HIP RT: A Ray Tracing Library in HIP

Takahiro Harada
2022/7

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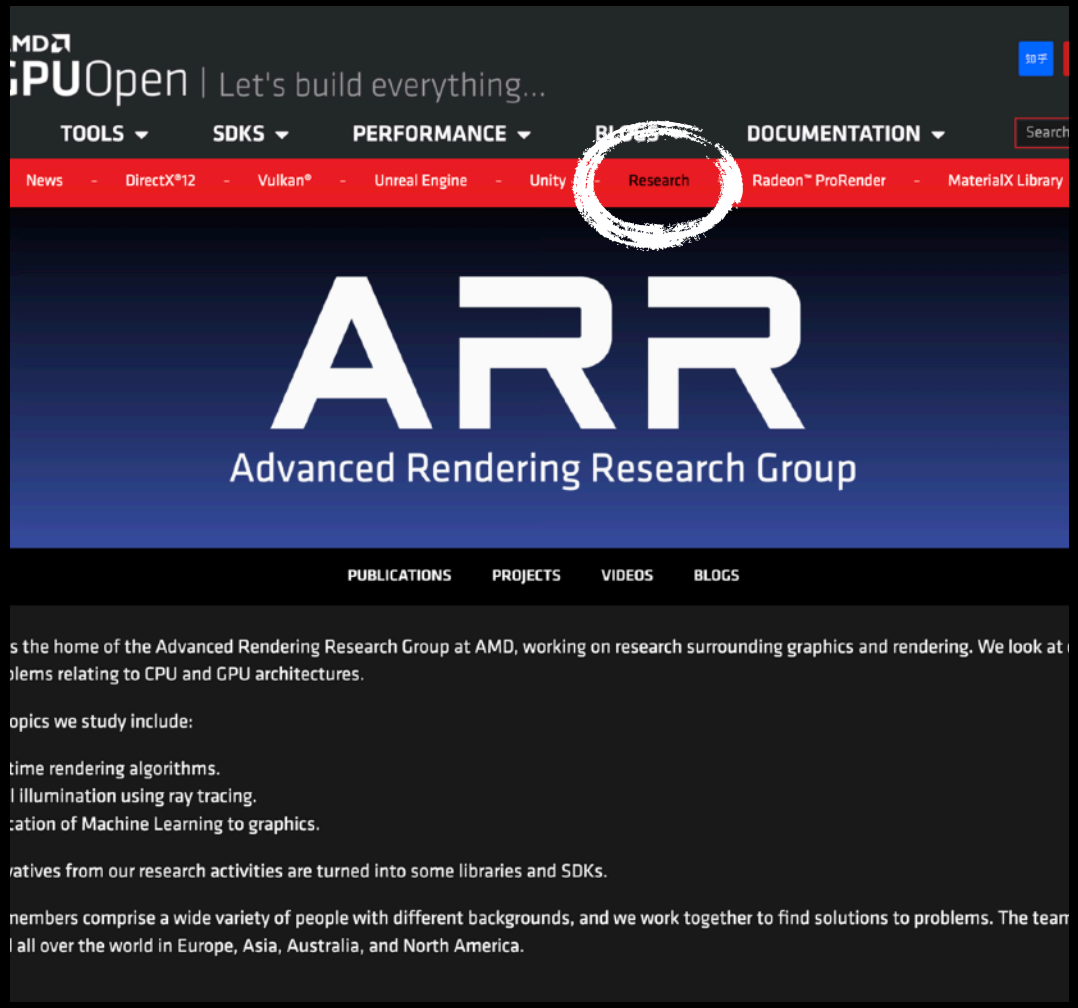
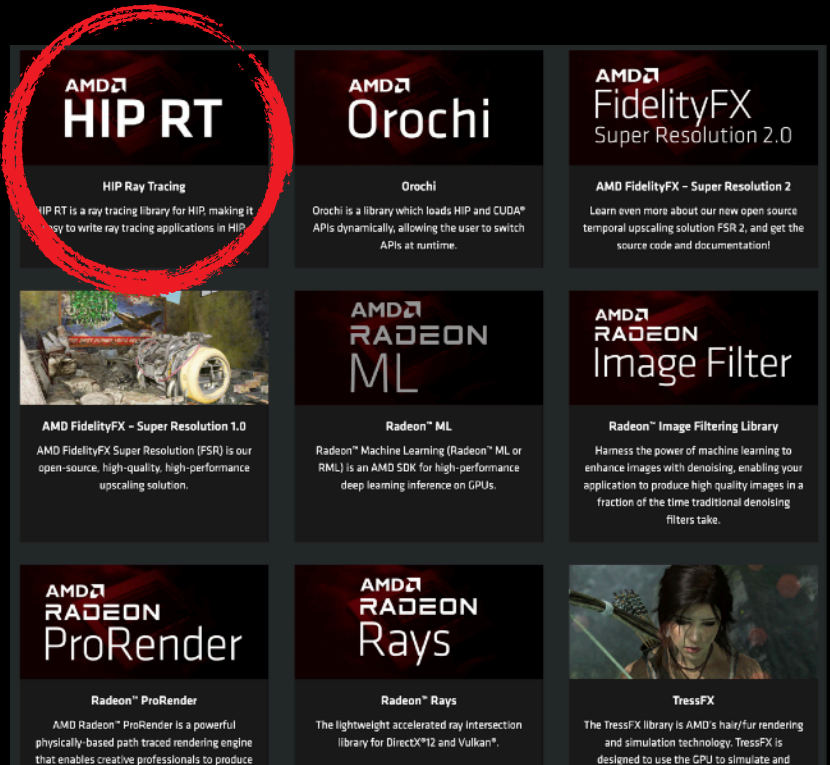


