Vulkanised 2024

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Common Mistakes when Learning Vulkan

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Presentation:
https://bit.ly/48THtwc

Outline

- Basics Usage
- Tooling Tips
- Abstract Advice
- API shenanigans
- Conceptual Conundrums
- Profiling Pro-tips

What is my Vulkan experience?

- Started learning Vulkan in 2017
- Joined the Vulkan Discord in 2018
- Began work at LunarG in 2019
  - Maintain the Vulkan-Loader, vulkaninfo, api_dump, & help with lots more
- Talked with everyone and anyone I could about Vulkan
- Helped countless others learning the API

Who is this talk for?

- People new to Vulkan
- People new to Vulkan *and* programming
- Some content may not be new to you
    - It was new to you at one point so bears repeating for everyone

Basic Usage

Mistake: Its Vul*KAN*, not Vul*CAN'T*!

- Don't count yourself out!
- Everybody was in your position
- You *KAN* do it!

Mistake: Ignoring programming best practices

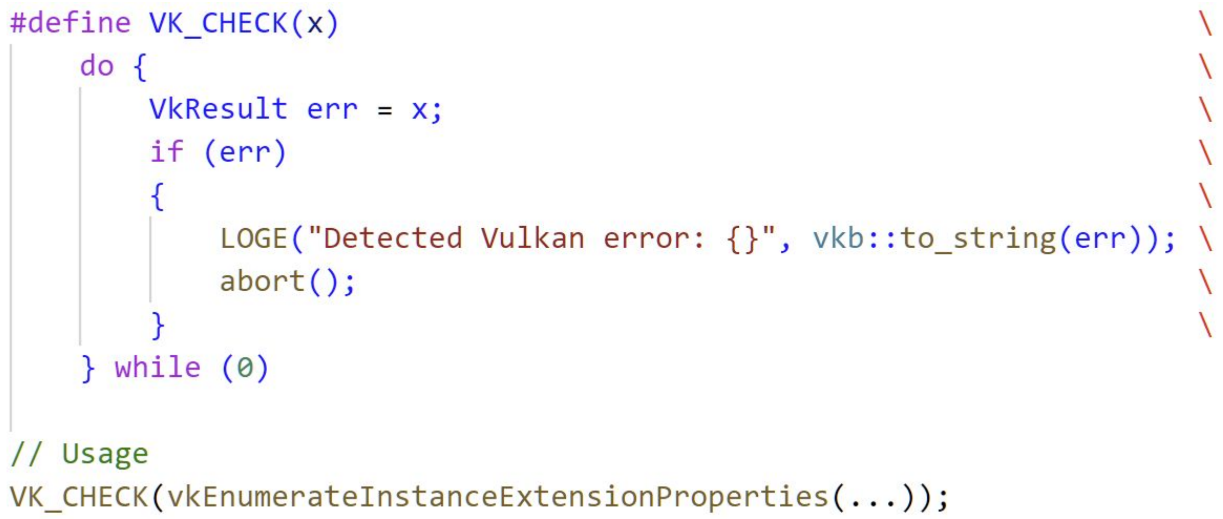
- Enable warnings in compilers: /W4 in MSVC, -Wall in gcc/clang
- Use Address Sanitizer for C & C++
- Use version control, such as Git

Mistake: Optimizing too early

- Feature first, speed second
- A single triangle is not a serious workload
- “Premature optimization is the root of all evil” - Donald Knuth
- Computers are way faster than you think
    - AAA games have thousands of shaders, pipelines, drawcalls, and more

Mistake: Ignoring VkResult return values

- Ignoring return values often results in crashing in subsequent code
- Error checking macro taken from Vulkan-Samples/framework/common/error.h



```
#define VK_CHECK(x)                                            \
    do {                                                       \
        VkResult err = x;                                      \
        if (err)                                               \
        {                                                      \
            LOGE("Detected Vulkan error: {}", vkb::to_string(err)); \
            abort();                                           \
        }                                                      \
    } while (0)

// Usage
VK_CHECK(vkEnumerateInstanceExtensionProperties(...));
```

