Instancing

Oregon State University

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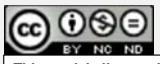

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Instancing – What and why?

- Instancing is the ability to draw the same object multiple times
- It uses all the same vertices and graphics pipeline each time
- It avoids the overhead of the program asking to have the object drawn again, letting the GPU/driver handle all of that

Must be ≥ 1 Must be ≥ 0

```
vkCmdDraw( CommandBuffers[nextImageIndex], vertexCount, instanceCount, firstVertex, firstInstance );
```

But, this will only get us multiple instances of identical objects drawn on top of each other. How can we make each instance look differently?

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Making each Instance look differently -- Approach #1

Use the built-in vertex shader variable **gl_InstanceIndex** to define a unique display property, such as position or color.

gl_InstanceIndex starts at 0

In the vertex shader:

```
int    NUMINSTANCES = 16;
float DELTA                =   3.0;

float xdelta = DELTA * float( gl_InstanceIndex % 4 );
float ydelta = DELTA * float( gl_InstanceIndex / 4 );
vColor = vec3( 1., float( (1.+gl_InstanceIndex) ) / float( NUMINSTANCES ), 0. );

xdelta -= DELTA * sqrt( float(NUMINSTANCES) ) / 2.;
ydelta -= DELTA * sqrt( float(NUMINSTANCES) ) / 2.;
vec4 vertex = vec4( aVertex.xyz + vec3( xdelta, ydelta, 0. ), 1. );

gl_Position = PVM * vertex;
```

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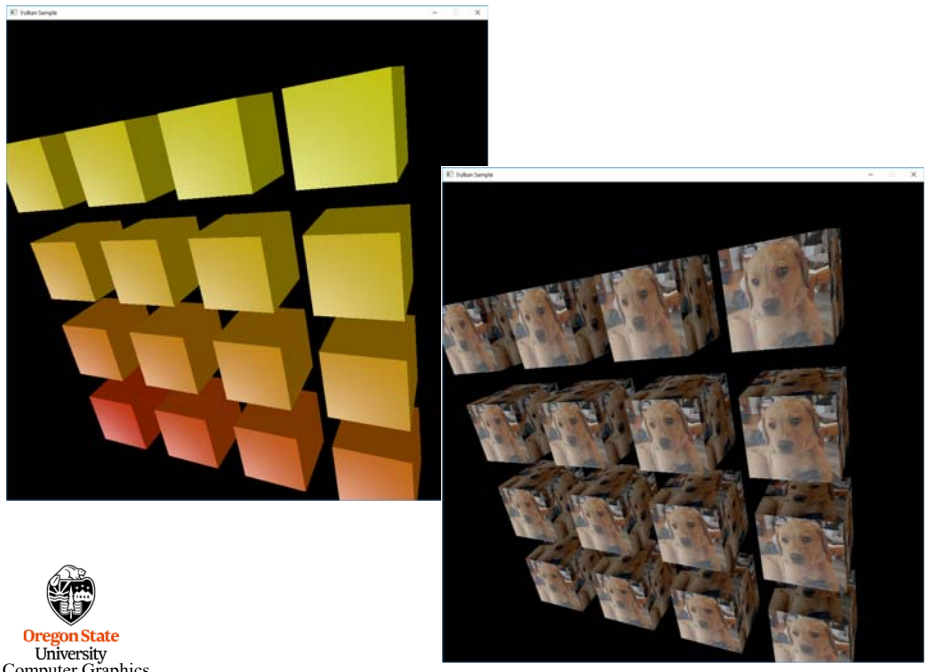

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Making each Instance look differently -- Approach #2

Put the unique characteristics in a uniform buffer and reference them

Still uses **gl_InstanceIndex**

In the vertex shader:

```
layout( std140, set = 3, binding = 0 ) uniform colorBuf
{
	vec3 uColors[1024];
} Colors;

out vec3 vColor;

	. . .

int index = gl_InstanceIndex % 1024;	// 0 - 1023

vColor = Colors.uColors[ index ];

gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
```

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Making each Instance look differently -- Approach #3

Put a series of unique characteristics in a data buffer, one element per instance.

