Source-level Shader Debugging in Vulkan with RenderDoc

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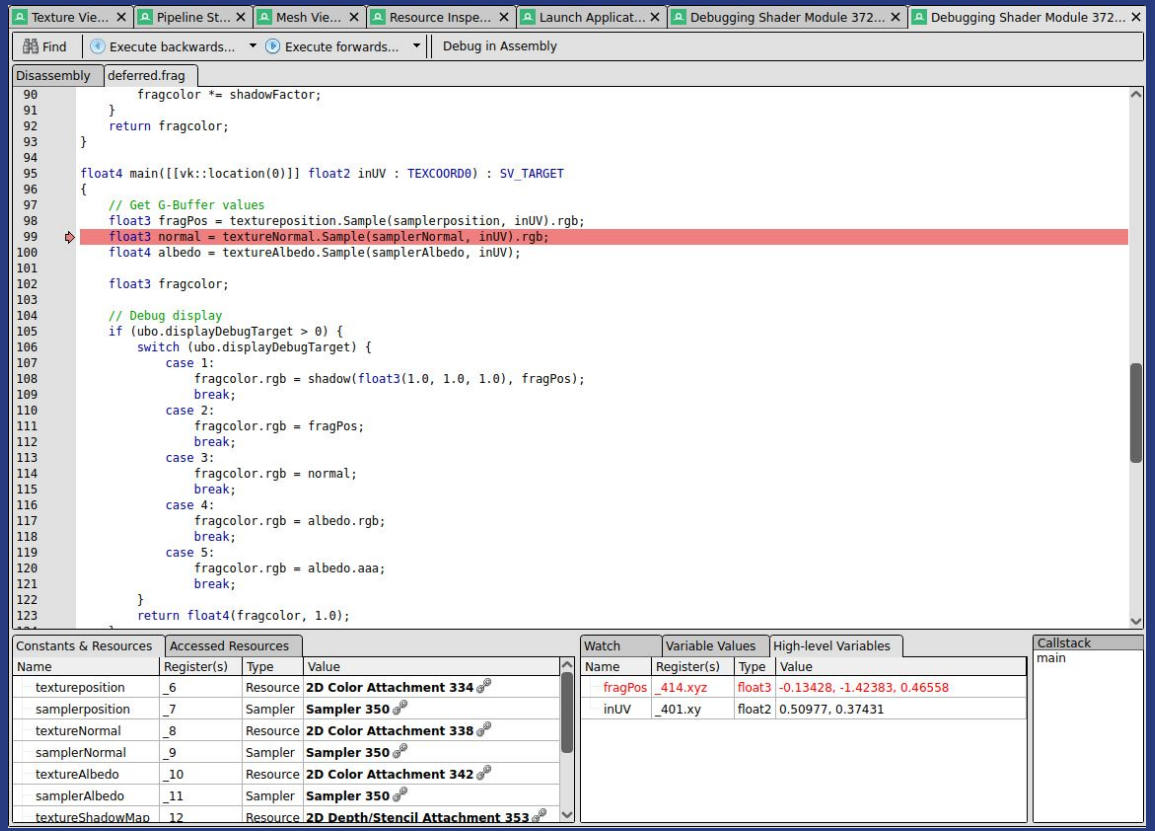
Presented at the Khronos Vulkanised 2023 Conference

LUNARG

Who is this guy?

- glslang moderator, developer, maintainer
- spirv-opt developer, maintainer
- dxc developer, maintainer(?)
- GPU-Assisted Validation developer, maintainer
- DebugPrintf developer, maintainer

Shader source debugging in Vulkan is here!



Agenda

- What is RenderDoc?
- What is NonSemantic.Shader.DebugInfo.100
- How to generate source-level debug information
- DebugInfo Instructions
- Status of compiler toolchain support
- Demo: How to debug shaders in RenderDoc

What is RenderDoc?

- Graphics Debugger for Vulkan and other APIs
- renderdoc.org
- Frame capture and debugging
- Shader debugging
  - Previously only SPIR-V disassembly
  - Now supports GLSL/HLSL source-level debugging
    - Source line stepping
    - Local variable names, values, scope-based display
  - Currently supported: fragment, vertex, compute shaders

NonSemantic.Shader.DebugInfo.100

- What?
  - Authored by Baldur Karlsson from RenderDoc
  - Non-semantic SPIR-V extended instruction set
    - (`OpExtInstImport "NonSemantic.Shader.DebugInfo.100"`)
    - NonSemantic instructions can be safely ignored by drivers
  - Derived from OpenCL.DebugInfo.100 and DWARF debugging standard
- Why?
  - Information useful to debugging is lost during compilation and optimization
    - Function Inlining
    - Local Variable Store and Load Elimination
  - This extension preserves the lost information
  - Allows source-level debugging of optimized shaders, especially legalized HLSL

