Data Buffers

A Data Buffer is just a group of contiguous bytes in GPU memory. They have no inherent meaning. The data that is stored there is whatever you want it to be. (This is sometimes called a “Binary Large Object”, or “BLOB”.)

It is up to you to be sure that the writer and the reader of the Data Buffer are interpreting the bytes in the same way!

Vulkan calls these things “Buffers”. But, Vulkan calls other things “Buffers”, too, such as Texture Buffers and Command Buffers. So, I have taken to calling these things “Data Buffers” and have even gone to far as to override some of Vulkan’s own terminology:

typedef VkBuffer VkDataBuffer;

Terminology Issues
VkBufferCreateInfo vbci;
vbci.sType = VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO;
vbci.pNext = nullptr;
vbci.flags = 0;
vbci.size = << buffer size in bytes >>
vbci.usage = <<or’ed bits of: >>
VK_USAGE_TRANSFER_SRC_BITVK_USAGE_TRANSFER_DST_BIT
VK_USAGE_UNIFORM_TEXEL_BUFFER_BIT
VK_USAGE_STORAGE_TEXEL_BUFFER_BIT
VK_USAGE_UNIFORM_BUFFER_BIT
VK_USAGE_STORAGE_BUFFER_BIT
VK_USAGE_INDEX_BUFFER_BIT
VK_USAGE_VERTEX_BUFFER_BIT
VK_USAGE_INDIRECT_BUFFER_BIT
vbci.sharingMode = << one of: >>
VK_SHARING_MODE_EXCLUSIVE
VK_SHARING_MODE_CONCURRENT
vbci.queueFamilyIndexCount = 0;
vbci.pQueueFamilyIndices = (const iont32_t) nullptr;

result = vkCreateBuffer( LogicalDevice, IN &vbci, PALLOCATOR,  OUT &Buffer );

Vulkan: Creating a Data Buffer

Doesn’t actually allocate memory – just creates a VkBuffer data structure

VkMemoryRequirements vmr;
result = vkGetBufferMemoryRequirements( LogicalDevice, Buffer, OUT &vmr );

VkMemoryAllocateInfo vmai;
vmai.sType = VK_STRUCTURE_TYPE_MEMORY_ALLOCATE_INFO;
vmai.pNext = nullptr;
vmai.flags = 0;
vmai.allocationSize = vmr.size;
result = FindMemoryThatIsHostVisible( );

VkDeviceMemory vdm;
result = vkAllocateMemory( LogicalDevice, IN &vmai, PALLOCATOR,  OUT &vdm );
result = vkBindBufferMemory( LogicalDevice, Buffer, IN vdm, 0 );
result = vkMapMemory( LogicalDevice, IN vdm, 0, VK_WHOLE_SIZE, 0, &ptr );
<< do the memory copy >>
result = vkUnmapMemory( LogicalDevice, IN vdm );

Vulkan: Allocating Memory for a Buffer, Binding a Buffer to Memory, and Writing to the Buffer

Finding the Right Type of Memory

int FindMemoryThatIsHostVisible( )
{
    VkPhysicalDeviceMemoryProperties vpdmp;
vkGetPhysicalDeviceMemoryProperties( PhysicalDevice, OUT &vpdmp );
for( unsigned int i = 0; i < vpdmp.memoryTypeCount; ++i )
{
    VkMemoryType vmt = vpdmp.memoryTypes[i];
    if( ( vmt.propertyFlags & VK_MEMORY_PROPERTY_HOST_VISIBLE_BIT ) != 0 )
    {
        return i;
    }
}
return -1;
}

Finding the Right Type of Memory

int FindMemoryThatIsDeviceLocal( )
{
    VkPhysicalDeviceMemoryProperties vpdmp;
vkGetPhysicalDeviceMemoryProperties( PhysicalDevice, OUT &vpdmp );
for( unsigned int i = 0; i < vpdmp.memoryTypeCount; ++i )
{
    VkMemoryType vmt = vpdmp.memoryTypes[i];
    if( ( vmt.propertyFlags & VK_MEMORY_PROPERTY_DEVICE_LOCAL_BIT ) != 0 )
    {
        return i;
    }
}
return -1;
}
Finding the Right Type of Memory

11 Memory Types:
- Memory 0: DeviceLocal
- Memory 1: DeviceLocal
- Memory 2: HostVisible HostCoherent
- Memory 3: HostVisible HostCoherent HostCached

2 Memory Heaps:
- Heap 0: size = 0xb7c00000 DeviceLocal
- Heap 1: size = 0xfac00000

Something I've Found Useful

I find it handy to encapsulate buffer information in a struct:

```c
typedef struct MyBuffer
{
    VkDataBuffer buffer;
    VkDeviceMemory vdm;
    VkDeviceSize size;
} MyBuffer;
```

It's the usual object-oriented benefit – you can pass around just one data-item and everyone can access whatever information they need.