Read a new characteristic for each instance

Internally uses **gl_InstanceIndex**, but you don't

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This is just the Vertex Input State Portion of the Graphics Pipeline Structure

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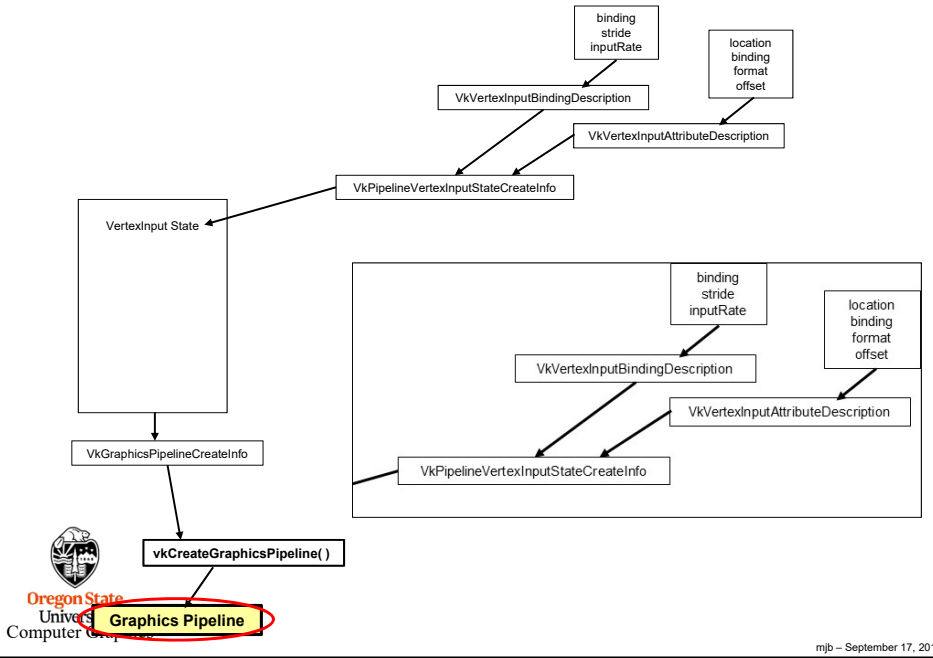

How We Constructed the Graphics Pipeline Structure Before

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```
VkVertexInputBindingDescription		vvibd[1];
                    // an array containing one of these per buffer being used
        vvibd[0].binding = 0;                           // which binding # this is
        vvibd[0].stride = sizeof( struct vertex );      // bytes between successive
        vvibd[0].inputRate = VK_VERTEX_INPUT_RATE_VERTEX;
```

This definition says that we should advance through the input buffer by this much every time we hit a new **vertex**

How We Constructed the Graphics Pipeline Structure Before


```
VkVertexInputAttributeDescription		vviad[4];
                    // an array containing one of these per vertex attribute in all bindings
                    // 4 = vertex, normal, color, texture coord
        vviad[0].location = 0;              // location in the layout decoration
        vviad[0].binding = 0;               // which binding description this is part of
        vviad[0].format = VK_FORMAT_VEC3;   // x, y, z
        vviad[0].offset = offsetof( struct vertex, position );          // 0

        vviad[1].location = 1;
        vviad[1].binding = 0;
        vviad[1].format = VK_FORMAT_VEC3;   // nx, ny, nz
        vviad[1].offset = offsetof( struct vertex, normal );            // 12

        vviad[2].location = 2;
        vviad[2].binding = 0;
        vviad[2].format = VK_FORMAT_VEC3;   // r, g, b
        vviad[2].offset = offsetof( struct vertex, color );             // 24

        vviad[3].location = 3;
        vviad[3].binding = 0;
        vviad[3].format = VK_FORMAT_VEC2;   // s, t
        vviad[3].offset = offsetof( struct vertex, texCoord );          // 36
```

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How We Constructed the Graphics Pipeline Structure Before


```
VkPipelineVertexInputStateCreateInfo		vpvisci;
                                    // used to describe the input vertex attributes
    vpvisci.sType = VK_STRUCTURE_TYPE_PIPELINE_VERTEX_INPUT_STATE_CREATE_INFO;
    vpvisci.pNext = nullptr;
    vpvisci.flags = 0;

    vpvisci.vertexBindingDescriptionCount = 1;
    vpvisci.pVertexBindingDescriptions = vvibd;

    vpvisci.vertexAttributeDescriptionCount = 4;
    vpvisci.pVertexAttributeDescriptions = vviad;
```

```
VkGraphicsPipelineCreateInfo		vgpci;
        vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
        vgpci.pNext = nullptr;
        vgpci.flags = 0;
        . . .
        vgpci.pVertexInputState = &vpvisci;
        . . .

result = vkCreateGraphicsPipelines( LogicalDevice, VK_NULL_HANDLE, 1, IN &vgpci,
                                    PALLOCATOR, OUT pGraphicsPipeline );
```

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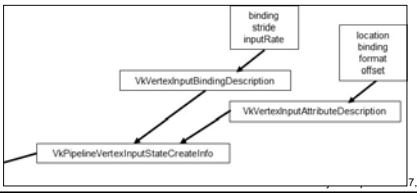
How We Construct the Graphics Pipeline Structure Now

Let's assign a different color per Instance.
Create a data buffer with one glm::vec3 (to hold r, g, b) for each Instance.

