Adding Vulkan to Pixar’s Hydra Storm Renderer

Henrik Edstrom
Autodesk

Ashwin Bhat
Autodesk

Caroline Lachanski
Pixar

Tom Cauchois
Pixar
Agenda

- Intro to Hydra and Storm
- Vulkan, Cross-Platform Hydra Graphics and Tooling at Autodesk
- Software rendering and LavaPipe
- Hydra Graphics Interface
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“Autodesk makes software for people who design and make things”
We need a wide range of graphics capabilities

2D & Simple 3D

3D Modeling

Realistic Rendering
Autodesk’s Graphics Objectives

Modern APIs
- Vulkan
- DirectX 12
- WebGPU

Open Standards
- USD
- MATERIALX
- OpenPBR
- OCIO

Decoupled Architecture

Available on Desktop, Mobile, and Web
Hydra and Storm for Autodesk’s Viewports

Desktop App
Mobile App
Web App

Scene Index / Delegate

UsdImaging

Custom Scene Index / Delegate

HdStorm
Fast Rasterized Viewport

HdAurora
Real-time Realistic Viewport

HdArnold
Production Renderer

HGI
Vulkan.

WebGPU

DirectX 12
Aurora: An Open Source Real-time Path Tracer

- For quick design / lookdev iteration, not final-frame production rendering
- Vendor and platform agnostic
  - Linux, Windows – NVIDIA, AMD, Intel
  - macOS/Metal (work in progress)
- Supports Hydra, MaterialX, and Standard Surface (OpenPBR coming)
- Recent updates
  - Performance improvements (~2X)
  - OpenUSD 24.08
- **Source code:** https://github.com/Autodesk/Aurora
An Open Source, Community Approach

Contributions  Communities  Collaboration

OpenUSD  Hydra  AOUSD  ASWF  Pixar  Adobe

OpenPBR  Metaverse  KHronos  NVIDIA  Apple

To advance the OpenUSD and Hydra ecosystem
Graphics requirements at Autodesk

• Create and Visualize large models for industry workflows
  o 2D and 3D dataset that can grow exponentially.
    • Billions of primitives (Points, Lines, Triangles, Patches).
  o Texture usage vary based on industry focus.
  o Shading requirements vary based on industry focus
    • Simple unlit to physically correct

• Cross-Platform Graphics and Visualization
  o Windows
  o Linux and Android
  o macOS and iOS
  o Web and Cloud native
  o Virtualized Environments

• Leverage NextGen Hardware capabilities and practices.
Objectives for Autodesk Graphics Platform (AGP)

- Build on OpenUSD
  - Extend Hydra Abstraction Layer
  - Enhance HdStorm renderer with capabilities for Autodesk.

- Community partnership to explore solutions together and contribute to Open-Source Projects.

- Support Large Model Viewing with HgiVulkan.

- Production ready HgiVulkan for Autodesk products on Windows, Linux and Android.

- Thanks to Apple for contributing macOS & iOS enhancements to hgiMetal!
Feature requirements for AGP

- Viewport representations
- Multiple Viewports
- Visual styles
- In-Canvas UI integration
- Materials (unlit, shaded, realistic …)
- Ray tracing
- Industry specific requirements
  - Lines, Line Styles, Text, Markups, 2D, Draw Order
  - and more...

Autodesk’s Next-Generation Viewport System [S62312]
https://www.nvidia.com/gtc/sessions/openusd-day/
Current State of Vulkan in AGP

- In-house hdStorm based application for validating features.
- Capable of rendering mid to large models.
- Cross platform: Windows, Linux & Android
- Thin Vulkan layer that acquires handles from HgiVulkan.
- Composition and presentation performed in application layer.
- Provides ease of debugging and integration with analysis tools.
## Vulkan Graphics analysis tools

<table>
<thead>
<tr>
<th>Usage</th>
<th>Windows/Linux (desktop)</th>
<th>Android (Mobile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Validation</td>
<td>Vulkan Debug and Validation Layers</td>
<td></td>
</tr>
<tr>
<td>Vulkan Profiler</td>
<td>VkTimestampQuery based profiler</td>
<td></td>
</tr>
<tr>
<td>CPU + GPU Profiling (occupancy &amp; bottleneck)</td>
<td>GPUView (Windows) &lt;br&gt; GPUVis (Linux)</td>
<td>Streamline Performance Analyzer (ARM) &lt;br&gt; <strong>Snapdragon Profiler</strong> (Qualcomm)</td>
</tr>
<tr>
<td>GPU Memory Profiling</td>
<td>VMA Dump &lt;br&gt; VK_EXT_device_memory_report &lt;br&gt; AMD Memory Visualizer</td>
<td></td>
</tr>
<tr>
<td>Playback Frame Debugger</td>
<td>RenderDoc &lt;br&gt; NVIDIA Nsight Systems</td>
<td>RenderDoc &amp; AGI (ARM) &lt;br&gt; <strong>Snapdragon Profiler</strong> (Qualcomm)</td>
</tr>
<tr>
<td>Vendor Specific Profiler</td>
<td>AMD – Radeon™ GPU Profiler &lt;br&gt; NVIDIA – Nsight Systems</td>
<td>ARM – Streamline Performance Analyzer Qualcomm – Snapdragon Profiler</td>
</tr>
</tbody>
</table>

Huge thanks to all providers for excellent tooling support!
Performance challenges

Cross platform - Performance optimizations needed

Strategy:
1. Collect traces, analyze and fix as needed across platforms.
2. Repeat.
Software Rasterization

- Customers with large deployments need stable CPU fallback.
  - Reason: Driver instability, GPU feature support, sustainability, cost, business continuity etc.