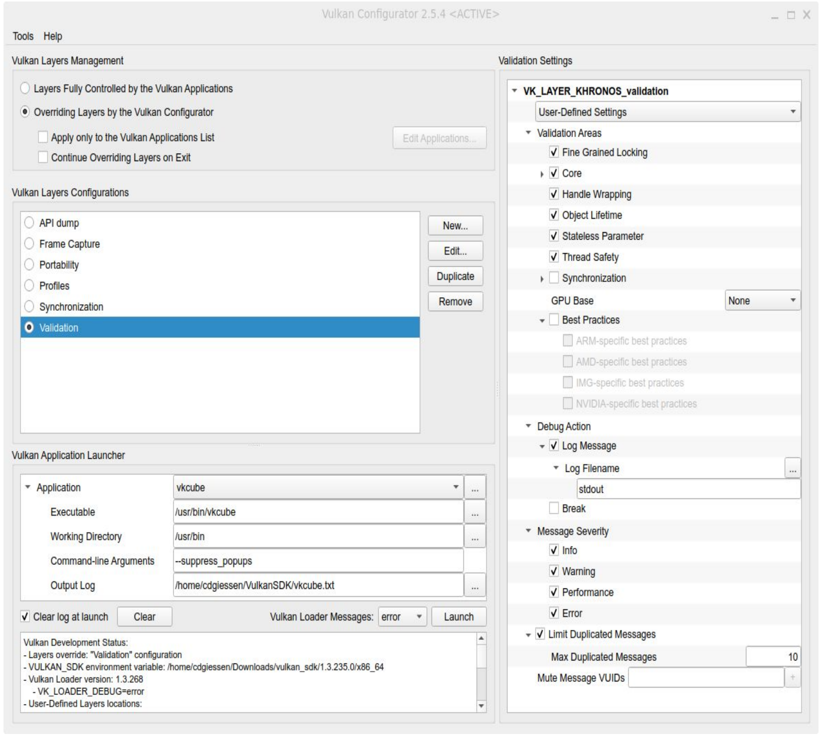
Tooling Tips

Mistake: Ignoring the SDK

- Building every tool is a hassle, save yourself the trouble
- Full of useful tools
  - Validation, shader compilers, shader reflection, Vulkan Configurator, gfxreconstruct, and more!
- More info “Everything you need to know about the Vulkan SDK”
  - Talk was held yesterday
- May need to close & reopen IDE after installing the SDK

Mistake: Not using Vulkan Configurator

- Super easy layer configuration
- Makes many validation settings just a click away
- My goto for using validation, api_dump, gfxreconstruct, disabling layers



Vulkan Layers Management
- ○ Layers Fully Controlled by the Vulkan Applications
- ● Overriding Layers by the Vulkan Configurator
  - ☐ Apply only to the Vulkan Applications List
  - ☐ Continue Overriding Layers on Exit

Vulkan Layers Configurations
- ○ API dump
- ○ Frame Capture
- ○ Portability
- ○ Profiles
- ○ Synchronization
- ● Validation

Vulkan Application Launcher

Application	vkcube
Executable	/usr/bin/vkcube
Working Directory	/usr/bin
Command-line Arguments	--suppress_popups
Output Log	/home/cdgiessen/VulkanSDK/vkcube.txt

✓ Clear log at launch — Vulkan Loader Messages: error

```
Vulkan Development Status:
- Layers override: "Validation" configuration
- VULKAN_SDK environment variable: /home/cdgiessen/Downloads/vulkan_sdk/1.3.235.0/x86_64
- Vulkan Loader version: 1.3.268
  - VK_LOADER_DEBUG=error
- User-Defined Layers locations:
```

Validation Settings
- VK_LAYER_KHRONOS_validation
  - User-Defined Settings
  - Validation Areas
    - ✓ Fine Grained Locking
    - ✓ Core
    - ✓ Handle Wrapping
    - ✓ Object Lifetime
    - ✓ Stateless Parameter
    - ✓ Thread Safety
    - ☐ Synchronization
    - GPU Base: None
    - ☐ Best Practices
      - ☐ ARM-specific best practices
      - ☐ AMD-specific best practices
      - ☐ IMG-specific best practices
      - ☐ NVIDIA-specific best practices
  - Debug Action
    - ✓ Log Message
      - Log Filename: stdout
    - ☐ Break
  - Message Severity
    - ✓ Info
    - ✓ Warning
    - ✓ Performance
    - ✓ Error
  - ✓ Limit Duplicated Messages
    - Max Duplicated Messages: 10
  - Mute Message VUIDs

