Make Your Game Friendly for Graphics Debugging and Optimization

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AGENDA

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Introduction
Iteration time is critically important

Good engine is not about awesome renderer. It’s about tools – like convenient editor.

- Shorter iteration time
- Good tools
Everyone benefits

Easier to search for bugs and performance optimizations – benefit for:

• developers
• QA
• external partners
Part 1

Basics
Options (1)

Provide configuration options:

• resolution
• display mode: Windowed / Borderless / Exclusive fullscreen
• V-sync On/Off
Options (2)

- texture resolution: important for GPUs with little memory
- texture filtering quality (linear vs anisotropic): impacts performance
- MSAA Disabled/2x/4x/…

- (extra) resolution scaling
Ways to provide options

Some may be *visible* to end users.
- in-game menu
- launcher window (e.g. Unity) or separate app

Some may be *hidden*.
- in-game developer/cheat panel
- in-game console (e.g. Unreal Engine)
- command line options
- configuration file, Windows registry
Options

The Talos Principle – in-game options
Options

Unity launcher window
Options

War Thunder – custom launcher app
Options

Unreal Engine – in-game console
Options (3)

Effects On/Off/quality level:

- user-facing
  - number of objects (e.g. grass distance)
  - shader complexity (e.g. water quality)
Options (4)

Effects On/Off/quality level:

- internal
  - CPU workloads
  - Graphics
  - GPU compute

Optimizations On/Off
Correctness/stability

“Safe mode”

• single threaded
• D3D12, Vulkan®: additional synchronization
• useful for debugging visual corruptions and GPU crashes (TDR)
Developer Game Build

• works as standalone EXE (without Steam, no UWP)
• works offline, no connection to server required
  • Server often down or incompatible during development.
  • Users may be behind restrictive firewall/VPN.
• no DRM/anti-cheat/anti-piracy protection (like Denuvo)
• Provide documentation of available settings, cheats, god mode.
• Provide saves for various locations.
Loading Time

Short loading time is critical.

- simple test scene with just few objects
- loading production scene should still be fast
- performance of debug build also important
Benchmark Mode

• *automated* testing (continuous integration)
  • correctness
  • performance

• *manual* testing
  • your developers
  • QA

[van Valburg]
Benchmark Mode

- launched with special command line parameter
- non-interactive – scripted camera flythrough
- representative scene
  - graphics
  - gameplay logic?
- deterministic
  - every run calculates and shows the same

Extra:
- ends automatically
- measures performance, writes results to text file
Part 2

Advanced

Beware! Code ahead.
In-Game Profiler

- FPS and average frame time
- Detailed counters – time of render passes

If not available, you can measure frame times with OCAT. [OCAT]
FPS and beyond

- Statistical measures – avg, min, max, percentile (1%, 99%)
- Catch spikes
- Draw frame histogram
In-Game Tools

Debug modes for visualization of intermediate data e.g. ambient occlusion only.

• Pixel inspector window
• Way to distinguish NaN, INF from 0, 1

Source: docs.unrealengine.com
Debug/Validation Layers

• Old APIs (*Direct3D 9, OpenGL®*): any function can return error.

• New APIs (*Direct3D 11, 12, Vulkan®*): no error checking.
• Debug/validation layer can be explicitly enabled.

• Use them in regular testing.
• Require to pass on all APIs.
Debug Layer – Direct3D 11, 12

D3D11_CREATE_DEVICE_DEBUG

CComPtr<ID3D12Debug> debug;
if(SUCCEEDED(D3D12GetDebugInterface(IID_PPV_ARGS(&debug))))
download->EnableDebugLayer();
Debug Layer – Direct3D

Visual Studio – Output
Debug Layer – Direct3D
Validation Layers – Vulkan®

VK_LAYER_LUNARG_standard_validation

• enable programmatically or
• set VK_INSTANCE_LAYERS=VK_LAYER_LUNARG_standard_validation

• messages delivered as callback
Driver Bug?

OGL, D3D11:
• driver handling complex logic
• crashes not expected – if crashed, **driver bug** very likely

Vulkan®, D3D12:
• game/engine responsible for most logic
• API is low level, driver is thin
• if crashing, most likely **your bug**
GPU-Assisted Validation

- Available in Vulkan ("GPU-assisted validation") and Direct3D 12 ("GPU-based validation").
- Enabled programmatically or externally.
- Injects additional code to shaders.

- Finds bugs in dynamic resource indexing - useful for "bindless".
Tools – RenderDoc

Alternatives: Nvidia® Nsight™, Intel® Graphics Performance Analyzers (GPA)
Tools – PIX
Tools – Radeon GPU Profiler
Tools – GPUView
Debug Markers

• Aka “labels”, “annotations”

• Wrap passes with Begin…End markers with custom names.

• Give names to resources.

• Supported by many tools.
Debug Markers

- D3D9+: D3DPERF_BeginEvent(), D3DPERF_EndEvent()
- D3D11.1+: ID3DUserDefinedAnnotation::BeginEvent(), EndEvent()
- Vulkan®: VK_EXT_debug_utils
  - previously: VK_EXT_debug_marker
Debugging GPU crash/hang

Crash/hang of driver/GPU doesn’t crash whole system.
• Handled by Timeout Detection & Recovery (TDR).

Difficult to debug.

Display driver stopped responding and has recovered
Display driver lddmkm stopped responding and has successfully recovered.

- VK_ERROR_DEVICE_LOST
- DXGI_ERROR_DEVICE_REMOVED
Debugging GPU crash/hang

- Solution: markers written on GPU between draw calls.
- After crash: inspect last written value, deduce culprit draw call.

- Vulkan®: `vkCmdFillBuffer`
- Vulkan® + AMD: `VK_AMD_buffer_marker`
- D3D12: `ID3D12GraphicsCommandList2::WriteBufferImmediate`
- D3D12 + AMD: breadcrumb markers in AGS [AGS]
- D3D11/D3D12 + NVIDIA: NVIDIA Aftermath [Aftermath]
Debugging GPU crash/hang

Heavyweight solution: record each draw call state to a blob.

- Support serialized states and draw calls.
- Recreate state, reproduce the crash.
- Even better: record command buffers.
Conclusion
Good Practices

- first **stability**, then **correctness**, then **performance**
- **test** early, **test** often
- **test** on various **GPUs**
  - AMD, NVIDIA, Intel
  - low-end, high-end
- **track** **regressions**
Conclusion

• Good tools and short iterations time is important.
• Ensure them with:
  • development practices
  • your code
  • external tools
• Everyone benefits 😊
References

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- [RenderDoc] RenderDoc
  - [RenderDoc](http://renderdoc.org/)
- [PIX] PIX on Windows
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- [GPUView] GPUView
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QUESTIONS?
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