Intro to Graphics Programming

Using Apple's Metal API

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August 30, 2017

What Is Metal

Similar to OpenGL. Metal gives you near direct access to the GPU on your iOS, TVOS, or MacOS device.

Useful for making games as well as performing complex calculations

Why Do We Use It?

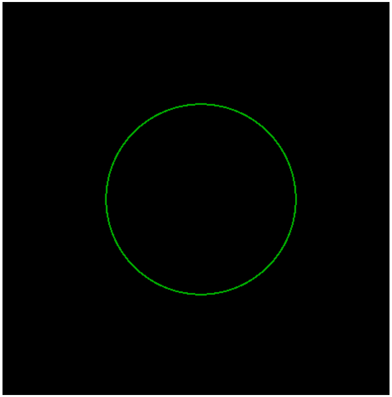
We needed a safe, reliable, and performant way to draw thousands of basic shapes on the screen every frame.

We ran into issues with SpriteKit so we decided to explore Metal

What Are We Doing Here?

We will be working through the process of drawing a shockwave as seen on the lazerbeam map

This includes drawing shapes and animating them



Code

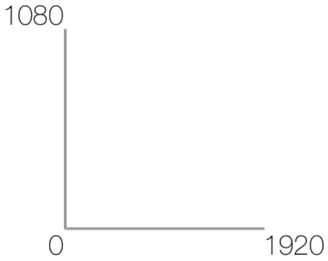
The code is separated into sections that correspond to each question. If there is no "start" folder, you must continue with the "finish" of the previous section

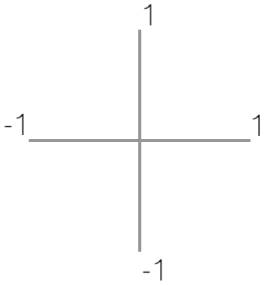
Repository

`https://github.com/Shopify/metal-workshop`

Coordinate Systems

Window Coordinate System **Clip Coordinate System**





Note: Window coordinate system in Metal is flipped on Y axis

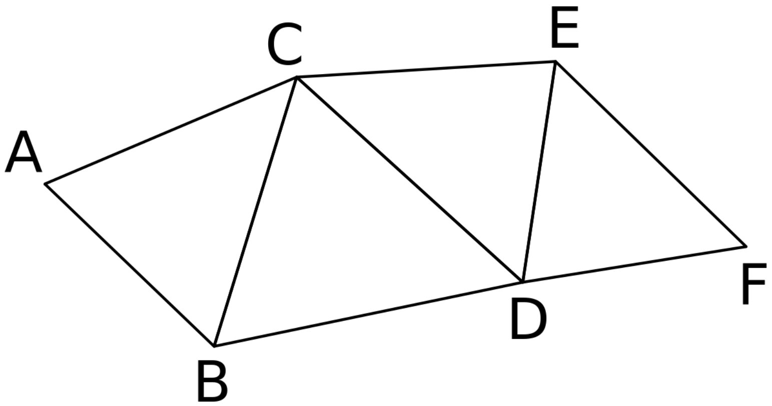
Vertices

Triangles are drawn with vertices. All shapes on the screen are represented by groups of triangles

```
struct Vertex {
    let position: vector_float4
    let color: vector_float4
}
```

Vertices - Triangle Strip

A more memory efficient way to draw lots of triangles



Buffers - Vertex Buffer

A byte array containing structs with vertex information. The order of this byte array is important

Buffers - Index Buffer

A byte array containing Ints that reference vertices in the Vertex Buffer

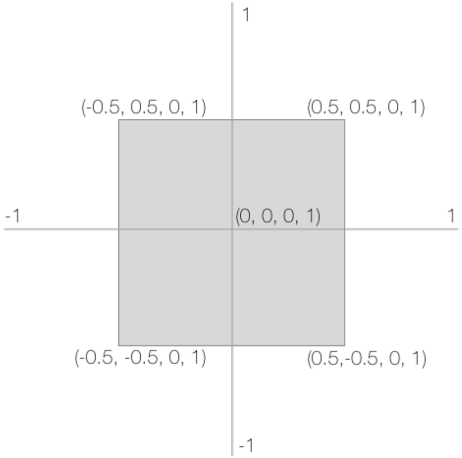
This array defines which order vertices are drawn