https://gpuopen.com/research/

Self Introduction

- **Takahiro Harada**
- Advanced Rendering Research Group at AMD
- R&D



What Do You Think about Ray Tracing APIs?

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- DirectX® Ray Tracing
- Vulkan® Ray Tracing
- Metal Performance Shaders
- NVIDIA OptiX

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Another Ray Tracing Library?

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- Necessity
  - AMD RDNA™ 2 GPUs (Navi2x) have hardware ray tracing unit “Ray Accelerator” which cannot be accessible from developers
  - Needed to add ray tracing API for HIP (Heterogeneous-Computing Interface for Portability*)
- How should we design?
  - Take existing API?
  - Design something new?
- Looked at different APIs, decided to design our own
  - Slightly different from others in a few ways

* https://rocmdocs.amd.com/en/latest/Programming_Guides/HIP-GUIDE.html

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Design

- Designed to be minimum
- No need to learn different shaders (kernels)
- Easier to add to existing applications
  - Adding RT to existing app. shouldn’t be that difficult

History

- Released v.1 in 2022/4
- v.1.1 is soon

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HIP RT API

Overview of HIP RT

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- Ray tracing using BVH

- Use hardware ray tracing on AMD GPUs (Navi 2x)
  - Runs on Vega or Navi1x, Navi2x GPUs
  - No support on Ellesmere and older (HIP)

- Make it run as many platforms as possible
  - HIP and CUDA implementation (AMD and NV)
    - Built on top of Orochi (https://gpuopen.com/orochi/)

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Orochi

AMD Orochi

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- Developers need to maintain HIP and CUDA host code
  - They are mostly the same :(
- It doesn't sound right