Mistake: Ignoring validation errors

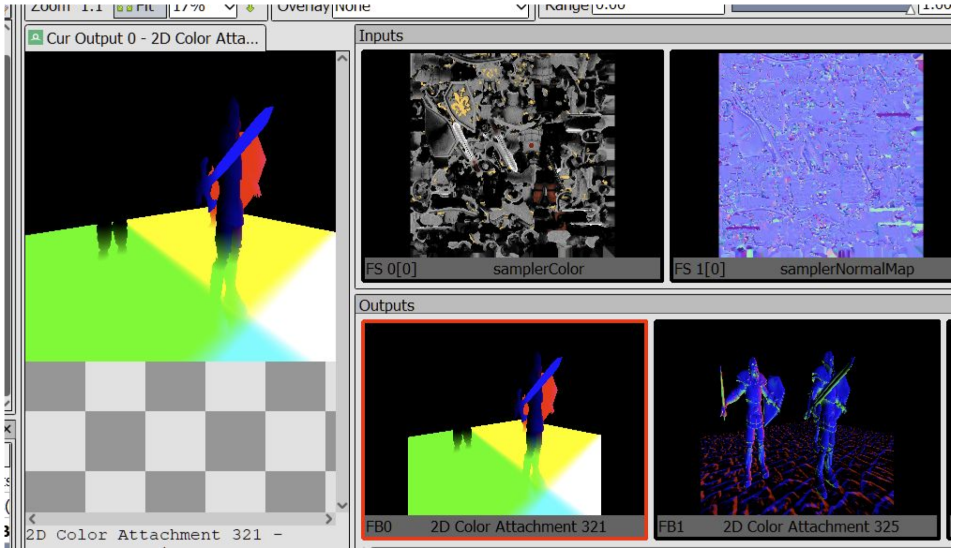
- They wouldn’t be called validation *errors* if they weren’t errors
- Undefined behavior (UB) ensues after all invalid usage
  - UB includes working on your current hardware
- Jeremy’s talk “Using Vulkan Validation Effectively” yesterday for more info

Mistake: Not utilizing educational resources

- https://docs.vulkan.org
  - Specification, Guide, Tutorial, & Samples all in one place
- People want to help!
  - https://discord.com/vulkan
  - https://khr.io/slack
  - https://reddit.com/r/vulkan

Mistake: Not using Graphics Debuggers

- Essential tool in every graphics programmers toolbox
- Many to choose from!
  - Renderdoc (cross platform)
  - Nsight (Nvidia)
  - Radeon Developer Tools Suite (AMD)
  - Intel GPA
  - Android GPU Inspector



Zoom 1:1 Fit 17%
Overlay None
Range 0.00 1.00
Cur Output 0 - 2D Color Atta...
Inputs
FS 0[0] samplerColor
FS 1[0] samplerNormalMap
Outputs
FB0 2D Color Attachment 321
FB1 2D Color Attachment 325
2D Color Attachment 321 -

Mistake: Ignoring helper libraries

- They exist to help you get things done
- Don’t try to reinvent the wheel
- I recommend Vk-bootstrap & Vulkan Memory Allocator & Volk
- Windowing libraries are essential
  - SDL or GLFW is fine
- Lots of other libraries out there
- Even AAA games uses libraries

Abstract advice

Mistake: Too much abstraction

- The Vulkan API is an abstraction siren, resist its call!
    - A bad abstraction is worse than no abstraction
- Vulkan is complex, learn how it works first before trying to abstract it!
    - Use libraries & frameworks before creating your own
- A overly abstract renderer makes is difficult to maintain & add onto
- KISS - Keep It Super Simple, Keep It Small and Simple, Keep It Stupidly Simple

