The Swap Chain

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How OpenGL Thinks of Framebuffers
What is a Swap Chain?

Vulkan does not use the idea of a “back buffer”. So, we need a place to render into before moving an image into place for viewing. This is called the **Swap Chain**.

In essence, the Swap Chain manages one or more image objects that form a sequence of images that can be drawn into and then given to the Surface to be presented to the user for viewing.

Swap Chains are arranged as a ring buffer

Swap Chains are tightly coupled to the window system.

After creating the Swap Chain in the first place, the process for using the Swap Chain is:

1. Ask the Swap Chain for an image
2. Render into it via the Command Buffer and a Queue
3. Return the image to the Swap Chain for presentation
4. Present the image to the viewer (copy to “front buffer”)
We Need to Find Out What our Display Capabilities Are

We Need to Find Out What our Display Capabilities Are

VulkanDebug.txt output for an Nvidia A6000:

***** Init08Swapchain *****

vkGetPhysicalDeviceSurfaceCapabilitiesKHR:

- minImageCount = 2, maxImageCount = 8
- currentExtent = 1024 x 1024
- maxImageExtent = 1024 x 1024
- maxImageArrayLayers = 1
- supportedTransforms = 0x0001
- currentTransform = 0x0001
- supportedCompositeAlpha = 0x0001
- supportedUsageFlags = 0x009f

vkGetPhysicalDeviceSurfaceSupportKHR:

** This Surface is supported by the Graphics Queue **

Found 3 Surface Formats:
1: 50 0 VK_COLOR_SPACE_SRGB_NONLINEAR_KHR
2: 64 0 VK_COLOR_SPACE_SRGB_NONLINEAR_KHR

Found 4 Present Modes:
0: 2 VK_PRESENT_MODE_FIFO_KHR
1: 3 VK_PRESENT_MODE_FIFO_RELAXED_KHR
2: 1 VK_PRESENT_MODE_MAILBOX_KHR
3: 0 VK_PRESENT_MODE_IMMEDIATE_KHR

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Here's What the Vulkan Spec Has to Say About Present Modes, I

VK_PRESENT_MODE_IMMEDIATE_KHR specifies that the presentation engine does not wait for a vertical blanking period to update the current image, meaning this mode may result in visible tearing. No internal queuing of presentation requests is needed, as the requests are applied immediately.

VK_PRESENT_MODE_MAILBOX_KHR specifies that the presentation engine waits for the next vertical blanking period to update the current image. Tearing cannot be observed. An internal single-entry queue is used to hold pending presentation requests. If the queue is full when a new presentation request is received, the new request replaces the existing entry, and any images associated with the prior entry become available for reuse by the application. One request is removed from the queue and processed during each vertical blanking period in which the queue is non-empty.

VK_PRESENT_MODE_FIT_TO_SCENE_KHR specifies that the presentation engine waits for the next vertical blanking period to update the current image. Tearing cannot be observed. An internal queue is used to hold pending presentation requests. New requests are appended to the end of the queue, and one request is removed from the beginning of the queue and processed during each vertical blanking period in which the queue is non-empty. This is the only value of presentMode that is required to be supported.

VK_PRESENT_MODE_FIT_TO_PIX_KHR specifies that the presentation engine generally waits for the next vertical blanking period to update the current image. If a vertical blanking period has already passed since the last update of the current image then the presentation engine does not wait for another vertical blanking period for the update, meaning this mode may result in visible tearing in this case. This mode is useful for reducing visual stutter with an application that will mostly present a new image before the next vertical blanking period, but may occasionally be late, and present a new image just after the next vertical blanking period. An internal queue is used to hold pending presentation requests. New requests are appended to the end of the queue, and one request is removed from the beginning of the queue and processed during or after each vertical blanking period in which the queue is non-empty.

Here's What the Vulkan Spec Has to Say About Present Modes, II

VK_PRESENT_MODE_SPLAY_REFRESH_KHR specifies that the presentation engine and application have concurrent access to a single image, which is referred to as a shared presentable image. The presentation engine is only required to update the current image after a new presentation request is received. Therefore the application must make a presentation request whenever an update is required. However, the presentation engine may update the current image at any point, meaning this mode may result in visible tearing.