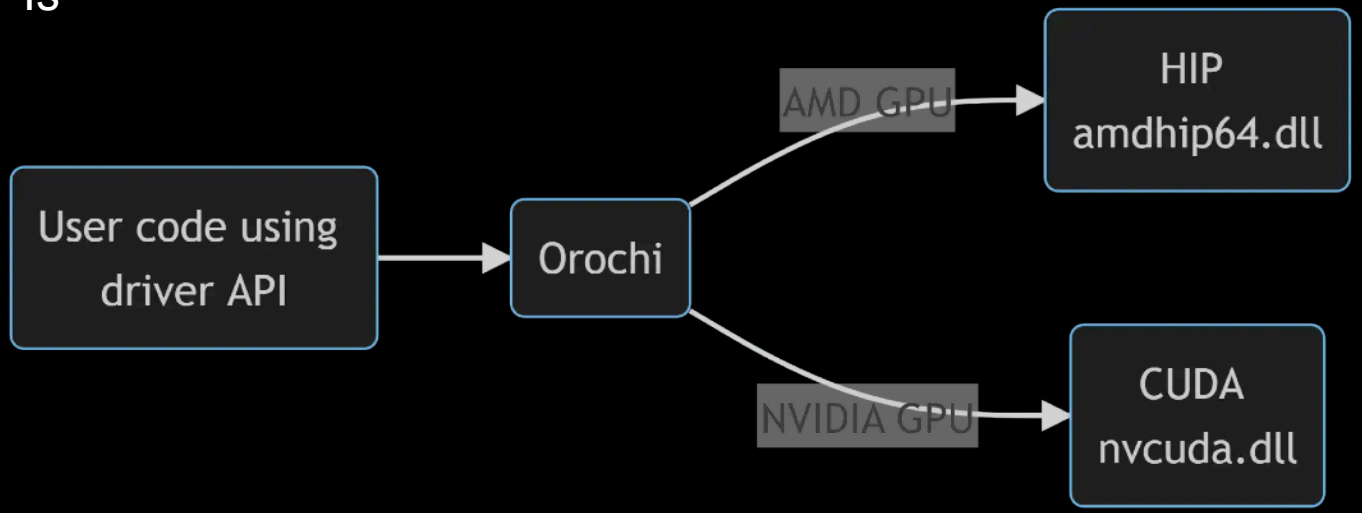
```
#include <hip/hip_runtime.h>

hipInit( 0 );
hipDevice device;
hipDeviceGet( &device, 0 );
hipCtx ctx;
hipCtxCreate( &ctx, 0, device );
```

- Write once using Orochi APIs, then your application
  - Runs on AMD GPUs using HIP
  - Runs on NVIDIA GPUs using CUDA
- No static linking thus it doesn't crash even if there is no GPU
- Implements driver APIs

```
#include <Orochi/Orochi.h>

oroInitialize( ORO_API_HIP, 0 );
oroInit( 0 );
oroDevice device;
oroDeviceGet( &device, 0 );
oroCtx ctx;
oroCtxCreate( &ctx, 0, device );
```



https://gpuopen.com/orochi/

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Overview of HIP RT

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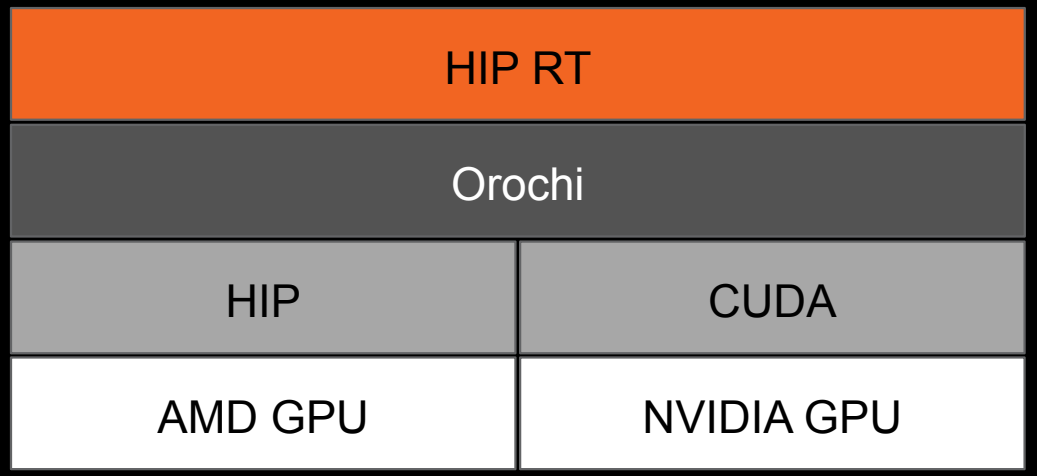
- Ray tracing using BVH

- Use hardware ray tracing on AMD GPUs (Navi 21)
  - Runs on Vega or Navi10, Navi20 GPUs
  - No support on Ellesmere and older (HIP)