- For Products: Small well scoped workloads can be executed using Software Rasterization.

- For Engineering teams: Cloud hosted environments and Cost of GPU virtualization is a limiting factor for CI and testing workflows.

- For DirectX users: WARP is Natively available on Windows
  https://devblogs.microsoft.com/directx/announcing-warp-preview-with-shader-model-6-7-support/

- Lack of Stable Software Rasterization is a go-no-go deal breaker for Vulkan adoption.
Software rasterization for Vulkan

- Early evaluation with SwiftShader
- Switched to llvmpipe/LavaPipe based on community feedback - thank you Vulkanised 2024!!
- Worked through build challenges on Windows.
- Evaluated llvmpipe/LavaPipe using Vulkan samples
- Problem solved?

Sascha Willems (https://github.com/SaschaWillems/Vulkan)
Illvmiipe/LavaPipe: HdStorm

LLVM ERROR: Instruction Combining did not reach a fixpoint after 1 iterations

test 722
Start 722: testUsdImagingGLBasicDrawing

722: Test command:
...
722: image diffing with ['idiff.exe', '-fail', '0.2', '-failpercent', '0.5', '-p', 'F:\source\USD-origin-vulkan\out\relwithdebuginfo\tests\test\testUsdImagingGLBasicDrawing\baseline\testUsdImagingGLBasicDrawing.png', 'testUsdImagingGLBasicDrawing.png']

1/10 Test #722: testUsdImagingGLBasicDrawing ....................... Passed 5.73 sec
Ilvmpipe/LavaPipe: USDView (HdStorm)

- USDView (HdStorm – Vulkan Lavapipe)
  - Mesa 24.1.4 (2024-07-17)
  - Ilvmpipe (LLVM 19.0.0, 256 bits)
  - VK_PHYSICAL_DEVICE_TYPE_CPU

- Autodesk Contributions to Mesa (Aleksi Sapon, Autodesk)
  - Lavapipe basic macOS support
  - gallivm: Fix LLVMPipe codegen issues discovered on Apple Silicon
  - Ilvmpipe: sampler matrix cache is slow because of mutex lock: 650% speedup by using RCU
Ilvmpipe/LavaPipe: Loader workflow

- Testing done using VK_ICD_FILENAMES override
  e.g., SET VK_ICD_FILENAMES=%MESA_DIR%\build\install\share\vulkan\icd.d\lvp_icd.x86_64.json

- Improve/simplify loader workflow
  e.g., from DirectX documentation

```cpp
if (m_useWarpDevice){
    ComPtr<IDXGIAdapter> warpAdapter;
    factory->EnumWarpAdapter(IID_PPV_ARGS(&warpAdapter));
    D3D12CreateDevice(warpAdapter.Get(),D3D_FEATURE_LEVEL_11_0, IID_PPV_ARGS(&m_device));
}
```

- How may we simplify CPU fallback workflows by ensuring lvp_icd is always available?
Next steps

• Prepare hgiVulkan for production usage
  o Specification compatibility.
  o Unit testing and coverage.

• Performance improvements
  o Improve CPU and GPU synchronization.
  o Render Graph support.
  o Optimize Vulkan usage on Desktop, Mobile (Android) and WebGPU.
  o Adopt Compute driven workflows esp. for current Geometry shader uses.
  o Occlusion Culling and HLOD integration.

• Software rasterization
  o Improve LavaPipe performance, deployment and loader.
Links and references

• OpenUSD homepage: https://openusd.org/
• OpenUSD GitHub: https://github.com/PixarAnimationStudios/OpenUSD
• Hydra intro: https://openusd.org/files/Siggraph2019_Hydra.pdf
• Alliance for OpenUSD: https://aousd.org/
• AOUSD Forum: https://forum.aousd.org/
• Vulkan SIGGRAPH BOF 2023 (recording on YouTube):
  – “Vulkan and Open Source Graphics at Autodesk”
  – “Vulkan for Cross-Platform Viewing of Large AEC Models”
• Autodesk Graphics Platform team contact: agp@autodesk.com
• Hydra contributions: https://github.com/Autodesk/openusd-hydra-contributions
• Aurora source code: https://github.com/Autodesk/Aurora
• Aurora contact: aurora@autodesk.com
• Autodesk Open Source landing page: https://opensource.autodesk.com/