VK_PRESENT_MODE_SPLAY_REFRESH_KHR specifies that the presentation engine and application have concurrent access to a single image, which is referred to as a shared presentable image. The presentation engine periodically updates the current image on its regular refresh cycle. The application is only required to make one initial presentation request, after which the presentation engine must update the current image without any need for further presentation requests. The application can indicate the image contents have been updated by making a presentation request, but this does not guarantee the timing of when it will be updated. This mode may result in visible tearing if rendering to the image is not timed correctly.
Creating a Swap Chain

1. vkGetDevicePhysicalSurfaceCapabilitiesKHR
2. VkSurfaceCapabilities

VkSwapchainCreateInfoKHR vscci;
vscci.sType = VK_STRUCTURE_TYPE_SWAPCHAIN_CREATE_INFO_KHR;
vscci.pNext = nullptr;
vscci.flags = 0;
vscci.surface = Surface;
vscci.minImageCount = 2; // double buffering
vscci.imageFormat = VK_FORMAT_B8G8R8A8_UNORM;
vscci.imageColorSpace = VK_COLORSPACE_SRGB_NONLINEAR_KHR;
vscci.imageExtent.width = surfaceRes.width;
vscci.imageExtent.height = surfaceRes.height;
vscci.imageUsage = VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT;
vscci.preTransform = VK_SURFACE_TRANSFORM_IDENTITY_BIT_KHR;
vscci.compositeAlpha = VK_COMPOSITE_ALPHA_OPAQUE_BIT_KHR;
vscci.imageArrayLayers = 1;
vscci.imageSharingMode = VK_SHARING_MODE_EXCLUSIVE;
vscci.queueFamilyIndexCount = 0;
vscci.pQueueFamilyIndices = (const uint32_t *)nullptr;
vscci.presentMode = VK_PRESENT_MODE_MAILBOX_KHR;
vscci.oldSwapchain = VK_NULL_HANDLE;
vscci.clipped = VK_TRUE;

result = vkCreateSwapchainKHR(LogicalDevice, IN &vscci, PALLOCATOR, OUT &SwapChain);
Creating the Swap Chain Images and Image Views

```c
uint32_t imageCount; // # of display buffers – 2? 3?
result = vkGetSwapchainImagesKHR( LogicalDevice, IN SwapChain, OUT &imageCount, (VkImage *)nullptr );

PresentImages = new VkImage[ imageCount ];
result = vkGetSwapchainImagesKHR( LogicalDevice, SwapChain, OUT &imageCount, PresentImages );

// present views for the double-buffering:
PresentImageViews = new VkImageView[ imageCount ];
for( unsigned int i = 0; i < imageCount; ++i )
{
    VkImageViewCreateInfo vivci;
    vivci.sType = VK_STRUCTURE_TYPE_IMAGE_VIEW_CREATE_INFO;
    vivci.pNext = nullptr;
    vivci.flags = 0;
    vivci.viewType = VK_IMAGE_VIEW_TYPE_2D;
    vivci.format = VK_FORMAT_B8G8R8A8_UNORM;
    vivci.components.r = VK_COMPONENT_SWIZZLE_R;
    vivci.components.g = VK_COMPONENT_SWIZZLE_G;
    vivci.components.b = VK_COMPONENT_SWIZZLE_B;
    vivci.components.a = VK_COMPONENT_SWIZZLE_A;
    vivci.subresourceRange.aspectMask = VK_IMAGE_ASPECT_COLOR_BIT;
    vivci.subresourceRange.baseMipLevel = 0;
    vivci.subresourceRange.levelCount = 1;
    vivci.subresourceRange.baseArrayLayer = 0;
    vivci.subresourceRange.layerCount = 1;
    vivci.image = PresentImages[ i ];
    result = vkCreateImageView( LogicalDevice, IN &vivci, PALLOCATOR, OUT &PresentImageViews[ i ] );
}
```

Rendering into the Swap Chain, I

```c
VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;
    VkSemaphore imageReadySemaphore;
    result = vkCreateSemaphore( LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );

uint32_t nextImageIndex;
uint64_t timeout = UINT64_MAX;
vkAcquireNextImageKHR( LogicalDevice, IN SwapChain, IN timeout, IN imageReadySemaphore, IN VK_NULL_HANDLE, OUT &nextImageIndex );

result = vkBeginCommandBuffer( CommandBuffers[ nextImageIndex ], IN &vcbbi );

vkCmdBeginRenderPass( CommandBuffers[ nextImageIndex ], IN &vrpbi,
                      IN VK_SUBPASS_CONTENTS_INLINE );
vkCmdBindPipeline( CommandBuffers[ nextImageIndex ], VK_PIPELINE_BIND_POINT_GRAPHICS, GraphicsPipeline );

vkCmdEndRenderPass( CommandBuffers[ nextImageIndex ] );
vkEndCommandBuffer( CommandBuffers[ nextImageIndex ] );
```
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Rendering into the Swap Chain, II

```
VkFenceCreateInfo vfci;
vfci.sType = VK_STRUCTURE_TYPE_FENCE_CREATE_INFO;
vfci.pNext = nullptr;
vfci.flags = 0;

VkFence renderFence;
vkCreateFence( LogicalDevice, &vfci, PALLOCATOR, OUT &renderFence );

VkQueue presentQueue;
vkGetDeviceQueue( LogicalDevice, FindQueueFamilyThatDoesGraphics( ), 0, OUT &presentQueue );

VkSubmitInfo vsi;

result = vkQueueSubmit( presentQueue, 1, IN &vsi, IN renderFence ); // 1 = submitCount
```