Survey of Parallel Volume Rendering Algorithms

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Overview

- Volume Rendering
- Problem, too much research
- Classification
- Example Taxonomy
- Hybrids differentiated
- Conclusions
Volume Rendering

- What it does: Image Slices to 3D Shaded Volumes
Volume Rendering: Parallel Theory

What it is: Volume Rendering is an Optimal Parallel Algorithm $P_t p = O(n)$

Object Space  Screen Space
The Problem

- IEEE Inspec Search Results Histogram by year
  - “parallel and (volume rendering or volume visualization)"
  - 100’s of papers

![Bar chart showing number of publications per year from 1989 to 1998.]}
Problem cont

- Field has achieved no consensus
- Replication of results
- No easy dissemination of results
- Incremental improvements?
Solution

- A Survey
  - spell out canonical approaches
  - point way to untried approaches
  - create means for dissemination of results to date
Classification

- Algorithm Control Flow
  - view reconstruction (B, F, MF, Σ)
  - outer loop data space (O, I)
- Hardware (G, V, PS, PD, D)
- Data characteristics
  - topology (R, C, U)
  - type (scalar, vector)
  - formats
- Visualization method
- Publication specifics
Algorithm Control Flow

- View Reconstruction
  - backward (B)
  - forward (F)
  - multipass forward (MF)
  - Fourier (F)

- Outer loop iteration data space
  - object (O)
  - image (I)
Targeted Hardware

- Graphics (G): PixelFlow
- Volume rendering (V): Vizard
- Parallel shared address space (PS): Convex-X Class
- Parallel distributed address space (PD): IBM SP-2
- Distributed (D): Sun render farm for Pixar Toy Story

HP X-Class
Application Data Characteristics

- Rectilinear (R)
- Curvilinear (C)
- Unstructured (U)

Spiral CT/Vertebrae  Nasa Langley Fighter
Visualization Method

- Shading
- Data Classification
- Transmission model
- Reconstruction
- Gradient

Voxelator OpenGL
Volume Rendering
Proposal
Publication Specifics

- Date published
- Number of processors
- Volume and data sizes
- Prototype or machine implemented
- Asymptotic complexity
- Performance
  - Mvoxels/second
  - Scalability
## Taxonomy

Prior Work: No differentiation

<table>
<thead>
<tr>
<th>Processing Order</th>
<th>Object</th>
<th>Image</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithm</td>
<td></td>
<td></td>
<td>A,B,C,D</td>
</tr>
</tbody>
</table>

Proposed differentiates all 4

<table>
<thead>
<tr>
<th>View Reconstruction</th>
<th>Multipass Forward (MF)</th>
<th>Multipass Forward (MF)</th>
<th>Backward (B)</th>
<th>Backward (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Loop</td>
<td>Object (O)</td>
<td>Image (I)</td>
<td>Object (O)</td>
<td>Image (I)</td>
</tr>
<tr>
<td>Algorithm</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td>B</td>
</tr>
</tbody>
</table>

Could be debated

A - Lacroute et al. Shear Warp  
B - Ma et al. Binary Swap  
C - My Permutation Warping  
D - Yagel et al./Schroeder et al.
## Taxonomy

<table>
<thead>
<tr>
<th>View</th>
<th>Loop</th>
<th>Graphics (G)</th>
<th>Volume (V)</th>
<th>Parallel shar. add (PS)</th>
<th>Parallel dist. add. (PD)</th>
<th>Dist. (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward (F)</td>
<td>O</td>
<td>[21]</td>
<td>[7]</td>
<td>[20]</td>
<td>[12] splat</td>
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<td>I</td>
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<td>I</td>
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<td>[14]</td>
<td>[16]D(line drawing)</td>
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</tr>
<tr>
<td>Backward (B)</td>
<td>O</td>
<td>[17]</td>
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<td>[22]C(perm warp)</td>
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<tr>
<td>Fourier</td>
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<td>I</td>
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</tbody>
</table>
Comprehensive Listing

- Collected over 100 papers in parallel volume rendering
- Complete listing too much
- Need several types of survey
- ACM Computing Surveys?
- Web gathering
  - I need your help! Fill out this simple form, and register your work for posterity’s sake ;)

PDPTA'98, July 15, 1998
Hybrids are differentiated

- View:
  - Multipass Forwards
    - Lacroute (A)
    - Yagel/Schroeder (D)
  - Backwards (ray casting)
    - Ma et al. (B)
  - Permutation (ray casting)
    - Wittenbrink et al. (C)
Shear warping (A)

- Object space iteration
- Multipass Forwards View

Result subdivisions

PDPTA'98, July 15, 1998
Binary Swap (B)

- Ray casting from eye into volume (binary swap)
- Conceptually simplest
Permutation Warping (C)

- Object space iteration
- backward view transform

Processor Grid \( T^{-1} \)

Object Space \( M \)

Screen Space

subdivisions

PDPTA'98, July 15, 1998
Line drawing/template based (D)

- Image space iteration
  - splats
- multipass forward view transform

Volume subdivisions

Screen subdivisions

PDPTA'98, July 15, 1998
Conclusions:

- Volume Rendering
- Parallel Volume Rendering
  - Too much research
- Solution: Classification
  - Algorithm Control Flow
    - View Reconstruction
    - Outer Loop
- Best algorithms not yet discovered
- More Work to be done!

http://www.cse.ucsc.edu/~craig/pdr.html
Special Thanks to all