NVIDIA IndeX™ - Enabling Interactive and Scalable Visualization for Large Data
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NVIDIA IndeX™ Positioning

NVIDIA IndeX is a commercial software product initially developed to serve the Hydrocarbon market. It is a cluster-based scalable software Platform as a Service (PaaS) ready for the cloud and enables distribution of large-scale data for compute and high quality visualization of volumetric and surface data with interactive frame-rates.

http://www.nvidia-arc.com/products/nvidia-index.html
NVIDIA IndeX - Enabling Interactive and Scalable Visualization for Large Data

- NVIDIA IndeX software leverages GPU-clusters for scalable large-scale data visualization
- NVIDIA IndeX is a GPU-cluster aware solution for interactive visual computing
- NVIDIA IndeX is a commercial software solution available and already deployed by customers for data interpretation

http://www.nvidia-arc.com/products/nvidia-index.html
Example: Exploration in Hydrocarbon Industries

- Scanning earth’s subsurface structure
- Cost-effective drilling for oil reservoirs
- Acquisition and preprocessing of subsurface data
  - Huge (peta bytes) subsurface dataset sizes
  - Automatic data processing

Visualization of a seismic volume with embedded height field and slices

Special thanks to Crown Minerals and the New Zealand Ministry of Economic Development for allowing us to display this Taranaki Basin dataset.
Crown Minerals manages the New Zealand Government’s oil, gas, mineral and coal resources.
More information is available at: www.crownminerals.govt.nz
Efficient Data Interpretation

- Knowledge and experience of experts in this field
- Visually assess subsurface data
- Interactive exploration
  - Real-time frame rates
  - Visual quality
- Especially in Oil & Gas domain

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NVIDIA IndeX - Scalable Interactive Large-Scale Data Visualization

- Distributed Rendering on GPU clusters
  - Supports today’s and tomorrow’s huge dataset sizes
- Real-Time Rendering
  - 260 GB volume
  - 14 cluster machines with 4 Tesla K10
  - 13 frames per second
Visual Quality and Accuracy

- Visualization at original data resolution
  - Avoiding distractions e.g., popping artifacts due to level-of-details
  - Highly accurate visual assessment
- Depth-correct transparency rendering
  - Example: height field embedded into volume
Visual Quality
Sort-Last Approach for Distributed and Scalable Rendering

- Object-space subdivision
- Later compositing of intermediate renderings
Distributed Rendering using GPU-Clusters
Parallel and Distributed Rendering

Data Distribution
- Viewer Node
- Rendering Node

Subsurface Data Rendering
- Render Sub Region
  - Horizons
  - Seismic Volume
- Compositing
  - Send composited image

Hierarchical Scene Decomposition
Distribute subsurface sub region data

Provide intermediate rendering results

Render Sub Region
Distribute subsurface sub region data

Send composited image

Compositing Phase
Performance and Scalability

- Cluster details
  - 2-16 cluster machines
  - 4 Tesla K10 per cluster machine
  - 8 GB per K10
  - 1k x 1k screen
  - 10 Gigabit Ethernet
Another Cluster Setup

- Cluster details
  - 2-35 cluster machines
  - 2 Tesla M2090 (Fermi) per cluster machine
  - 1k x 1k screen
  - 10 Gigabit Ethernet
Dataset Scalability

- **Target performance**: $\geq 10$ fps @ 1024x1024
- **Volume dataset sizes**
- **Cluster details**
  - 2-35 cluster machines
  - 2 Tesla M2090 (Fermi) per cluster machine
  - 1k x 1k screen
  - 10 Gigabit Ethernet
Scalability at Various Screen Resolutions

Target performance:
- $\geq 10$ fps,
- $\geq 20$ fps,
- $\geq 30$ fps

40 GB volume dataset

Screen resolutions:
- 1024x1024 (Baseline) (1,048,576 pixels)
- 1920x1080 (Full HD) (2,073,600 pixels, 1.98 x Baseline)
- 2560x1440 (WQHD) (3,686,400 pixels, 3.5 x Baseline)
- 3840x2160 (QFHD) (8,294,400 pixels, 7.9 x Baseline)
Interactively on Workstations, Clusters, and Clouds

