Progressive Volume Rendering of Large Unstructured Grids

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Motivation

- Large-scale simulations produce a lot of data
- Interactive visualization techniques not keeping up
- Meshes may be too large to render locally
Progressive Volume Rendering

3%
0.01 sec

33%
7 sec

66%
18 sec

100%
34 sec
Objective

- Progressive Rendering
  - Show intermediate results
  - Reuse intermediate results
  - Allow user interrupt
  - Only render pertinent data

- Client-Server Architecture
  - Support a thin client with limited memory
  - Standard server used as a data repository
  - Facilitate remote visualization
Issues

- Tetrahedra are not natively supported
  - Projected Tetrahedra
    - [Shirley and Tuchman ‘90, Wiley et al. ‘02]
- Compositing requires strict order
  - Visibility Sorting
    - [Williams et al. ‘92]
  - Ray Casting
    - [Bunyk et al. ‘97, Weiler et al. ‘03]
  - Hybrids
    - [Farias et al. ‘00, Callahan et al. ‘05]
Issues

- Hierarchical level-of-detail not suitable
  - Regular Sampling
    - [Leven et al. 2002]
  - Geometry Simplification
    - [Cignoni et al. 2005]
  - LOD Without Hierarchies
    - [Callahan et al. 2005]

- Remote Visualization difficult using a standard server
  - Image Transmission
    - [Engel et al. 2000]
  - Uncomposited Image Transmission
    - [Bethel et al. 2000]
  - Data Transmission
Background

- Hardware-Assisted Visibility Sorting
  - Sort in both object-space and image-space

[Callahan et al. 2005]
http://havs.sourceforge.net and vtk/ParaView
Background

- Dynamic Level-of-Detail

[Callahan et al. 2005]
http://havs.sourceforge.net and vtk/ParaView
Overview

- **Server**: Processes geometry and transmits triangles in visibility order
- **Client**: Receives geometry and renders it progressively
The Server

- Preprocess
  - Create min-max octree
- Geometry Server
- Octree Traversal
- Object-Space Sort
The Server

- Preprocess
- Geometry Server
  - Calculate depth range
- Octree Traversal
- Object-Space Sort
The Server

- Preprocess
- Geometry Server
- Octree Traversal
  - Cull range geometry
  - Frustum cull geometry
- Object-Space Sort
The Server

- Preprocess
- Geometry Server
- Octree Traversal
- Object-Space Sort
  - Sort geometry by centroid
  - Compress and send
The Client

- Preprocess
  - Get boundary geometry from server
  - Build pre-integration table
- Interactive Mode
- Progressive Mode
- Completed Mode
The Client

- Preprocess
- Interactive Mode
  - Volume render the boundary geometry
  - Keep the back boundary fragments
- Progressive Mode
- Completed Mode
The Client

- Preprocess
- Interactive Mode
- Progressive Mode
  - Render range of geometry
  - Display progressive image
- Completed Mode
Use three buffers to render progressive image
- *Complete*: finished volume rendering
- *Active*: temporary storage of $k$ fragments
- *Progressive*: *Complete* blended with approximation

**Progressive Mode**
Progressive Mode

- Pass 1:
  - Render geometry into Active buffer
  - Composite overflow fragments into Complete buffer.
Progressive Mode

- Pass 2:
  - Render empty space into Progressive buffer using Active buffer and back boundary fragments

Approximate Empty Space
Progressive Mode

- Pass 3:
  - Composite *Complete* buffer into *Progressive* buffer
  - Display *Progressive* buffer
  - Keep *Complete* and *Active* buffers for next progressive step

Approximate = Complete + Approximate
Overview

- Preprocess
- Interactive Mode
- Progressive Mode
- Completed Mode
  - Composite Active buffer into Complete buffer
  - Display and store Complete buffer
Results
Results
Considerations

- The network
- Transfer functions
- Other interaction methods
Conclusion

- Remote visualization of large unstructured grids
- Progressions converge to full-quality renderings
- Allows interactive exploration of large datasets

Future Work:
- Cutting planes
- Stream compression
- Time-varying data
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