- Make it run as many platforms as possible
  - HIP and CUDA implementation (AMD and NV)
    - Built on top of Orochi (https://gpuopen.com/orochi/)
  - Hardware ray tracing works only on HIP
  - Windows and Linux OSes

- Intersection against triangles
  - Can extend to any primitives by writing a custom intersection functions



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Overview of HIP RT

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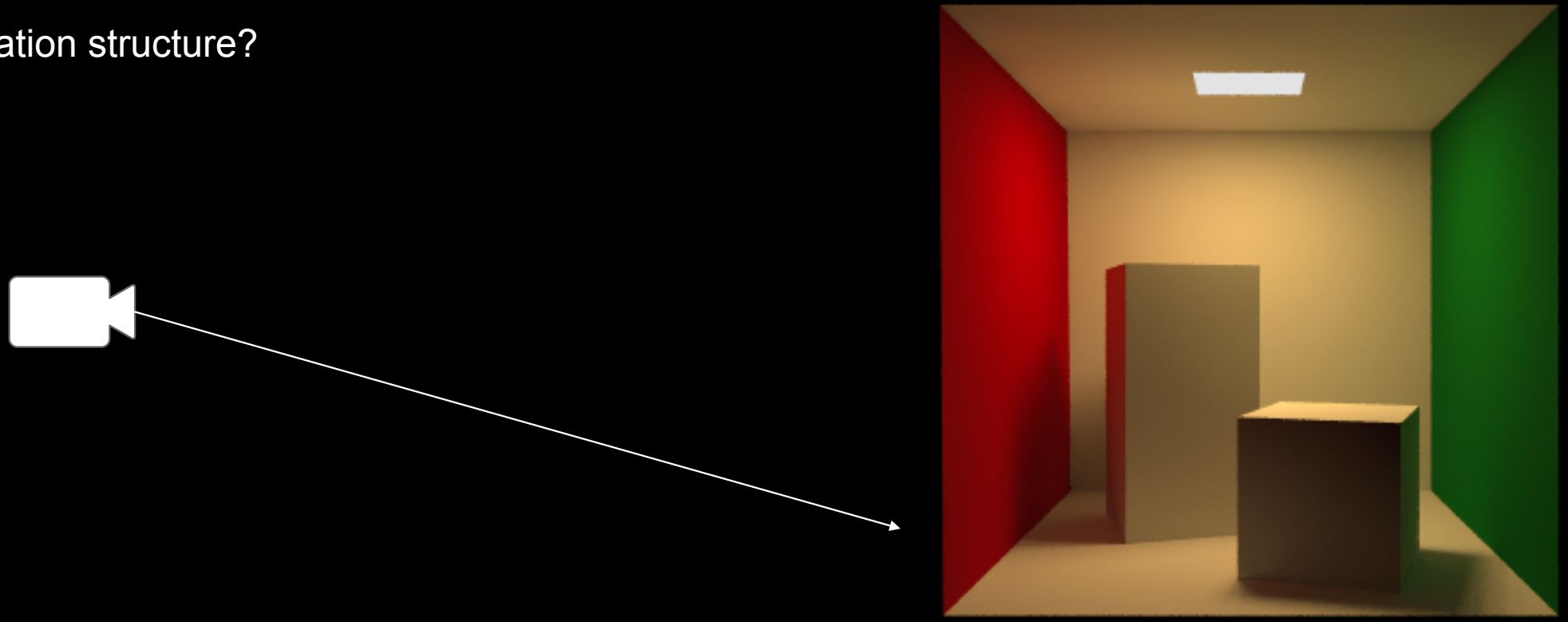
- What are the essential things we need to define?
  - Camera?
  - Acceleration structure?



