Vulkan Topologies

VK_PRIMITIVE_TOPOLOGY_POINT_LIST

VK_PRIMITIVE_TOPOLOGY_LINE_LIST

VK_PRIMITIVE_TOPOLOGY_LINE_STRIP

VK_PRIMITIVE_TOPOLOGY_TRIANGLE_LIST

VK_PRIMITIVE_TOPOLOGY_TRIANGLE_STRIP

VK_PRIMITIVE_TOPOLOGY_TRIANGLE_FAN
Vulkan Topologies

typedef enum VkPrimitiveTopology
{
    VK_PRIMITIVE_TOPOLOGY_POINT_LIST,
    VK_PRIMITIVE_TOPOLOGY_LINE_LIST,
    VK_PRIMITIVE_TOPOLOGY_LINE_STRIP,
    VK_PRIMITIVE_TOPOLOGY_TRIANGLE_LIST,
    VK_PRIMITIVE_TOPOLOGY_TRIANGLE_STRIP,
    VK_PRIMITIVE_TOPOLOGY_TRIANGLE_FAN,
    VK_PRIMITIVE_TOPOLOGY_LINE_LIST_WITH_ADJACENCY,
    VK_PRIMITIVE_TOPOLOGY_LINE_STRIP_WITH_ADJACENCY,
    VK_PRIMITIVE_TOPOLOGY_TRIANGLE_LIST_WITH_ADJACENCY,
    VK_PRIMITIVE_TOPOLOGY_TRIANGLE_STRIP_WITH_ADJACENCY,
    VK_PRIMITIVE_TOPOLOGY_PATCH_LIST
} VkPrimitiveTopology;

A Colored Cube Example

static GLuint CubeTriangleIndices[3] =
{
  { 0, 2, 3 },
  { 0, 3, 1 },
  { 4, 5, 7 },
  { 4, 7, 6 },
  { 1, 3, 7 },
  { 1, 7, 5 },
  { 0, 4, 6 },
  { 0, 6, 2 },
  { 2, 6, 7 },
  { 2, 7, 3 },
  { 0, 1, 5 },
  { 0, 5, 4 }
};
Triangles Represented as an Array of Structures

From the file SampleVertexData.cpp:

```cpp
struct vertex
{
    glm::vec3       position;
    glm::vec3       normal;
    glm::vec3       color;
    glm::vec2       texCoord;
};

struct vertex VertexData[ ] =
{
    // triangle 0-2-3:
    // vertex #0:
    { -1., -1., -1. },
    {  0.,  0., -1. },
    {  0.,  0.,  0. },
    {  1., 0. },

    // vertex #2:
    { -1.,  1., -1. },
    {  0.,  0., -1. },
    {  0.,  1.,  0. },
    {  1., 1. },

    // vertex #3:
    {  1.,  1., -1. },
    {  0.,  0., -1. },
    {  1.,  1.,  0. },
    {  0., 1. },
};
```

From the file SampleVertexData.cpp:

```
// Modeled in right-handed coordinates
```

Non-indexed Buffer Drawing

Stream of Vertices

From the file SampleVertexData.cpp:

```cpp
struct vertex
{
    glm::vec3       position;
    glm::vec3       normal;
    glm::vec3       color;
    glm::vec2       texCoord;
};

struct vertex VertexData[ ] =
{
    // triangle 0-2-3:
    // vertex #0:
    { -1., -1., -1. },
    {  0.,  0., -1. },
    {  0.,  0.,  0. },
    {  1., 0. },

    // vertex #2:
    { -1.,  1., -1. },
    {  0.,  0., -1. },
    {  0.,  1.,  0. },
    {  1., 1. },

    // vertex #3:
    {  1.,  1., -1. },
    {  0.,  0., -1. },
    {  1.,  1.,  0. },
    {  0., 1. },
};
```
Struct vertex VertexData[] =
{
    ... 
};

MyBuffer MyVertexDataBuffer:

Init05MyVertexDataBuffer( sizeof(VertexData), OUT &MyVertexDataBuffer );
Fill05DataBuffer( MyVertexDataBuffer, (void *) VertexData );

VkResult
Init05MyVertexDataBuffer( IN VkDeviceSize size, OUT MyBuffer * pMyBuffer )
{
    VkResult result;
    result = Init05DataBuffer( size, VK_BUFFER_USAGE_VERTEX_BUFFER_BIT, pMyBuffer );
    return result;
}

