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Virtual reality-based visualization of large scientific data
Outline

- Motivation
- Results
- Extensions
Visualization

• Integral part of the scientific method
• Helps exploring and understanding data

• **Inspection:**

the act of *looking* at something *carefully*, or an official visit to a building or organization to check that everything is correct and legal

• **Interaction:**

an occasion when two or more people or things *communicate* with or *react* to each other.

Definitions from *Cambridge dictionary*
Being “In” the Data

Ulusoy, T., Danyluk, K. T., & Willett, W. J. (2018). Beyond the physical: Examining scale and annotation in virtual reality visualizations. Department of Computer Science, University of Calgary.
Large Datasets warrent new inspection modalies

- More intuitive navigation
- Easier mapping from Real world to virtual world
- Zooming by moving head
- Requires more than 80 FPS for a pleasant experience (12.5ms pr frame)*

Image source: https://www.pricerunner.dk/pl/1469-5283214/VR-Virtual-Reality/Oculus-Quest-2-64GB-Sammenlign-Priser

Using Virtual Reality for Visualization

3D Scanning
14,504,882 triangles

Shape Generation
38,629,758 triangles
VR vs Desktop: Landmark Annotation
Limitation of the Study, VR and the Typical Workflow

- Based on game development
- Many smaller meshes vs one big mesh
- Game engines did not introduce 32-bit index buffers until 2017
Outline

- Motivation
- Results
- Extensions
Compared Platforms

**BUT FASTER!**

- Out of the box
- Custom shader
- Deferred rendering
- Allow mesh optimization
- Removed lighting effects
- Custom shader
- Forward rendering
- Out of the box
- VR plug-in
- Vulkan
- Vertex Shading pipeline
- Forward rendering
- Vulkan
- Mesh Shading pipeline
- Forward rendering

https://unity.com/
https://www.paraview.org/
https://www.housebeautiful.com/lifestyle/g3972/beautiful-train-routes/
https://www.wired.co.uk/article/japan-bullet-train-alfa-x-nose
Rasterization Pipelines

Vertex Shading Pipeline

Mesh Shading Pipeline
Initial Comparison for the skull

average render time for skull

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NVIDIA RTX 2080 TI

- Vertex Shader
- Unity
- UnityURP
- Meshlet Shader
- ParaView
Initial Comparison for the wing

average render time for wing

NVIDIA RTX 2080 Ti

average render time in ms

Far
Close

Vertex Shader
Unity
UnityURP
Mesh Shader
ParaView
Achieving better performance with Vulkan features

- Multi-View Rendering
- Variable-Rate Shading
- Custom Meshlet Clustering Algorithm

NVIDIA RTX 2080 Ti
Outline

- Motivation
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Multi-View Extension
Multi-View Extension

• Renderpass Creation
  • Extend the RenderPassCreateInfo structure with:
    • renderPassMultiViewRCreateInfo structure
    • Allows the user to set a viewmask and correlation mask
  • Create Framebuffer image attachments with corresponding layercount to match desired number of views

• Fast Multi-View Rendering for Real-Time Applications Guggenberger and Kerbl et al.
Multi-View Extension

• GLSL extension
  • `#extension GL_NVX_multiview_per_view_attributes: enable`

• In Task Shader Built-in variables:
  • `gl_MeshViewCountNV`

• Mesh Shader Built-in variables:
  • `gl_MeshViewCountNV`
  • `gl_MeshViewIndicesNV[]`
  • `gl_MeshVerticesNV[]`
    • `perviewNV vec4 gl_PositionPerViewNV[];`
  • `perviewNV`
Variable-Rate Shading Extension
Variable-Rate Image Extension

- Image Usage
  - VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV
- Allocate Image sized array
  - Fill with values from VkShadingRatePaletteEntryNV
    - VK_SHADING_RATE_PALETTE_ENTRY_16_INVOCATIONS_PER_PIXEL_NV
    - VK_SHADING_RATE_PALETTE_ENTRY_4_INVOCATION_PER_PIXELS_NV
    - VK_SHADING_RATE_PALETTE_ENTRY_1_INVOCATION_PER_PIXELS_NV
    - VK_SHADING_RATE_PALETTE_ENTRY_1_INVOCATION_PER_2X1_PIXELS_NV
    - VK_SHADING_RATE_PALETTE_ENTRY_1_INVOCATION_PER_2X2_PIXELS_NV
- Upload
  - to shading image with vkCmdCopyBufferToImage()
Variable-Rate Image Extension

- Pipeline Creation
  - Extend viewportCreateInfo structure with ShadingRateCreateInfo structure
  - Use the shadingRatePalette strcture to inform about which palette entries and how many have been used for the image
- Command buffer recording
  - Use vkCmdBindShadingRateImageNV(); to bind the shading rate image before drawing
Our Meshlet Clustering Algorithm

- Requires the use of a vertex data structure and triangle data structure.
Our Meshlet Clustering Algorithm

- Sorts vertices after biggest bounding box axis length
Our Meshlet Clustering Algorithm

• Run through sorted vertex list:
  • Starts meshlets from a vertex and grows it out.
    • While meshlet is not full
      • Add triangle from border that minimizes the meshlet bounding sphere or already has all its vertices in the meshlet
      • If meshlet hits vertex limit triangles at the edge are checked
Achieving better performance with Vulkan

- Access to hardware specific extensions
  - VK_NV_SHADING_RATE_IMAGE_EXTENSION_NAME
  - VK_NV_MESH_SHADER_EXTENSION_NAME
- Now in Vulkan Core
- Mesh Shading is in UE5 after 4 years
Thank you