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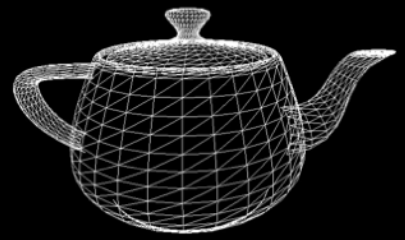
Overview of HIP RT

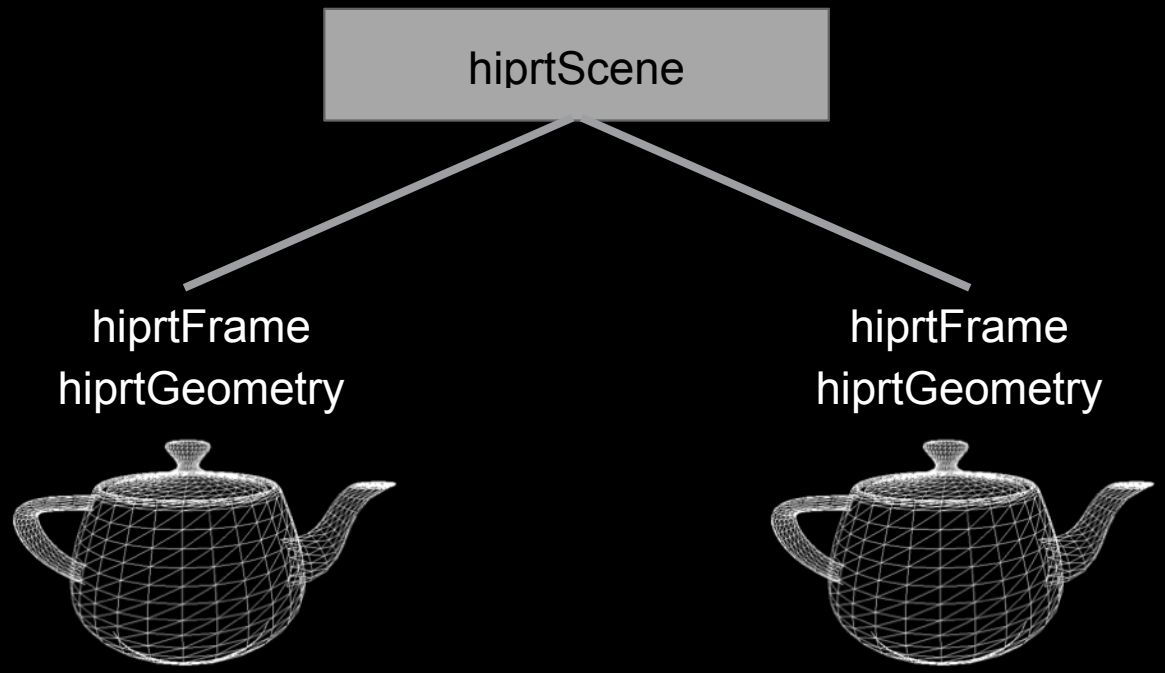
- User need to understand these objects
  - hiprtGeometry
    - This is an instance in other APIs
    - Collection of primitives (triangles)
  -

hiprtGeometry



Overview of HIP RT

- User need to understand these objects
  - hiprtGeometry
    - This is an instance in other APIs
    - Collection of primitives (triangles)
  - hiprtScene
    - Collection of hiprtGeometries to make a scene



Overview of HIP RT

- Hit types
  - hiprtTraversalTerminateAtAnyHit = 1,
  - hiprtTraversalTerminateAtClosestHit = 2,

- Multiple BVH types depending on your needs
  - hiprtBuildFlagBitPreferFastBuild = 1,
  - hiprtBuildFlagBitPreferHighQualityBuild = 2,
  - hiprtBuildFlagBitPreferBalancedBuild = 3,
  - You can even build a BVH by yourself, pass it to HIP RT

Using HIPRT

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- Get the latest driver package from AMD website
- Agree the license, download the SDK package from project page
  - https://gpuopen.com/hiprt/
- Get the latest tutorials at (Optional)
  - https://github.com/gpuopen-LibrariesAndSDKs/hiprtsdk
- Link your HIP/CUDA program with HIPRT

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Using HIPRT

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- Link your HIP/CUDA program with HIPRT

https://github.com/GPUOpen-LibrariesAndSDKs/HIPRTSDK/tree/main/tutorials

[Tutorial] Geometry Intersection

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- 4 steps
  - Context creation
  - Geometry (or Scene) construction
  - Kernel compilation
  - Kernel execution

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[Tutorial] Geometry Intersection