```
VkVertexInputBindingDescription		vvibd[2];
	vvibd[0].binding = 0;				// which binding # this is
	vvibd[0].stride = sizeof( struct vertex );	// bytes between successive
	vvibd[0].inputRate = VK_VERTEX_INPUT_RATE_VERTEX;

	vvibd[1].binding = 1;				// which binding # this is
	vvibd[1].stride = sizeof( glm::vec3 );		// bytes between successive entries
	vvibd[1].inputRate = VK_VERTEX_INPUT_RATE_INSTANCE;
```

This definition says that we should advance through the input buffer by this much every time we hit a new **instance**



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How We Construct the Graphics Pipeline Structure Now

Let's assign a different color per Instance.
Create a data buffer with one glm::vec3 (to hold r, g, b) for each Instance.

```
VkVertexInputAttributeDescription		vviad[5];
		// an array containing one of these per vertex attribute in all bindings
		// 4 = vertex, normal, color, texture coord
	vviad[0].location = 0;		// location in the layout decoration
	vviad[0].binding = 0;		// which binding description this is part of
	vviad[0].format = VK_FORMAT_VEC3;	// x, y, z
	vviad[0].offset = offsetof( struct vertex, position );		// 0

		. . .

	vviad[5].location = 0;		// location in the layout decoration
	vviad[5].binding = 1;		// which binding description this is part of
	vviad[5].format = VK_FORMAT_VEC3;	// r, g, b
	vviad[5].offset = 0;		// just one element, so offset is 0
```

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How We Construct the Graphics Pipeline Structure Now

Let's assign a different color per Instance.
Create a data buffer with one glm::vec3 (to hold r, g, b) for each Instance.

```
VkPipelineVertexInputStateCreateInfo        vpvisci;
        vpvisci.sType = VK_STRUCTURE_TYPE_PIPELINE_VERTEX_INPUT_STATE_CREATE_INFO;
        vpvisci.pNext = nullptr;
        vpvisci.flags = 0;

        vpvisci.vertexBindingDescriptionCount = 2;
        vpvisci.pVertexBindingDescriptions = vvibd;

        vpvisci.vertexAttributeDescriptionCount = 5;
        vpvisci.pVertexAttributeDescriptions = vviad;
```

Note: same names as before, but different sizes

```
VkGraphicsPipelineCreateInfo        vgpci;
        vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
        vgpci.pNext = nullptr;
        vgpci.flags = 0;
        . . .
        vgpci.pVertexInputState = &vpvisci;
        . . .

result = vkCreateGraphicsPipelines( LogicalDevice, VK_NULL_HANDLE, 1, IN &vgpci,
                                    PALLOCATOR, OUT pGraphicsPipeline );
```


How We Write the Vertex Shader Now


```
#version 400
#extension GL_ARB_separate_shader_objects  : enable
#extension GL_ARB_shading_language_420pack : enable

        . . .

layout( location = 0 ) in vec3 aVertex;
layout( location = 1 ) in vec3 aNormal;
layout( location = 2 ) in vec3 aColor;
layout( location = 3 ) in vec2 aTexCoord;

layout( location = 4 ) in vec3 aInstanceColor;

layout ( location = 0 ) out vec3 vNormal;
layout ( location = 1 ) out vec3 vColor;
layout ( location = 2 ) out vec2 vTexCoord;

void
main( )
{
        mat4 PVM = Matrices.uProjectionMatrix * Matrices.uViewMatrix * Matrices.uModelMatrix;

        vNormal    = normalize( vec3( Matrices.uNormalMatrix * vec4(aNormal, 1.) ) );
        //vColor    = aColor;
        vColor = aInstanceColor;
        vTexCoord = aTexCoord;

        gl_Position = PVM * vec4( aVertex, 1. );
}
```