Tips for abstracting Vulkan

- Focus on exactly what your application requires
- Don’t support every possible Vulkan feature
  - Stick to the features & capabilities you make use of
  - Combinatorial explosion of code paths is exponentially more difficult to maintain
- Areas where its very easy to go overboard:
  - Memory allocation
  - Automatic barrier placement
  - Descriptor set handling
  - Initialization/device selection
  - Swapchain resizing
  - Resource uploading

Mistake: Falling into Analysis Paralysis

- Don’t let PERFECT be the enemy of GOOD ENOUGH
- Best way to find out the answer is to start trying them out
- If you really can’t decide - pick randomly
- No ‘best’ way, only different ways with different tradeoffs
- Example: Data Uploading
    - Push constants, memory mapped buffers, device local buffers, & more

Mistake: Not throwing code away

- Best Vulkan code I’ve written is code I rewrote countless times
- Code that was difficult to write the first time becomes easier to do
- Good solutions come from knowing the exact problem being solved
    - Hard to know what the real problem is at first
- Good use of version control means code is never really gone
- This isn’t an excuse to write bad code!

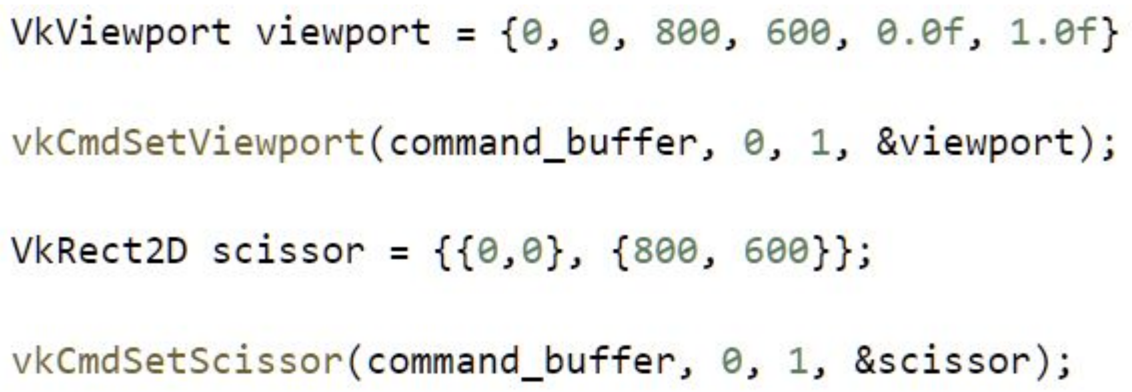
Mistake: Assuming you are a solo developer

- The “other” person may be you in the future
- Don’t assume the you of the future will know what the you of today was thinking
- Vulkan has plenty of rules that aren’t obvious from just looking at samples
    - So simple, obvious code to make them apparent

API Shenanigans

Mistake: Not using dynamic viewport & scissor

- Greatly simplifies using pipelines
- No performance penalty
- Supported since launch



```
VkViewport viewport = {0, 0, 800, 600, 0.0f, 1.0f}

vkCmdSetViewport(command_buffer, 0, 1, &viewport);

VkRect2D scissor = {{0,0}, {800, 600}};

vkCmdSetScissor(command_buffer, 0, 1, &scissor);
```

Mistake: Not using Dynamic Rendering

- Removes VkRenderPass & subpasses
  - The most confusing part of Vulkan 1.0
- From VK_KHR_dynamic_rendering, made core in 1.3
- Makes the API more consistent - but not *easier*
- VK_KHR_dynamic_rendering_local_read just released!
  - Lets multiple passes stay on tile, which previously required subpasses

Mistake: Not knowing your hardware requirements

- If you aren't actively testing on a platform, you don't support that platform
  - Focus on the hardware & OS you have
  - Cross-platform is more work
- If a hardware vendor doesn't support it, neither should you
- Fallback paths for old hardware is often not worth it
  - 1.3, released in 2022 is widely supported on desktop hardware

Mistake: Prioritizing smooth swapchain resizing

- Doesn’t provide enough benefit for the cost
- Resizing is often slow to begin with, increasing complexity
- Difficult to do when generating a frame is expensive, like in games
- Requires VK_EXT_swapchain_maintenance1 to do it properly
- Resizing can happen anytime, complicates multithreaded renderers