A Preview of What Init05DataBuffer Does

VkResult
Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer * pMyBuffer )
{
    VkResult result = VK_SUCCESS;
    VkBufferCreateInfo vbc;
    vbc.sType = VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO;
    vbc.pNext = nullptr;
    vbc.flags = 0;
    vbc.size = pMyBuffer->size = size;
    vbc.usage = usage;
    vbc.sharingMode = VK_SHARING_MODE_EXCLUSIVE;
    vbc.queueFamilyIndexCount = 0;
    vbc.pQueueFamilyIndices = (const uint32_t *)nullptr;
    result = vkCreateBuffer( LogicalDevice, IN &vbc, PALLOCATOR, OUT &pMyBuffer->buffer );
    VkMemoryRequirements vmr;
    vkGetBufferMemoryRequirements( LogicalDevice, IN pMyBuffer->buffer, OUT &vmr );         // fills vmr
    VkMemoryAllocateInfo vmai;
    vmai.sType = VK_STRUCTURE_TYPE_MEMORY_ALLOCATE_INFO;
    vmai.pNext = nullptr;
    vmai.allocationSize = vmr.size;
    vmai.memoryTypeIndex = FindMemoryThatIsHostVisible( );
    VkDeviceMemory vdm;
    result = vkAllocateMemory( LogicalDevice, IN &vmai, PALLOCATOR, OUT &vdm );
    pMyBuffer->vdm = vdm;
    result = vkBindBufferMemory( LogicalDevice, pMyBuffer->buffer, IN vdm, 0 );             // 0 is the offset
    return result;
}
We will come to the Pipeline later, but for now, know that a Vulkan pipeline is essentially a very large data structure that holds (what OpenGL would call) the state, including how to parse its input.

C/C++:

```c
struct vertex
{
    glm::vec3 position;
    glm::vec3 normal;
    glm::vec3 color;
    glm::vec2 texCoord;
};
```

GLSL Shader:

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

Always use the C/C++ construct `offsetof`, rather than hardcoding the value!
We will come to the Pipeline later, but for now, know that a Vulkan Pipeline is essentially a very large data structure that holds (what OpenGL would call) the state, including how to parse its vertex input.

```c
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;

VkPipelineInputAssemblyStateCreateInfo vpiasci;
    vpiasci.sType = VK_STRUCTURE_TYPE_PIPELINE_INPUT_ASSEMBLY_STATE_CREATE_INFO;
    vpiasci.pNext = nullptr;
    vpiasci.flags = 0;
    vpiasci.topology = VK_PRIMITIVE_TOPOLOGY_TRIANGLE_LIST;

VkGraphicsPipelineCreateInfo vgpci;
    vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
    vgpci.pNext = nullptr;
    vgpci.flags = 0;
    vgpci.stageCount = 2;                // number of shader stages in this pipeline
    vgpci.pStages = vpssci;
    vgpci.pVertexInputState = &vpvisci;
    vgpci.pInputAssemblyState = &vpiasci;
    vgpci.pTessellationState = (VkPipelineTessellationStateCreateInfo *)nullptr;
    vgpci.pViewportState = &vpvsci;
    vgpci.pRasterizationState = &vprsci;
    vgpci.pMultisampleState = &vpmsci;
    vgpci.pDepthStencilState = &vpdssci;
    vgpci.pColorBlendState = &vpcbsci;
    vgpci.pDynamicState = &vpdsci;
    vgpci.layout = IN GraphicsPipelineLayout;
    vgpci.renderPass = IN RenderPass;
    vgpci.subpass = 0;                   // subpass number
    vgpci.basePipelineHandle = (VkPipeline) VK_NULL_HANDLE;
    vgpci.basePipelineIndex = 0;

result = vkCreateGraphicsPipelines( LogicalDevice, VK_NULL_HANDLE, 1, IN &vgpci,
                                      PALLOCATOR, OUT &GraphicsPipeline );
```
We will come to Command Buffers later, but for now, know that you will specify the vertex buffer that you want drawn.

```cpp
VkBuffer buffers[1] = MyVertexDataBuffer.buffer;

vkCmdBindVertexBuffers(CommandBuffers[nextImageIndex], 0, 1, vertexDataBuffers, offsets);

const uint32_t vertexCount = sizeof(VertexData) / sizeof(VertexData[0]);
const uint32_t instanceCount = 1;
const uint32_t firstVertex = 0;
const uint32_t firstInstance = 0;

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

**Telling the Command Buffer what Vertices to Draw**

**Drawing with an Index Buffer**

Stream of Vertices

<table>
<thead>
<tr>
<th>Vertex 7</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex 5</td>
<td>5</td>
</tr>
<tr>
<td>Vertex 4</td>
<td>4</td>
</tr>
<tr>
<td>Vertex 1</td>
<td>1</td>
</tr>
<tr>
<td>Vertex 3</td>
<td>3</td>
</tr>
<tr>
<td>Vertex 0</td>
<td>0</td>
</tr>
</tbody>
</table>

Stream of Indices

<table>
<thead>
<tr>
<th>Vertex Lookup</th>
</tr>
</thead>
<tbody>
<tr>
<td>{ -1., -1., -1. }</td>
</tr>
<tr>
<td>{ 1., -1., -1. }</td>
</tr>
<tr>
<td>{ -1., 1., -1. }</td>
</tr>
<tr>
<td>{ 1., 1., -1. }</td>
</tr>
</tbody>
</table>

Triangles

<table>
<thead>
<tr>
<th>Draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
Drawing with an Index Buffer