Initializing a Data Buffer

It's the usual object-oriented benefit – you can pass around just one data-item and everyone can access whatever information they need.

```c
VkResult Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer *pMyBuffer )
{
    //...
    vbci.size = pMyBuffer->size = size;
    //...
    result = vkCreateBuffer ( LogicalDevice, IN &vbci, PALLOCATOR, OUT &pMyBuffer->buffer );
    //...
    pMyBuffer->vdm = vdm;
    //...
}
```

Here's the C struct to hold some uniform variables

```c
struct matBuf
{
    glm::mat4 uModelMatrix;
    glm::mat4 uViewMatrix;
    glm::mat4 uProjectionMatrix;
    glm::mat3 uNormalMatrix;
} Matrices;
```

Here's the shader code to access those uniform variables

```c
layout( std140, set = 0, binding = 0 ) uniform matBuf
{
    mat4 uModelMatrix;
    mat4 uViewMatrix;
    mat4 uProjectionMatrix;
    mat4 uNormalMatrix;
} Matrices;
```
Filling those Uniform Variables

```cpp
glm::vec3 eye(0., 0., EYEDIST);
glm::vec3 look(0., 0., 0.);
glm::vec3 up(0., 1., 0.);
Matrices.uModelMatrix = glm::mat4(1);  // identity
Matrices.uViewMatrix = glm::lookAt(eye, look, up);
Matrices.uProjectionMatrix = glm::perspective(FOV, (double)Width/(double)Height, 0.1, 1000.);
Matrices.uNormalMatrix = glm::inverseTranspose(glm::mat3(Matrices.uModelMatrix));
```

The Descriptor Set for the Buffer

We will come to Descriptor Sets later, but for now think of them as the link between the BLOB of uniform variables in GPU memory and the block of variable names in your shader programs.

```cpp
VkDescriptorBufferInfo vdbi0;
vdbi0.buffer = MyMatrixUniformBuffer.buffer;
vdbi0.offset = 0;  // bytes
vdbi0.range = sizeof(Matrices);

VkWriteDescriptorSet vwds0;
// ds 0:
vwds0.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
vwds0.pNext = nullptr;
vwds0.dstSet = ... = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
vwds0.pBufferInfo = &vdbi0;
vwds0.pImageInfo = (VkDescriptorImageInfo *)nullptr;

vkUpdateDescriptorSets(LogicalDevice, 1, &vwds0, IN 0, (VkCopyDescriptorSet *)nullptr);
```

The Parade of Data

CPU: `struct matBuf Matrices;`
The MyBuffer does not hold any actual data itself. It just represents a container of data buffer information that will be used by Vulkan

This C struct is holding the actual data. It is writeable by the application.

The Data Buffer in GPU memory is holding the actual data. It is readable by the shaders

The Descriptor Set for the Buffer

```cpp
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vdbi0.buffer = MyMatrixUniformBuffer.buffer;
vdbi0.offset = 0;  // bytes
vdbi0.range = sizeof(Matrices);

VkWriteDescriptorSet vwds0;
// ds 0:
vwds0.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
vwds0.pNext = nullptr;
vwds0.dstSet = ... = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
vwds0.pBufferInfo = &vdbi0;
vwds0.pImageInfo = (VkDescriptorImageInfo *)nullptr;

vkUpdateDescriptorSets(LogicalDevice, 1, &vwds0, IN 0, (VkCopyDescriptorSet *)nullptr);
```

Filling the Data Buffer

```cpp
VkDevice logicalDevice;
VkCommandBuffer commandBuffer = logicalDevice.beginCommandBuffer(VK_COMMAND_BUFFER_USAGE_ONE_TIME_SUBMISSION_BIT);

// do some drawing...

cpuFrameBuffer.beginRenderPass();

Matrices.uModelMatrix = glm::mat4(1);  // identity
Matrices.uViewMatrix = glm::lookAt(vec3(1, 2, 3), vec3(1, 0, 0), vec3(0, 1, 0));
Matrices.uProjectionMatrix = glm::perspective(FOV, (double)Width/(double)Height, 0.1, 1000.);

glDrawElements();

cpuFrameBuffer.endRenderPass();

logicalDevice.endCommandBuffer();

vkQueueSubmit(queue, 1, &commandBuffer, IN nullptr);

vkQueueWaitIdle(queue);
```

Filling those Uniform Variables

```
Filling the Data Buffer

```cpp
void* pMatrices = &Matrices;

Init05UniformBuffer(sizeof(Matrices), &MyMatrixUniformBuffer);
Fill05DataBuffer( MyMatrixUniformBuffer, (void*) &Matrices );
```
Creating and Filling the Data Buffer – the Details

VkResult Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer * pMyBuffer )
{
    VkResult result = VK_SUCCESS;
    VkBufferCreateInfo vbci = {
        .sType = VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO,
        .pNext = nullptr,
        .flags = 0,
        .size = pMyBuffer->size,
        .usage = usage,
        .sharingMode = VK_SHARING_MODE_EXCLUSIVE,
        .queueFamilyIndexCount = 0,
        .pQueueFamilyIndices = (const uint32_t *)nullptr,
    };
    result = vkCreateBuffer( LogicalDevice, &vbci, PALLOCATOR, pMyBuffer->buffer );
    VkMemoryRequirements vmr;
    vkGetBufferMemoryRequirements( LogicalDevice, pMyBuffer->buffer, &vmr );
    VkMemoryAllocateInfo vmai = {
        .sType = VK_STRUCTURE_TYPE_MEMORY_ALLOCATE_INFO,
        .pNext = nullptr,
        .allocationSize = vmr.size,
        .memoryTypeIndex = FindMemoryThatIsHostVisible(),
    };
    VkDeviceMemory vdm;
    result = vkAllocateMemory( LogicalDevice, &vmai, PALLOCATOR, &vdm );
    pMyBuffer->buffer = vdm;
    result = vkBindBufferMemory( LogicalDevice, pMyBuffer->buffer, vdm, 0 );
    return result;
}

Copy to GPU Memory via Memory Mapping

VkResult Fill05DataBuffer( IN MyBuffer myBuffer, IN void * data )
{
    // the size of the data had better match the size that was used to Init the buffer!
    void * pGpuMemory;
    vkMapMemory( LogicalDevice, myBuffer.vdm, 0, VK_WHOLE_SIZE, 0, &pGpuMemory );
    memcpy( pGpuMemory, data, (size_t)myBuffer.size );
    vkUnmapMemory( LogicalDevice, myBuffer.vdm );
    return VK_SUCCESS;
}