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Mistake: Not understanding VkPresentModeKHR

- No perfect mode - know the tradeoffs

Present Mode	Tearing	Latency	Drops Frames	Support	Consumes Battery	Notes
Immediate	Yes	Lower	YES	Almost Guaranteed	Yes	
Mailbox	No	Low	Yes	In newer drivers	Yes	
FIFO	No	Highest	No	Guaranteed	Not as much	Good default
FIFO_relaxed	Yes	High	Yes, but rarely	In newer drivers	Not as much	

Mistake: Enabling all features and extensions

- Be explicit about which versions, features, and extensions you use
- Some extensions have significant performance penalties
    - For example, the robustness extensions cost performance
- Blindly enabling things greatly limits cross-platform support
    - May accidentally use features not found on other platforms
- Use Vulkan Profiles as baselines
    - VP_KHR_roadmap_2022 & VP_ANDROID_baseline_2022

Mistake: Forgetting portability extensions

- Enable VK_KHR_portability_enumeration on the instance
- Enable VK_KHR_portability_subset on the device
- Validation will complain otherwise

Mistake: Trying to use all available VkQueues

- First queue supports graphics, compute, and transfer operations
  - This queue can do everything you need*
- Multi-queue can offer performance advantages
  - More difficult implementation wise
  - Example: Requires queue family ownership transfers

* Video encode/decode may require separate queues

Mistake: Calling vkQueueWaitIdle every frame

- Causes the CPU to wait for the GPU to finish before continuing
- Significantly reduces pipelining, if not eliminates it
- And especially don’t call vkDeviceWaitIdle!
    - Same as calling vkQueueWaitIdle on *all* queues

Conceptual Conundrums

Mistake: Modifying/Destroying objects in use

- “In use” refers to objects referenced by command buffers that are executing
- Anything used by a command buffer is subject to this rule
- Vulkan is asynchronous by nature
    - Think of Vulkan like a remote server
    - Must explicitly sync with fences & timeline semaphores
- Anything with “externally synchronized” makes you handle synchronization

Mistake: Assuming Vulkan is Object Oriented

- Vulkan is an API - doesn’t follow OO paradigms
- Vulkan objects aren’t analogous to OOP objects
- RAII wrappers are difficult to get correct
    - The lifetime of CPU objects doesn’t line up with Vulkan objects implicitly

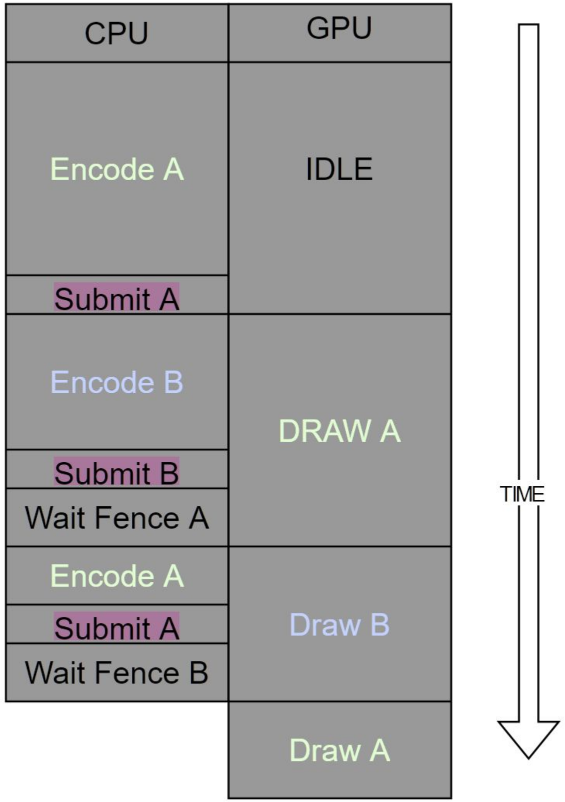
Advice: Use a deletion queue to manage cleanup

- Deletion queue contains objects & their associated “expiration”
  - Centralizes cleanup of old objects
- “In-use” objects that need to be deleted are added to the queue
- Every frame, deletion queue checks which objects have expired
  - Checks can be a fence, timeline semaphore, or similar
  - Calls appropriate cleanup calls on each object, such as vkDestroyImage()

