LumiBench

a benchmark suite for hardware ray tracing

IISWC 2023

Lufei Liu, Mohammadreza Saed, Yuan Hsi Chou, Davit Grigoryan, Tyler Nowicki, and Tor M. Aamodt
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Background + Motivation

Ray Tracing

physically-based photo-realistic computer renderings

Background + Motivation

Ray Tracing Hardware

[further improvements are still necessary]
Vulkan-Sim


- extends GPGPU-Sim cycle-level architectural simulator
- models hardware ray tracing accelerator
- supports Vulkan API ray tracing applications

LumiBench is designed to execute with Vulkan-Sim
Ray Tracing Benchmarks

Background + Motivation

← realistic workloads       detailed evaluations →
Background + Motivation

Real RTX Game

- Many scene options
- Millions of triangles
- Complex lighting effects
- Lacks detailed profiling

Vulkan-Sim Scenes

- Only 5 scenes available
- Low triangle count
- Limited ray behavior
- Cycle-level simulation

← realistic workloads | LumiBench | detailed evaluations →
Outline

1. Background and motivation
2. Benchmark design
3. Diversity analysis
4. Characterization results
5. Conclusion
Benchmark Design
The Ray Tracing Pipeline

Benchmark Design
The Ray Tracing Pipeline

Benchmark Design

Ray Generation Shader

traceRay start

scene

primary rays

image

camera

[Stanford 1994]

Ray Tracing Pipeline

Acceleration Structure Traversal

Hit?

Closest Hit Shader

Miss Shader

Fixed Function RT Unit

traceRay complete
The Ray Tracing Pipeline

Benchmark Design

Fixed Function RT Unit

Ray Generation Shader

traceRay start

Acceleration Structure Traversal

Hit ?

Closest Hit Shader

traceRay complete

Miss Shader

Anyhit Shader

Intersection Shader

Intersection Shader
LumiBench Goals

Benchmark Design

Non-proprietary models
- avoid 3D models with artistic IPs
- choose from public repositories:
  - Computer Graphics Archive
  - Blender Demo
  - …

Fast simulation time
- simulates in hours to days
- simple shaders and materials
- lower resolution images

Coverage of different scenarios
- scenes with stress cases
- common ray behavior
- use of optional shaders

More analysis in paper!
Benchmark Design

Stress Cases

Large Working Set

Long and Thin

Indoor and Enclosed

Optional Shaders

Scenes with stress cases

Common ray behavior

Use of optional shaders
Benchmark Design

Ray Generation

- Full path tracing
- Mirror-like reflections
- Direct lighting shadows
- Ambient occlusion
The Full Benchmark

Benchmark Design

Scenes with stress cases
Common ray behavior
Use of optional shaders

scenes
Benchmark Design

The Full Benchmark

Scenes with stress cases
Common ray behavior
Use of optional shaders
The Full Benchmark

Benchmark Design

- Non-proprietary models
- Fast simulation time
- Coverage of different scenarios
Diversity Analysis
Diversity Analysis

Measuring Similarity

Apply Principal Component Analysis using a comprehensive set of metrics collected from Vulkan-Sim

- Rodinia workloads
- CS:GO game scenes
- LumiBench workloads
Diversity Analysis

Measuring Similarity

Apply Principal Component Analysis using a comprehensive set of metrics collected from Vulkan-Sim
Diversity Analysis

Similarity to Real Games

Diversity Analysis

Representative Subset

LumiBench Subset

More diversity evaluation in paper!
Characterization Results
Characterization Results

Methodology

Vulkan-Sim

- Vulkan RT Application
  - Mesa3D
    - Intel Vulkan RT Driver
      - NIR to PTX Translator
  - GPU Simulation
    - Vulkan RT Functional Model
      - RT Core Timing Model
Methodology

Characterization Results

Vulkan-Sim 2.0

- Modified RayTracingInVulkan Application
- Mesa3D
  - Lavapipe
  - Vulkan RT Driver
- GPU Simulation
  - Vulkan RT Functional Model
  - RT Core Timing Model
- NIR to PTX Translator
Performance

Characterization Results
RT Unit Efficiency

Characterization Results

RT Occupancy: average number of active warps in the RT unit
RT Efficiency: average number of active rays per warp in the RT unit

More characterization in paper!
Conclusion

**LumiBench** is:

- the first benchmark suite for evaluating ray tracing hardware using a microarchitecture simulator
- composed of a diverse set of scenes, shaders, and ray types
- different from existing general purpose GPU benchmarks
- useful for identifying insights for architectural research

*Thank you!*
https://github.com/ubc-aamodt-group/vulkan-sim