Accelerating Your VR Games with VRWorks

Manuel Kraemer
Talk Overview

- NVIDIA Pascal Overview
- VRWorks Graphics Features
  - Multi-Res Shading, Lens Matched Shading
  - Single Pass Stereo, VRSLI
- SMP Assist  (new)
- Vulkan extensions  (new)
- VR Tools - Nsight, FCAT VR
NVIDIA In VR
NVIDIA VR
Powerful Hardware & Tools to Enhance Your VR Experiences

Hardware

SDKs & Tools
VRWorks
PhysX
NSIGHT & FCAT VR

Applications
NVIDIA Pascal GPU Architecture

16NM FF  G5X  CRAFTSMANSHIP  SIMULTANEOUS MULTI-PROJECTION & PRE-EMPTION
NVIDIA PASCAL

- Pixel Level Preemption Improves Responsiveness For VR
NVIDIA PASCAL

- Simultaneous Multi-Projection Engine
VR GRAPHICS CHALLENGES
VR Demands Serious Performance

Frame Rate
- 90FPS / 11 ms

Resolution
- 800M Pixels/Sec

Latency
- <20ms
3D Game System

**Assets**
- Geometry
- Textures
- Lights
- Shaders

**Game Simulation**
- Shadow Maps
- Raster
- Shade
- AO
- Post FX*

**Renderer**
- HDMI, Sync

**User Input**
- Input Devices

* Includes depth of field, reflections, fog, color grading, motion blur, antialiasing
VR LATENCY WITHOUT TIMEWARP

Sample head pose

Submit to GPU

Flip

Scan-out

Flash backlight

Latency
VR LATENCY WITH TIMEWARP

Sample head pose → CPU → Submit to GPU → GPU → Timewarp based on latest head pose → Flip → Scan-out → Flash backlight → Latency
DROPPED FRAME

Rendered Frames

Runtime Time Warp

Scan Out

Frame 1

Warp 1

Frame 1 + Warp 1

11ms

Frame 2

Warp 2

Frame 1 + Warp 2

11ms

Frame 3

Warp 3

Frame 2 + Warp 3

11ms

Warp 4

Frame 3 + Warp 4

11ms
Lens Distortion

Image Displayed → Optics → User’s view
## NVIDIA VRWORKS

**Bringing Reality to VR**

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# NVIDIA VRWORKS

Bringing Reality to VR

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VRWORKS GRAPHICS

**RENDER LESS PIXELS**
- Multi-Resolution Shading (MRS)
- Lens Matched Shading (LMS)

**HANDLE LARGER SCENES**
- Single Pass Stereo (SPS)
- VRSLI
Render Less Pixels
VR OPTICS

LCD display → Optics → User’s view
VR RENDERING
VR RENDERING

GPU renders many pixels that never make it to screen
VRWORKS MULTI-RES SHADING
Multi-resolution shading
Fast viewport broadcast on NVIDIA Maxwell and beyond GPUs
VRWORKS LENS MATCHED SHADING

Renders to a lens corrected surface
LENS MATCHED SHADING

Renders to a lens corrected surface
LENS MATCHED SHADING

Breakdown
LENS MATCHED SHADING

Breakdown
LENS MATCHED SHADING

Breakdown
LENS MATCHED SHADING

Breakdown
LMS vs. MRS

Baseline (no warp)
2.54 MPix / eye

MRS
2.03 MPix / eye

LMS
1.57 MPix / eye

Conservative (no worse than baseline)
1.17 MPix / eye

Aggressive (3/4 Reso. of conservative)
0.87 MPix / eye

Quality (no undersampling)

Conservative (no worse than baseline)

Aggressive (3/4 Reso. of conservative)
LMS / MRS Challenges

- Require unwarping
  - Minor speed and quality degradation

- Require application changes for
  - Setting / creating new "fast" geometry shaders
  - Set viewport / scissor state
  - Modifying shaders
  - Introducing SMP Assist to help with some of this
Unwarping

- Oculus PC SDK 1.19 introduces native LMS support in the compositor!
- Avoids having to do it in-engine
- Improves quality and performance
Introducing SMP Assist
Helping with app complexity

- **Application**
  - Creates ID3DNvSMPAssist interface
  - Sets up projections
  - Calls Enable/Disable around render passes/draw calls
  - Use GetConstants results in shaders

- **Driver**
  - Creates & binds Fast Geometry Shaders for culling & projecting
  - Sets scissor and viewport rectangles
  - Returns constant buffer data needed

```cpp
interface ID3DNvSMPAssist
{
    void Enable(IUnknown *pDevContext, EyeIndex);
    void Disable(IUnknown *pDevContext);
    void GetConstants(...);
    void SetupProjections(IUnknown *pDevice);
    void UpdateInstancedStereoData(IUnknown *pDevice,...);
};
```
SMP Assist levels of support

- **NV_SMP_ASSIST_LEVEL_FULL**
  - App selects a pre-baked MRS/LMS config (HMD type, quality level).
  - Driver handles correct setting of viewport, scissors and FastGS.
  - Driver provides constant buffer data for remapping.

