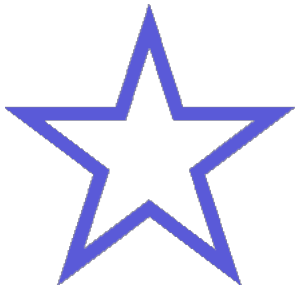
Additional Techniques: Extrusion

- Often don't draw `Path2` objs
  - Lines only one pixel wide
  - Too thin for hi-res monitors
  - Only useful for debugging
- Want `Path2` to have *width*
- **Idea:** convert to a `Poly2`
  - But not triangulation!
  - **Extrude** volume along path
- Some choices to make
  - Shape of ends
  - Shape of corners

SQUARE



MITRE



ROUND

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Class PathExtruder

Using the GDIAC Tools

PolyTriangulator

```
Poly2 triangulate(Path2 path) {

    PolyTriangulator triang;
    Poly2 result;

    triang = new PolyTriangulator();
    triang.set(path);

    // Add any holes here

    triang.calculate();
    result = triang.getPolygon();

    return result;
}
```

PathExtruder

```
Poly2 extrude(Path2 path) {

    PathExtruder extruder;
    Poly2 result;

    extruder = new PathExtruder();
    extruder.set(path);

    // Set cap, joints here

    extruder.calculate(width);
    result = extruder.getPolygon();

    return result;
}
```

Using the GDIAC Tools

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                          PathExtruder();
                        h);

                        s here

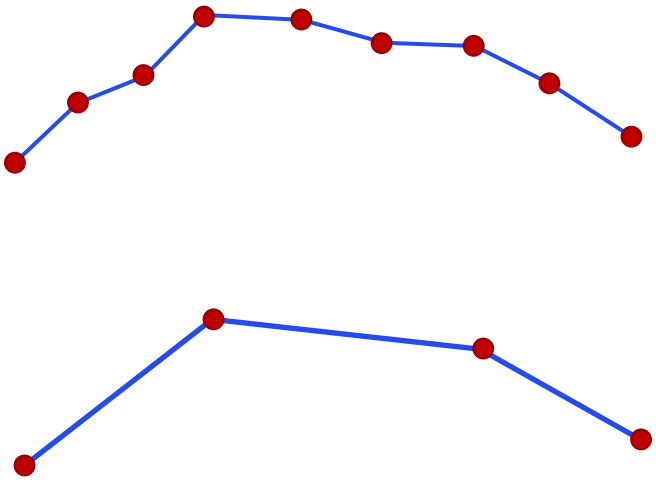
    extruder.calculate(width);
    result = extruder.getPolygon();

    return result;
}
```

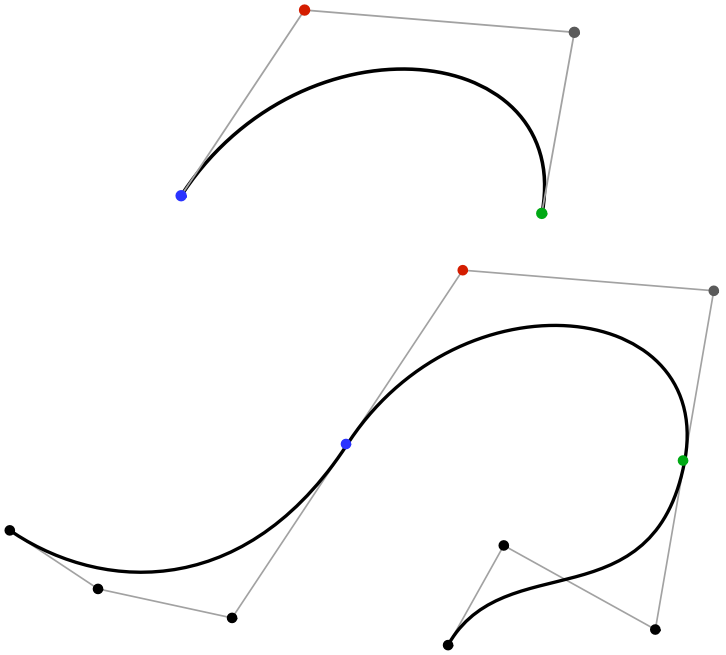
Very similar structure

Other GDIAC Features

Path Smoothing



Splines



Other GDIAC Features

Path Smoothing

Splines

Summary

- GDIAC extensions have many new features
  - Leverages strength of OpenGLES 3.0
  - But still backwards compatible with LibGDX
- Tools for **computation geometry**
  - Factories for `Poly2` and `Path2` objects
  - Triangulation and extrusion
  - Spline support for curves
- Tools for **texture manipulation**
  - `SpriteMesh` is an easy extension of `Poly2`
  - `RenderTarget` makes offscreen rendering easy