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- 4 steps
  - Context creation
  - Geometry (or Scene) construction
  - Kernel compilation
  - Kernel execution

```
hiprtContext ctxt;
hiprtCreateContext( HIPRT_API_VERSION, m_ctxtInput, &ctxt );
```


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[Tutorial] Geometry Intersection

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- 4 steps
  - Context creation
  - Geometry (or Scene) construction
  - Kernel compilation
  - Kernel execution

```
hiprtGeometryBuildInput geomInput;
geomInput.type = hiprtPrimitiveTypeTriangleMesh;
geomInput.triangleMesh.primitive = &mesh;

size_t geomTempSize;
hiprtDevicePtr geomTemp;
hiprtBuildOptions options;
options.buildFlags = hiprtBuildFlagBitPreferFastBuild;
hiprtGetGeometryBuildTemporaryBufferSize( ctxt, &geomInput, &options, &geomTempSize );
dMalloc( (u8*&)geomTemp, geomTempSize );

hiprtGeometry geom;
hiprtCreateGeometry( ctxt, &geomInput, &options, &geom );
hiprtBuildGeometry( ctxt, hiprtBuildOperationBuild, &geomInput, &options, geomTemp, 0, geom );
```


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[Tutorial] Geometry Intersection

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- 4 steps
  - Context generation
  - Geometry (or Scene) construction
  - Kernel compilation
  - Kernel execution

```
oroFunction func;
buildTraceKernel( ctxt, "../01_geom_intersection/TestKernel.h", "MeshIntersectionKernel", func );
```

```
hiprtBuildTraceProgram(hiprtContext context, const char* functionName, const char* src,… );
```


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[Tutorial] Geometry Intersection

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- 4 steps
  - Context generation
  - Geometry (or Scene) construction
  - Kernel compilation
  - Kernel execution

```
oroModuleLaunchKernel( func, nb.x, nb.y, 1, tpb.x, tpb.y, 1, sharedMemBytes, 0, (void**)args, 0 );
```


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[Tutorial] Geometry Intersection

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```
extern "C" __global__ void MeshIntersectionKernel(                  unsigned char* gDst, int2 cRes)
{
        const int gIdx = blockIdx.x * blockDim.x + threadIdx.x;
        const int gIdy = blockIdx.y * blockDim.y + threadIdx.y;

        hiprtRay ray;
        float3 o = { gIdx / (float)cRes.x, gIdy / (float)cRes.y, -1.0f};
        float3 d = { 0.0f, 0.0f, 1.0f};
        ray.origin = o;
        ray.direction = d;
        ray.maxT = 1000.f;




        int dstIdx = gIdx + gIdy * cRes.x;
        gDst[ dstIdx * 4 + 0 ] = hasHit ? ((float)gIdx / cRes.x) * 255 : 0;
        gDst[ dstIdx * 4 + 1 ] = hasHit ? ((float)gIdy / cRes.y) * 255 : 0;
        gDst[ dstIdx * 4 + 2 ] = 0;
        gDst[ dstIdx * 4 + 3 ] = 255;
}
```


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[Tutorial] Geometry Intersection

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```
extern "C" __global__ void MeshIntersectionKernel(hiprtGeometry geom, unsigned char* gDst, int2 cRes)
{
	const int gIdx = blockIdx.x * blockDim.x + threadIdx.x;
	const int gIdy = blockIdx.y * blockDim.y + threadIdx.y;

	hiprtRay ray;
	float3 o = { gIdx / (float)cRes.x, gIdy / (float)cRes.y, -1.0f};
	float3 d = { 0.0f, 0.0f, 1.0f};
	ray.origin = o;
	ray.direction = d;
	ray.maxT = 1000.f;

	hiprtGeomTraversalClosest tr(geom, ray);
	hiprtHit hit = tr.getNextHit();
	bool hasHit = hit.primID != hiprtInvalidValue;

	int dstIdx = gIdx + gIdy * cRes.x;
	gDst[ dstIdx * 4 + 0 ] = hasHit ? ((float)gIdx / cRes.x) * 255 : 0;
	gDst[ dstIdx * 4 + 1 ] = hasHit ? ((float)gIdy / cRes.y) * 255 : 0;
	gDst[ dstIdx * 4 + 2 ] = 0;
	gDst[ dstIdx * 4 + 3 ] = 255;
}
```


