Real-Time Ray-Tracing Techniques for Integration into Existing Renderers

TAKAHIRO HARADA, AMD
3/2018
AGENDA

- Radeon ProRender, Radeon Rays update

- Unity GPU Lightmapper using Radeon Rays (by Jesper)
  - Helping the game content creator to make better assets

- Radeon ProRender + Universal Scene Description
  - Real-time preview of assets

- Radeon ProRender Real-time Rendering
  - Hybrid ray tracing is a stepping stone to a fully ray traced future, as the same path was followed with production movie rendering. Our solution provides a way to fully path traced rendering with Radeon pro render
RADEON PRORENDER, RADEON RAYS

AMD’s Ray tracing solutions
RADEON PRORENDER, RALEON RAYS
AMD’S RAY TRACING SOLUTIONS

△ Radeon ProRender
- A complete renderer (ray casting, shading)
- Physically based rendering library
- Output - Rendered image
- For renderer users, or developers

△ Radeon Rays
- For developers
- Ray intersection library
- Output - Intersections
RADEON PRORENDER

- For developers
  - SDK available today on request
  - Bruno.Stefanizzi@amd.com

- C API
- OpenCL 1.2, Metal 2
- Multi platform solution
  - OS (Windows, MacOs, Linux)
  - Vendors (AMD,...)

- For content creators
  - Plugins
    - Maya, 3DS Max, Blender, Rhino, SolidWorks
  - Direct integration
    - Cinema4D (Maxon, R19~)
    - Modo (The Foundry, Beta)

RPR for Blender on MacOs

(BMW from Mike Pan)
RADEON PRORENDER
FEATURE HIGHLIGHTS

- Heterogeneous device support
  - GPU+GPU, GPU+CPU
  - Less latency for interactive render

- No limit for the texture usage
  - Out of core texture
  - Use system memory or disk

- MacOs Metal support
  - Maya, Blender betas, C4D available today

Multi GPU render
WX7100 + WX9100
RADEON PRORENDER

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4.4k x 1k textures (4.4G texels) on WX7100 (8GB)
Texture size (~16GB) is larger than 8GB VRAM size!!
RADEON PRORENDER

SDK UPDATES

- Improved heterogeneous volume
  - Efficient sampling, less memory
- Metal support on MacOS
  - Requires MacOS High Sierra (10.13.3)
- Nested Dielectrics
- More AOVs
  - Per BRDF AOVs (diffuse, reflect, refract, volume)
- Color LUTs
  - Color correction using .cube file
- Procedural UVs (Decal projection, triplanar)
- Easier to use Uber Material (Closer to Disney)
- Performance improvements
- Real time denoiser
1  rpr_int  tahoePluginID = rprRegisterPlugin("Tahoe64.dll");
2  rpr_int  plugins[] = { tahoePluginID };  
3  rprCreateContext(RPR_API_VERSION, plugins, 1,
4  #if MACOS_METAL
5  RPR_CREATION_FLAGS_ENABLE_GPU0 | RPR_CREATION_FLAGS_ENABLE_METAL,
6  #else
7  RPR_CREATION_FLAGS_ENABLE_GPU0,
8  #endif
9  NULL, NULL, &context);  
10 rprContextSetActivePlugin(context, plugins[0]);
11 rpr_material_system matsys;
12 rprContextCreateMaterialSystem(context, 0, &matsys);  
13 // Create a scene
14 rpr_scene scene;
15 rprContextCreateScene(context, &scene);
16 rprContextSetScene(context, scene);
17 // Create cube mesh
18 rpr_shape cube;
19 rprContextCreateMesh(context, ... );
20 rprSceneAttachShape(scene, cube);
21 // Create camera
22 rpr_camera camera;
23 rprContextCreateCamera(context, &camera);
24 rprCameraLookAt(camera, 5, 5, 20, 0, 0, 0, 1, 0);
25 rprSceneSetCamera(scene, camera);

27 // Create point light
28 rpr_light light;
29 rprContextCreatePointLight(context, &light);
30 rprPointLightSetRadiantPower3f(light, 100, 100, 100);
31 rprSceneAttachLight(scene, light);