```c
vkCmdBindVertexBuffers( commandBuffer, firstBinding, bindingCount, vertexDataBuffers, vertexOffsets );
vkCmdBindIndexBuffer( commandBuffer, indexDataBuffer, indexOffset, indexType );

typedef enum VkIndexType {
    VK_INDEX_TYPE_UINT16 = 0, // 0 – 65,535
    VK_INDEX_TYPE_UINT32 = 1, // 0 – 4,294,967,295
} VkIndexType;

vkCmdDrawIndexed( commandBuffer, indexCount, instanceCount, firstIndex, vertexOffset, firstInstance);
```

Drawing with an Index Buffer

```c
VkResult Init05MyIndexDataBuffer(IN VkDeviceSize size, OUT MyBuffer * pMyBuffer)
{
    VkResult result = Init05DataBuffer(size, VK_BUFFER_USAGE_INDEX_BUFFER_BIT, pMyBuffer);
    // fills pMyBuffer
    return result;
}

Init05MyVertexDataBuffer( sizeof(JustVertexData), IN &MyJustVertexDataBuffer );
Fill05DataBuffer( MyJustVertexDataBuffer, (void *) JustVertexData );
Init05MyIndexDataBuffer( sizeof(JustIndexData), IN &MyJustIndexDataBuffer );
Fill05DataBuffer( MyJustIndexDataBuffer, (void *) JustIndexData );
```
Drawing with an Index Buffer

```cpp
VkBuffer vBuffers[1] = { MyJustVertexDataBuffer.buffer };  
VkBuffer iBuffer = { MyJustIndexDataBuffer.buffer };  

vkCmdBindVertexBuffers( CommandBuffers[nextImageIndex], 0, 1, vBuffers, offsets );  
// 0, 1 = firstBinding, bindingCount  
vkCmdBindIndexBuffer( CommandBuffers[nextImageIndex], iBuffer, 0, VK_INDEX_TYPE_UINT32 );

const uint32_t vertexCount = sizeof( JustVertexData ) / sizeof( JustVertexData[0] );  
const uint32_t indexCount = sizeof( JustIndexData ) / sizeof( JustIndexData[0] );  
const uint32_t instanceCount = 1;  
const uint32_t firstVertex = 0;  
const uint32_t firstIndex = 0;  
const uint32_t firstInstance = 0;  
const uint32_t vertexOffset = 0;

vkCmdDrawIndexed( CommandBuffers[nextImageIndex], indexCount, instanceCount, firstIndex,  
vertexOffset, firstInstance );
```

Indirect Drawing (not to be confused with Indexed)

```c
typedef struct
VkDrawIndirectCommand
{
    uint32_t    vertexCount;
    uint32_t    instanceCount;
    uint32_t    firstVertex;
    uint32_t    firstInstance;
} VkDrawIndirectCommand;
```

```cpp
vkCmdDrawIndirect( CommandBuffers[nextImageIndex], buffer, offset, drawCount, stride);  

Compare this with:

```cpp
vkCmdDraw( CommandBuffers[nextImageIndex], vertexCount, instanceCount, firstVertex, firstInstance );
```
Indexed Indirect Drawing (i.e., both Indexed and Indirect)

```c
vkCmdDrawIndexedIndirect(commandBuffer, buffer, offset, drawCount, stride);
```

typedef struct
    VkDrawIndexedIndirectCommand {
        uint32_t indexCount;
        uint32_t instanceCount;
        uint32_t firstIndex;
        int32_t vertexOffset;
        uint32_t firstInstance;
    } VkDrawIndexedIndirectCommand;

Compare this with:

```c
vkCmdDrawIndexed(commandBuffer, indexCount, instanceCount, firstIndex, vertexOffset, firstInstance);
```

Sometimes the Same Point Needs Multiple Attributes

A color-interpolated cube like this actually has both. Point #7 above has the same color, regardless of what face it is in. However, Point #7 has 3 different normal vectors, depending on which face you are defining. Same with its texture coordinates.

Thus, when using indexed buffer drawing, you need to create a new vertex struct if any of (position, normal, color, texCoords) changes from what was previously-stored at those coordinates.
Sometimes the Same Point Needs Multiple Attributes

Where values match at the corners (color)

Where values do not match at the corners (texture coordinates)

V / T / N

The OBJ File Format – a triple-indexed way of Drawing

V / T / N

Note: The OBJ file format uses 1-based indexing for faces!