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[Tutorial] Geometry Intersection

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```
extern "C" __global__ void MeshIntersectionKernel(hiprtGeometry geom, unsigned char* gDst, int2 cRes)
{
	const int gIdx = blockIdx.x * blockDim.x + threadIdx.x;
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	hiprtRay ray;
	float3 o = { gIdx / (float)cRes.x, gIdy / (float)cRes.y, -1.0f};
	float3 d = { 0.0f, 0.0f, 1.0f};
	ray.origin = o;
	ray.direction = d;
	ray.maxT = 1000.f;

	hiprtGeomTraversalClosest tr(geom, ray);
	hiprtHit hit = tr.getNextHit();
	bool hasHit = hit.primID != hiprtInvalidValue;

	int dstIdx = gIdx + gIdy * cRes.x;
	gDst[ dstIdx * 4 + 0 ] = hasHit ? ((float)gIdx / cRes.x) * 255 : 0;
	gDst[ dstIdx * 4 + 1 ] = hasHit ? ((float)gIdy / cRes.y) * 255 : 0;
	gDst[ dstIdx * 4 + 2 ] = 0;
	gDst[ dstIdx * 4 + 3 ] = 255;
}
```

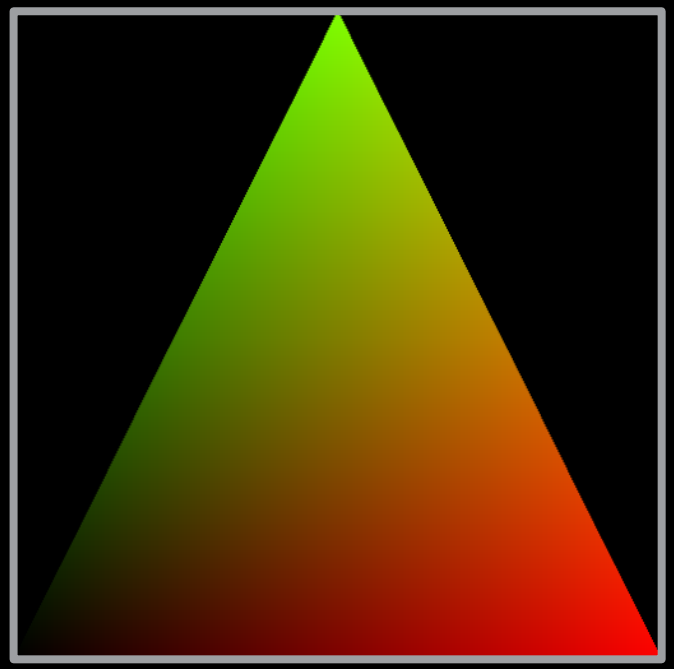

How much code do you need to write to render a single triangle in another API?

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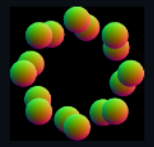
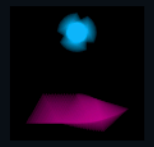
HIPRT Tutorials

List of tutorials

01_geom_intersection		Intersection using hiprtGeometry.
02_scene_intersection		Intersection using hiprtScene.
03_custom_intersection		Using a custom intersection function.
04_shared_stack		Using shared stack for traversal which is essential to get a good performance.
05_custom_bvh		Loading a BVH a user provides.
06_obj_AO		Loading obj file and rendering AO.
07_motion_blur		Rendering objects under motion.

Closing

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- Next Release
  - At SIGGRAPH2022
  - Bounding box program
  - More optimization

- **Thanks for HIPRT development team in ARR, David McAllistor, Bruno Stefanizzi**

- Project page:
  - https://gpuopen.com/hiprt/
- Blog:
  - https://gpuopen.com/learn/introducing-hiprt/
- Github repository:
  - https://github.com/gpuopen-LibrariesAndSDKs/hiprtsdk
- Documentation
  - https://radeon-pro.github.io/RadeonProRenderDocs/en/hiprt/about.html

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