33 // Create framebuffer to store rendering result
34 rpr_framebuffer_desc desc;
35 desc.fb_width = 800; desc.fb_height = 600;
36 rpr_framebuffer_format fmt = {4, RPR_COMPONENT_TYPE_FLOAT32};
37 rpr_framebuffer frame_buffer;
38 rprContextCreateFrameBuffer(context, fmt, &desc, &frame_buffer);
39 rprFrameBufferClear(frame_buffer);
40 rprContextSetAOV(context, RPR_AOV_COLOR, frame_buffer);
41 rprContextRender(context);

44 // Save the result to file
45 rprFrameBufferSaveToFile(frame_buffer, "rprRender.png");
WHAT’S NEW IN RADEON RAYS

△ Revised BVH builder
  - Up to **10x** faster builds
    - Manual vectorization
    - Multithreading
  - Lower memory overhead

△ Improved BVH layouts
  - Using less GPU memory bandwidth
  - Up to 20% performance improvement (for secondary rays)

△ Available today at GPUOpen

△ Vulkan version!
RADEON RAYS VULKAN

△ We have done proper Vulkan version (available in soon)

- Simplified C API
- Designed around flexible interop with graphics
  - Commit calls now return VK command buffers
  - Intersect calls now return VK command buffers
  - Can run asynchronously with graphics
  - Application uses VK semaphores to setup dependencies
1 int nativeidx = -1;
2 // Always use OpenCL
3 IntersectionApi::SetPlatform(DeviceInfo::kOpenCL);
4
5 for (auto idx = 0U; idx < IntersectionApi::GetDeviceCount(); ++idx)
6 {
7  DeviceInfo devinfo;
8   IntersectionApi::GetDeviceInfo(idx, devinfo);
9   if (devinfo.type == DeviceInfo::kGpu && nativeidx == -1)
10       nativeidx = idx;
11 }
12
13 IntersectionApi* api = IntersectionApi::Create(nativeidx);
14
15 //adding triangle to tracing scene
16 Shape* shape = api->CreateMesh(g_vertices, 3, 3 * sizeof(float), g_indices, 0, g_numfaceverts, 1);
17 api->AttachShape(shape);
18 api->Commit();
19
20 // prepare rays for intersection
21 ray rays[3] = {...};
22 auto ray_buffer = api->CreateBuffer(3 * sizeof(ray), rays);
23
// prepare intersection data
Intersection isect[3];
auto isect_buffer = api->CreateBuffer(3 * sizeof(Intersection), nullptr);

// intersection
api->QueryIntersection(ray_buffer, 3, isect_buffer, nullptr, nullptr);

// get results
Event* e = nullptr;
Intersection* tmp = nullptr;
api->MapBuffer(isect_buffer, kMapRead, 0, 3 * sizeof(Intersection), (void**) &tmp, &e);

// RadeonRays calls are asynchronous, so need to wait for calculation to complete.
e->Wait();
api->DeleteEvent(e);
UNITY GPU LIGHTMAPPER

Unity + Radeon Rays

Jesper Mortensen
Unity
Unity at GDC
Jesper Mortensen
Lead Graphics Engineer, Unity Technologies
GPU Progressive Lightmapper
So what's up?

• Who are we?
• Why do we need lightmap baking at all?
• What’s the problem with baking?
• Progressive Lightmapping
• Integration with AMD RadeonRays
• Some results
• Live demo
• Questions
Who are we?
500+ R&D Developers

Massive community of game devs

50% - all new mobile games
60% - all new AR/VR

20+ billion yearly installs
on 3+ billion unique devices
Why lightmaps?
Why lightmaps?