- Single or multiple GPU(s)
- Smaller dataset sizes
- Interactive rendering performance

- Unlimited number of GPUs
- Huge dataset sizes
- Increasing rendering performance

Workstation

NVIDIA GRID Visual Computing Appliance (VCA)

GPU Clusters
Interactive GPU-Cluster aware Visual Computing

Interactive attribute generation for instantaneous visualization

Applications
- Flow simulations
- Atmospheric dynamics visualization
- Combustion simulation
- Molecular dynamics simulations
- Seismic attribute generation for survey visualization
Architectural Challenges for Interactive GPU-Cluster aware Visual Computing

- Raw n-dimensional data is huge
  - Multiple times larger than generated attributes
- Process raw data using user-defined algorithms
  - Plethora of possible types of attribute
  - Manifold parallel compute algorithms
  - Diversity of algorithm-specific subdivision schemes
- Interactive attribute generation for instantaneous visualization
  - Scalability
Mapping Attribute onto Scene Geometries
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Proxy Shapes for Attribute Visualization

- Proxy shapes
  - Slices
  - Height fields
  - Triangle meshes
  - Volumes
- Part of the scene description
- Canvas for attribute visualization
Distributed Attribute Visualization Process

- User-defined attribute computation
  - Compute jobs launched per portion
  - Proxy shape intersection
  - Algorithm-specific subdivision schemes

- Attribute mapping
  - Rendering proxy shapes
  - Analogy: procedural texturing
Attribute Generation and Visualization Process
GPU Cluster Setup for Scalable Visual Computing

- Asynchronous compute maximizes performance
  - Rendering and compute process run in parallel
  - Compute integration into rendering

Example: GPU Cluster Layout for Visual Computing
Extensible Software Architecture

- Interactive Cluster-aware Visual Computing (NVIDIA IndeX Core)
- Base layer for networking, job scheduling, distributed data storage (DiCE library)
- Remote Access
- Multi User
- Video Streaming
- Other Application Domains

E&P Domain

C++ API

Application
NVIDIA IndeX’s Building Blocks for Managing Distributed Data

- Data locality information
  - *Spatial query* tells which cluster machine stores which portions of data
  - Depends on dataset type
- Accessing large-scale data
  - Assemble from cluster machines
  - Can be restricted to portions
- Editing large-scale data
  - Direct editing/compute to the distributed data
  - Can be restricted to portions
  - Simple example: user-defined filter
OpenGL Integration

1. Rasterize opaque geometry
   - Capture depth and color buffers
2. Volume ray casting
   - OpenGL depth buffer
3. Alpha-based color blending
   - Result of NVIDIA IndeX’s large-scale data rendering with alpha
   - OpenGL color buffer

Pseudo code

```
// OpenGL rendering to color- and depth-buffer on local machine
(gl_buffer_RGBA, gl_buffer_z) ← renderGL();

// Distributed, scalable rendering with depth-buffer input
result_RGBA ← nvidia_index->render(buffer_z);

// Blending rendering results
blend(gl_buffer_RGBA, result_RGBA);
```
Proof-of-Concept Example

Opaque OpenGL geometry integrated in NVIDIA IndeX

OpenGL color buffer
OpenGL depth buffer (inverted)
Final combined rendering
Depth-correct OpenGL Integration

- Z-buffer compressions
- Multicasting z-buffer data

Possible extensions
- Transparent OpenGL
- InfiniBand and RDMA
- GPUdirect support
Remote Visualization

- Video streaming
  - H.264 video encoding
  - Hardware-accelerated on Kepler
- Private and public clouds
  - Web-based applications
  - Thin clients (tablets)
- Multi-user support for world-wide collaboration
Live Demo

GPU cluster located in Berlin, Germany
- 8 cluster nodes
- 2 Tesla M2090 each
- 82 GB volume
- Height field with 250 million triangles
- H.264-based video streaming

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Thank you ...

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