NonSemantic.Shader.DebugInfo.100 - Instructions

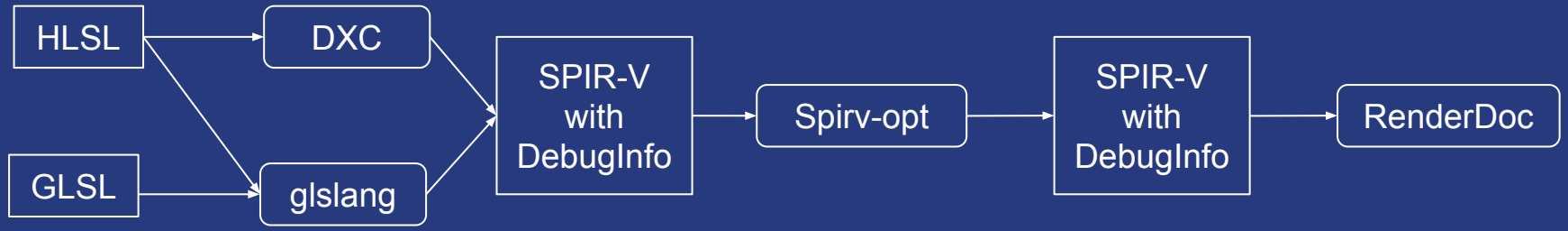
- Location
  - Source: DebugSource
  - Line / Column: DebugLine / DebugNoLine
- Types
  - int / floats / bool: DebugTypeBasic
  - vectors: DebugTypeVector
  - matrix: DebugTypeMatrix
  - arrays: DebugTypeArray
  - structure: DebugTypeComposite / DebugTypeMember
  - functions: DebugTypeFunction
- Variables
  - globals: DebugGlobalVariable
  - locals: DebugLocalVariable, DebugDeclare, DebugValue

NonSemantic.Shader.DebugInfo.100 - Instructions (cont'd)

- Procedures
  - DebugTypeFunction, DebugFunction
- Scope
  - DebugScope / DebugNoScope
    - Compilation unit: DebugCompilationUnit
    - Function: DebugFunction
    - Structure: DebugTypeComposite
    - Everything else: DebugLexicalScope

NonSemantic.Shader.DebugInfo.100

- How?
  - Annotates locations, scopes, types, variables, values, and procedures
  - DXC and glslang compiler support
  - SPIRV-Tools support
    - Optimization, Validation, Disassembly, Assembly
    - Optimization preserves DebugInfo



Generating Debug Information - DXC

```
\path\to\dxc.exe -spirv -fspv-target-env=vulkan1.3
      -T <target-profile> -E <entry-point>
      -fspv-extension=SPV_KHR_non_semantic_info
      -fspv-debug=vulkan-with-source
      <hlsl-src-file> -Fo <spirv-bin-file>
```

- `-fspv-debug=vulkan-with-source` instructs the compiler to generate DebugInfo instructions and embed the source string in the `DebugSource` instruction. RenderDoc reads the high-level source from this instruction.

- `-fspv-extension=SPV_KHR_non_semantic_info` instructs the compiler to use the `SPV_KHR_non_semantic_info` extension which is required to use non semantic extended instruction sets. Not required for Vulkan 1.3.

Generating Debug Information - glslang

HLSL

```
\path\to\glslangValidator.exe -e main -gVS -D -o <spirv-bin-file> <hlsl-src-file>
```

GLSL

```
\path\to\glslangValidator.exe -e main -gVS -V -o <spirv-bin-file> <glsl-src-file>
```

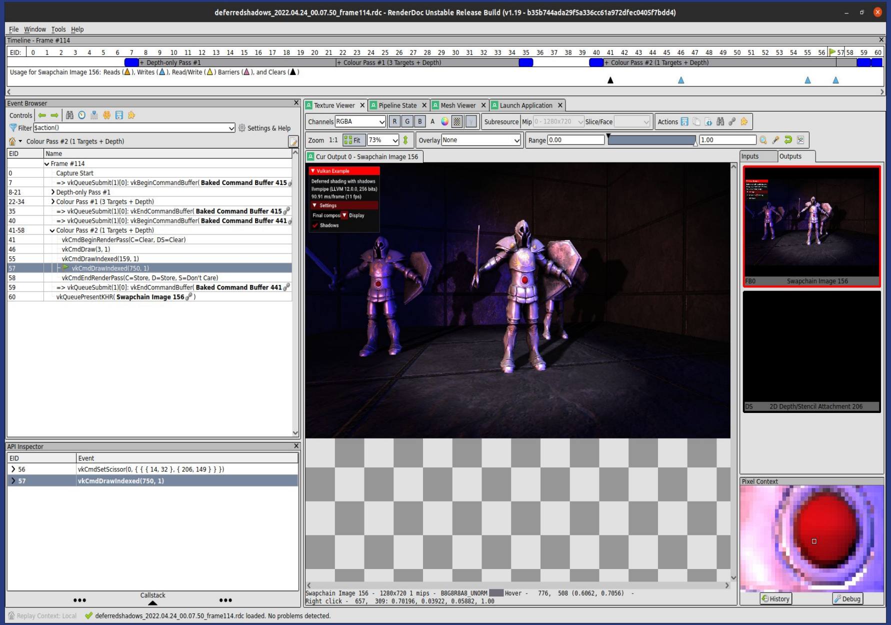
- `-gVS` instructs the compiler to embed the source string in the `DebugSource` instruction (similar to the `-fspv-debug=vulkan-with-source` argument in DXC).
- `-D` tells the compiler that the source is HLSL.
- `-V` tells the compiler that the source is GLSL under Vulkan semantics.