Mistake: Misunderstanding Frames in Flight

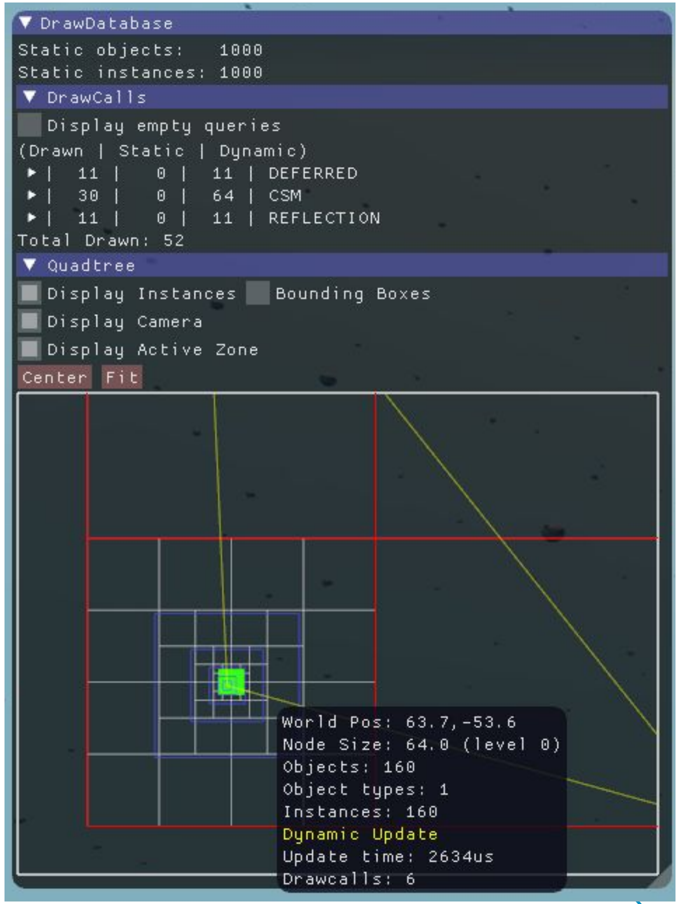
Img source: https://vkguide.dev/docs/new_chapter_1/vulkan_mainloop/

- Concept CPU and GPU to work on different frames at the same time
  - Often called “Double buffering” or “multi-buffering”
- It is NOT equal to swapchain image count
- 2 Frames in flight is fine
- Only need to duplicate resources that are written by CPU & read by GPU
  - Depth buffer does not need double buffering



Mistake: Waiting to add a GUI

- Reduces development time of graphics features
- Quickly change what is being shown
  - Rather than have to close & reload application
- Dear ImGUI is a great choice
  - But many other options are available



```
▼ DrawDatabase
Static objects:   1000
Static instances: 1000
▼ DrawCalls
Display empty queries
(Drawn | Static | Dynamic)
► |  11 |    0 |  11 | DEFERRED
► |  30 |    0 |  64 | CSM
► |  11 |    0 |  11 | REFLECTION
Total Drawn: 52
▼ Quadtree
Display Instances   Bounding Boxes
Display Camera
Display Active Zone
Center  Fit
World Pos: 63.7,-53.6
Node Size: 64.0 (level 0)
Objects: 160
Object types: 1
Instances: 160
Dynamic Update
Update time: 2634us
Drawcalls: 6
```

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Profiling Pro-tips

Mistake: Not measuring

- Don’t think, measure
- Deciding things without measuring is like no better than guessing
  - It’s like scientists using “feelings” instead of “facts”
- Don’t waste your time optimizing things that aren’t slow
- Understand Amdahl’s law
  - "The overall performance improvement gained by optimizing a single part of a system is limited by the fraction of time that the improved part is actually used"

Mistake: Not using a profiler

- Gives a wealth of information
  - Drawcall execution time, memory pressure, register spilling, occupancy, & more
- Many great profilers exist - for example:
  - AMD Radeon GPU Profiler
  - Android GPU Inspector (AGI)
  - ARM Mobile Studio & PerfDoc
  - Nvidia Nsight Tools
  - Qualcomm Snapdragon Profiler
  - Tracy Profiler - cross vendor
- Bonus Mistake: Renderdoc *isn't* a profiler -