Buffers - Uniform Buffer

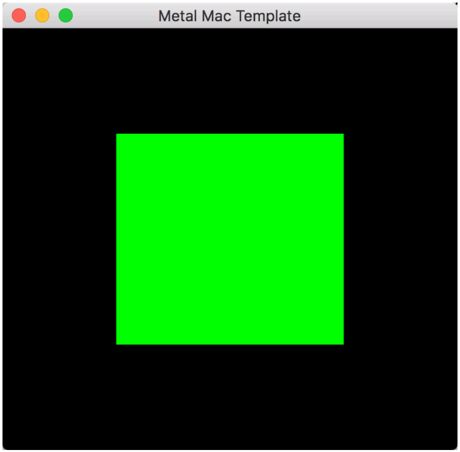
A byte array containing structs that define transforms for vertices

This buffer must align with the Vertex Buffer

Exercise - Draw a Box



Exercise - Expected Result



Exercise - Vertex Buffer

```
[ Vertex{position: -0.5, 0.5, 0, 1, color: 0, 1, 0, 1},
Vertex{position: -0.5, -0.5, 0, 1, color: 0, 1, 0, 1},
Vertex{position: 0.5, 0.5, 0, 1, color: 0, 1, 0, 1},
Vertex{position: 0.5, 0.5, 0, 1, color: 0, 1, 0, 1} ]
```

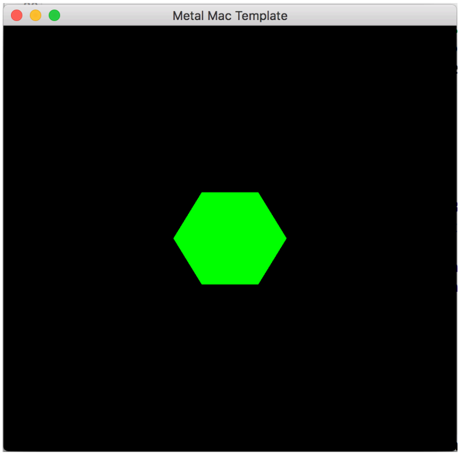
Exercise - Index Buffer

[0, 1, 3, 2]

Exercise - Uniform Buffer

[BoxUniform{},
BoxUniform{},
BoxUniform{},
BoxUniform{}]

Drawing a Circle

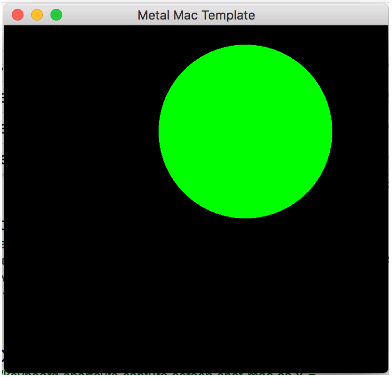


Drawing a Circle

The more facets, the smoother circle, right?

Fragment Shader

We can draw a *smooth* circle inside a box using the fragment shader and save memory at the same time!



Fragment Shader

A function that takes a **Vertex** as input and provides a **color** as output

Fragment Shader Function Signature

```
fragment float4 box_fragment_main(OutVertex outVertex [[stage_in]])
```

Fragment Shader

Allows you to perform calculations on a per-pixel basis using the *window coordinate system*

Fragment Shader

We would draw a circle by calculating an individual pixel's distance from the origin of the circle.

If it falls within some radius, return the vertex color, otherwise return clear

Exercise - Draw a Circle

There is a function provided to you in Metal called **distance_away** located in **Util.metal** that you need

Distance Function Signature

```
float distance_away(float2 p1, float2 p2);
```

Animations

Animations are made using Uniforms. Change a vertex's uniform every frame and you have an animation

Uniforms are applied in the Vertex Shader

Animations

This will make the box appear to fade onto the screen

Frame 1	BoxUniform{alpha: 0}
Frame 15	BoxUniform{alpha: 0.25}
Frame 30	BoxUniform{alpha: 0.5}
Frame 45	BoxUniform{alpha: 0.75}
Frame 60	BoxUniform{alpha: 1}

Exercise - Fade Circle In

Hint: use input values for *PulsingCircleUniform's animationTime* property in $(0, \pi)$. $abs(sin(x))$ has a period of π.

Exercise - Shockwave

Make a small change to the fragment shader to draw a shockwave

Exercise - Timing Function

Cubic Bezier Curve

$$f(t) = (1-t)^3 P_0 + 3(1-t)^2 t P_1 + 3(1-t) t^2 P_2 + t^2 P_3$$

Hint: GPU's excel at performing dot products