• Need high fidelity physically based GI
• Must be performant
  • Consoles and PC
  • Mobile and VR
• Mix and match
  • Realtime direct / shadowmasks / baked direct
  • Realtime GI / baked GI
  • Realtime AO / baked AO
the problem with lightmapping...
500 msec
Progressive updates
Prioritize view
Integration with RadeonRays aka GPU Progressive Lightmapper
OpenCL + RadeonRays

- Cross platform (Editor)
- Vendor agnostic
- Wavefront compute based
  - Kernels operate on lightmaps
  - Compaction removes empty areas
- Very little RadeonRays code
  - It’s a lean and mean interface
- Up to 10x faster than CPU
Results
Cornellbox, Sponza and Blacksmith

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vega</td>
<td></td>
</tr>
<tr>
<td>RadeonRX580</td>
<td></td>
</tr>
<tr>
<td>Threadripper</td>
<td></td>
</tr>
</tbody>
</table>

- Cornellbox
- Sponza
- Blacksmith
GPU bake
Live demo
What’s next

- Use the rays better
  - MIS
  - Light power sampling
- Shoot fewer rays
  - Denoising
- Exploit coherence
- Multi GPU
Acknowledgements

• AMD RadeonRays team
• Special thanks
  • Dmitry Kozlov
  • Guillaume Boisse
  • Bruno Stefanizzi
  • Bikram Singh
Questions?
Thank you!
PRORENDER + USD

Real-time preview of assets
UNIVERSAL SCENE DESCRIPTION

- Scene description from Pixar
- Interchange between applications
- Used in production VFX and animation
- Quickly becoming standard in VFX industry
One of the tools comes with USD

Handy for investigation of a USD file

Comes with the high performance Hydra OGL renderer
- Visual debugging
- Scalability
- OpenSubdiv support
- Designed for multiple back-ends, front-ends

Hydra OGL isn’t designed to investigate materials, lights visually
- Nicer to visualize the work in real time closer to final than OGL
- Computationally expensive to solve light transport equation
  - (Embree backend)
- Radeon ProRender can help
CURRENT WORKFLOW

OGL BACKEND

- Export from Maya
- Debug display in usdview

USD file
WORKFLOW WITH RPR
PRORENDER BACKEND

- Export from Maya
- See the lighting and shading in real time in usdview with RPR
PRORENDER + USD
PROTOTYPE IMPLEMENTATION FEATURE LIST

- **Light**
  - Rect light
  - Dome light

- **Material**
  - PxrSurface, RPR
  - Image Textures

- **Geometry**
  - Quad, triangle mesh
  - Instancing

![Rect Light](image1.png)
![Artistic Reflection](image2.png)

![Dome Light](image3.png)
![Physical Reflection](image4.png)

(Rolling Teapot from Pixar)
WHY IMPLEMENTED A HYDRA BACKEND?

RPR IN 3DCC TOOLS

- RPR is implemented as a usdImaging plugin
- Some applications are integrating USD Hydra as the main viewport renderer
  - You can get ProRender viewport automatically
- Multiplatform support
RADEON PRORENDER
REAL TIME RAY TRACING

Bridging the gap
In Pro Graphics (e.g., 3DCC tools)
- Viewport is using mostly OpenGL

2 issues
- Scalability
- Quality of the rendering

Announce 2 solutions
- V-EZ
  - Better performance from Vulkan without going through API complexity
- Radeon ProRender real-time ray tracing
  - Bringing the viewport to the next level
Problem
- Vulkan API adoption among ProGraphics ISVs slow
- Vulkan API difficult to learn relative to OpenGL
- Inordinate amounts of code relative to OpenGL
- ISVs see no compelling reasons to migrate from OpenGL
- Vulkan middleware layers and libraries exist but not being adopted
- Vulkan missing required CAD features (ex: line stipple)

Objectives
- Provide a simplified layer on top of Vulkan
- Be a stepping stone between OpenGL and Vulkan
- Maintaining existing API semantics
- Allow ISVs to learn Vulkan API without the explicit responsibilities
- Allow for interop with native Vulkan
- Make GLSL a first class citizen again
Solution
- A slimmed down Vulkan API that still exposes the strengths of Vulkan
  - Multi-threaded command buffer recording
  - Asynchronous compute
  - Asynchronous transfers
  - Multi-gpu
- Alleviates responsibilities from application:
  - Swapchain management
  - Memory management
  - Command pools
  - Descriptor pools
  - Descriptor sets
  - Pipeline permutations
  - Render pass management
  - Render pass compatibility
  - Pipeline barriers
  - Image layout transitions
  - SPIR-V compilation