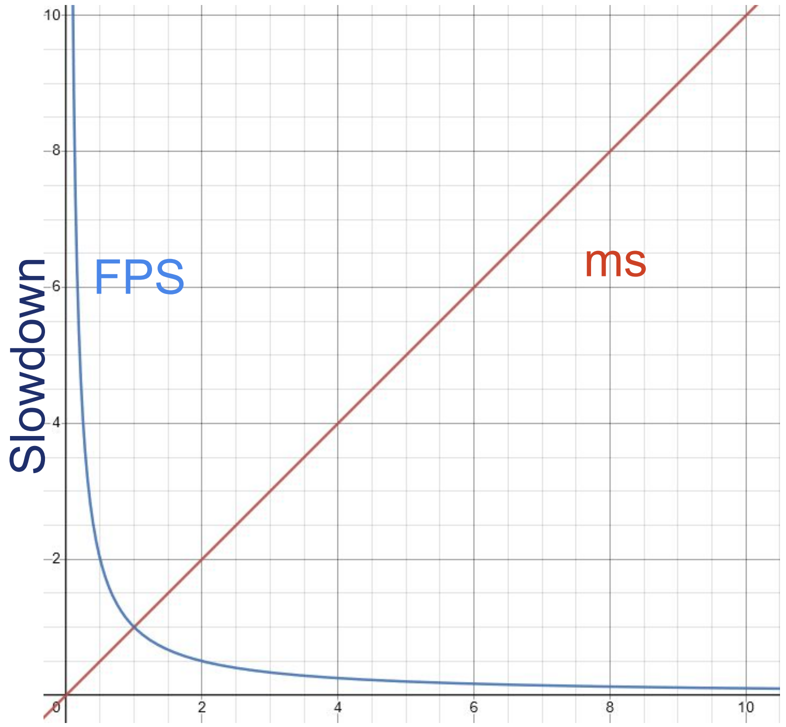
Mistake: Not following vendor Best Practices

- Vendors want you to succeed
- Best practices from vendors are available in the validation layer
- Written guides also are available

- AMD: https://gpuopen.com/performance/
- Intel: https://software.intel.com/content/www/us/en/develop/articles/developer-and-optimization-guide-for-intel-processor-graphics-gen11-api.html
- Nvidia: https://developer.nvidia.com/blog/vulkan-dos-donts/
- ARM: https://developer.arm.com/solutions/graphics-and-gaming/developer-guides/advanced-guides/mali-gpu-best-practices
- Qualcomm: https://developer.qualcomm.com/sites/default/files/docs/adreno-gpu/developer-guide/gpu/best_practices.html

Mistake: Using Frames Per Second

- Use milliseconds instead!
- FPS doesn’t measure time
  - ∆ FPS is meaningless without context
  - ∆ ms means the same thing always
- Milliseconds is linear & more granular
- Profilers give you ms, not FPS



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Recap

Recap

- Use the validation layer, debuggers, profilers, & other tools
- Use all available resources - educational, people, and libraries
- Don’t overthink it - KISS again
- Don’t think you need to use every Vulkan feature
- Measure, then act

Help Us Improve the Vulkan SDK and Ecosystem

Share Your Feedback

Take the LunarG annual developer's survey

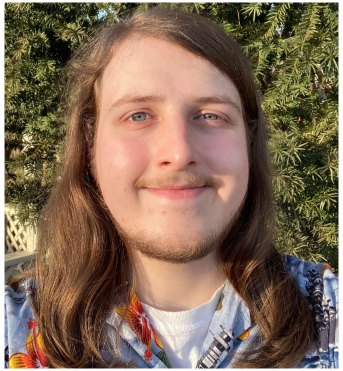
https://www.surveymonkey.com/r/KTBZDCM

- Survey results are tabulated
- Shared with the Vulkan Working Group
- Actions are assigned
- Results are reported

Survey closes February 26, 2024

Today's Presentation:

https://bit.ly/48THtwc



Thank you!

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