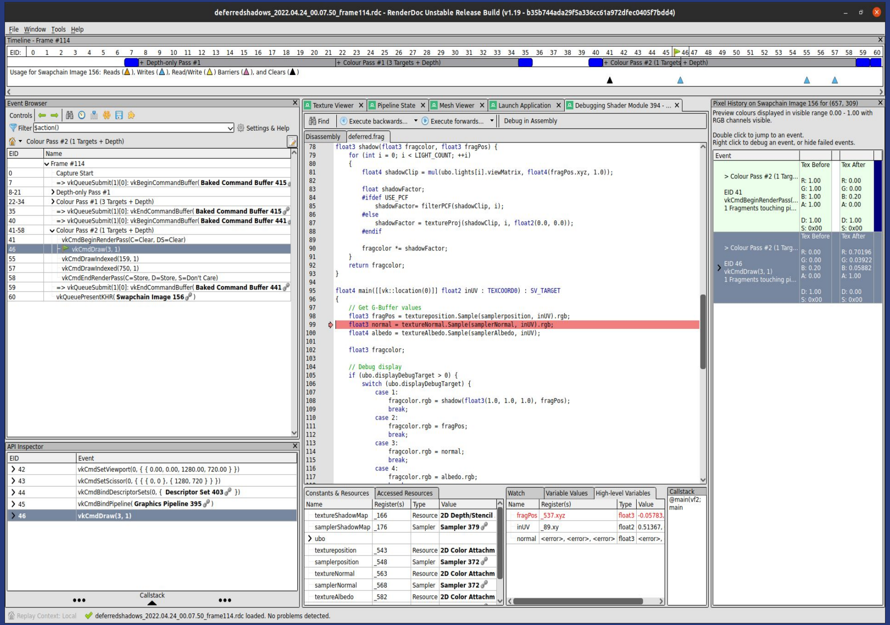
Debug information will increase the size of your SPIR-V (2-3X increase)

dxc/glslang Status

- Supported as of Vulkan SDK (1.3.231.1) and Renderdoc v1.25
- Valve shaders (thanks to Dan Ginsburg)
- Sascha Willems samples
  - 79 samples
    - 281 HLSL/GLSL Shaders
      - 127 vertex shaders
      - 131 fragment shaders
      - 10 compute shaders
      - 3 geometry shaders
      - 5 tesselation control shaders
      - 5 tesselation evaluation shaders
- Geom, Tesc, Tese untested
- DebugInfo not yet generated for: Ray Tracing, Mesh Shaders

Demo


deferredshadows_2022.04.24_00.07.50_frame114.rdc - RenderDoc Unstable Release Build (v1.19 - b35b744ada29f5a336cc61a972dfec0405f7bdd4)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Future work

- Squash bugs
- DebugBuildIdentifier / DebugStoragePath
  - Store debug information in a separate file

Thanks!

- Jeremy Hayes (LunarG)
  - original Vulkan Webinar presentation, DebugInfo in glslang
- Google
  - OpenCL.Debuginfo.100 support in DXC, SPIRV-Tools
- Baldur Karlsson (Valve)
  - NonSemantic.Shader.Debuginfo.100, RenderDoc
- Dan Ginsburg (Valve)
  - shaders, testing
- Sascha Willems
  - shaders, samples

Questions or presentation feedback?

Greg Fischer: greg@lunarg.com
Jeremy Hayes: jeremy@lunarg.com

Report bugs or make feature requests here:
https://github.com/KhronosGroup/glslang
https://github.com/microsoft/DirectXShaderCompiler

For more information:
https://www.lunarg.com/news-insights/white-papers/source-level-shader-debugging-in-vulkan-with-renderdoc-feb2023/

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