Additional benefits:
- Vulkan interop
- GLSL and SPIR-V reflection
- Line stipple support
REAL TIME RAY TRACING
MOTIVATION

Offline Renderers
- Photo real
- Long render time
- Fully physically based

Game Engine Renderers
- Good quality
- Real time
- Relaxed physically based
- Fakes

Slow

Fast

35

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|					GDC	2018				|				19-23	MARCH	2018
REAL TIME RAY TRACING

MOTIVATION

Offline Renderers
- Photo real
- Long render time
- Physically accurate

ProRender Real-time Ray Tracing
- Better quality
- Adjustable computational cost
- Lerp( accurate, fake, your flavor )
- We take care the complexity in the API
- Add physically based effect on your raster renderer

Game Engine Renderers
- Good quality
- Real time
- Relaxed physically based
- Fakes

Slow

Fast
REAL TIME RAY TRACING

DETAIL

- Add physically based effect on your rasterization based renderer
- Implemented using Vulkan
- Asynchronous compute in mind
- Dispatch the ray tracing effect kernels at the back of the graphics tasks
- Adjust the amount of ray tracing effect depends on the target (HW and frame rate)
- Built in denoiser to produce less noise image for effects using Monte Carlo integration
PRORENDER REAL-TIME RAY TRACING

- Rasterization for primary visibility and lighting
  - No noise in primary
  - Fast feedback

- Deferred shading
  - First step is render G-buffers
    - Normal and depth
    - Albedo and transparency
    - Roughness, metallicity and motion vectors
PRORENDER REAL-TIME RAY TRACING

- Rasterization for primary visibility and lighting
  - No noise in primary
  - Fast feedback
- Asynchronous ray tracing for secondary and complex effects
  - Based on RadeonRays
- You choose
  - Ambient occlusion
  - Glossy reflections
  - Diffuse global illumination
  - Area lighting
- Effects can be turned on/off based on HW capabilities
- MC-based effects are denoised using wavelet filter
AMBIENT OCCLUSION

- True ray traced ambient occlusion (shadow from an IBL)
- Compute shader generates AO rays based on G-buffer position and normal
- RadeonRays traces rays asynchronously
- Ambient occlusion is applied to an IBL component of a direct illumination
- Performance:
  - ~500-600 MRays/s for moderate scenes*

*Depends on the number of pixels marked for AO / visibility complexity
GLOSSY REFLECTIONS

- True ray traced reflections (multiple bounces)
- Compute shader handles Gbuffer
  - Generates reflection rays for pixels marked for reflection
- RadeonRays traces rays asynchronously
- Resolve kernel calculates illumination
- Performance:
  - ~500-600 MRays/s for moderate scenes*

*Depends on the number of pixels marked for reflection
GLOSSY REFRACTION

- Ray traced refractions
- Compute shader handles Gbuffer
  - Generates refraction rays for pixels marked for refraction
- RadeonRays traces rays asynchronously
- Resolve kernel calculates illumination
- Performance:
  - ~1-1.5GRays/s for moderate scenes*
- If you are not satisfied with these…

*Depends on the number of pixels marked for refraction
FULL GI
TURNING IT TO 11

- True ray traced reflections (# of bounces, your choice)
- Compute shader starts reflection or diffuse rays
- RadeonRays traces rays asynchronously
- Resolve kernel calculates illumination
- Performance:
  - ~300 MRays/s for moderate scenes*

*Depends on the number of pixels marked for AO/visibility complexity
CONCLUSION

- Gave latest updates on Radeon ProRender, Radeon Rays
- Showed the Unity GPU Lightmapper using Radeon Rays improves the game contents creation pipeline
- Showed Radeon ProRender + USD extends the capability of the hydra renderer, added lighting preview functionality
- Empower the Pro Graphics viewport by 2 new solutions, V-EZ and Radeon ProRender real-time rendering
FOR SDK ACCESES

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