- **NV_SMP_ASSIST_LEVEL_PARTIAL**
  - App provides a custom MRS/LMS config.
  - Driver handles correct setting of viewport, scissors and FastGS.
  - Driver provides constant buffer data for remapping.

- **NV_SMP_ASSIST_LEVEL_MINIMAL**
  - App provides viewports and scissors.
  - App sets FastGS as required.
  - App sets LMS params as required (NvAPI_D3D_SetModifiedWMode).
  - Driver handles correct setting of viewports and scissors.
  - Driver provides constant buffer for remapping.
Shader Modification Example

The input SVPos is in LMS space. So convert it to linear space, since CameraVector is used to calculate lighting with GBuffer data, which is also in linear space.

InUV is LMS space. When fetching data from GBuffers, use LMS space coordinates directly: GBuffer is indexed in LMS space.
Handle Larger Scenes
TRADITIONAL STEREO RENDERING

Requires 2 geometry passes

Left Eye (Pass 1)

Right Eye (Pass 2)
NVIDIA PASCAL

- Simultaneous Multi-Projection Engine
VRWORKS SINGLE PASS STEREO
Renders left & right eye in one geometry pass
VRWORKS VR SLI

- Scales performance across multiple GPUs
“Normal” SLI

GPUs render alternate frames

- CPU: N | N+1
- GPU 0: N
- GPU 1: N+1
- Display: N | N+1

Latency
VR SLI

Each GPU renders one eye—lower latency
VRWORKS SPEEDUPS

*Performance measured on GeForce GTX 1080 using VRWorks MRS, LMS, or VR SLI
Eco-system
VRWorks Graphics Support

- Engines
  - UnrealEngine 4
  - Unity

- APIs
  - Direct3D (11 and 12)
  - OpenGL
  - Vulkan
VRWorks for Unreal Engine

Unreal Engine integration

- Full VRWorks suite available

- VRSLI, Multi-resolution Shading, Single Pass Stereo, Lens Matched Shading
  - Most post passes, instanced stereo supported

- 4.19 coming soon
VRWorks for Unity
Available in Unity 2017.1 and higher

- Implemented as a native Unity plugin
- Supports MRS, SPS, LMS, and VRSLI
- DX11 only, supports basic post processing, forward rendering

developer.nvidia.com/nvidia-vrworks-and-unity
Vulkan extensions / VRWorks building blocks

- Multi-Resolution Shading (Maxwell+)
  - VK_NV_viewport_array2
  - VK_NV_geometry_shader_passthrough
- Lens Matched Shading (Pascal+)
  - VK_NV_clip_space_w_scaling
- Single Pass Stereo (Pascal+)
  - VK_NVX_multiview_per_view_attributes
Vulkan Multi-GPU for VR

- Vulkan 1.1 / VK_KHR_device_group_{creation}
  - Explicit MGPU for AFR, SFR, VR
  - Command buffers & commands can be directed to subsets of devices
  - Viewport/scissor state can diverge between devices
  - Shader built-in gl_DeviceIndex
  - Select per eye view transform

- See vr_sli_vk sample in VRWorks SDK
- See Jeff Bolz` MGPU talk:
- https://youtu.be/RkXa4RiERu8?t=1566
Measuring Performance
PERFORMANCE TUNING
NSIGHT

- Understand CPU/GPU interaction
- Debug your frame as it is rendered
- Profile your frame to understand bottlenecks
- Save your frame for targeted analysis
- Leverage the Microsoft Visual Studio platform
- Also available in the newly released tool, Nsight Graphics
FCAT VR

MEASURING THE QUALITY OF YOUR VR EXPERIENCE
PERFORMANCE TUNING

FCAT

- Create charts and analyze data for:
  - Frametimes
  - Dropped frames
  - Runtime warp dropped frames
  - Asynchronous Space Warp (ASW)
  - Synthesized frames
# NVIDIA VRWorks

Access Latest SDKs at developer.nvidia.com/vr

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Questions?

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