Title: Survey and Analysis of Multiresolution Methods for Turbulence Data

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Enabling Remote Visualization and Scale Analysis of Large Turbulence Databases

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Introduction

General

- Remote analysis and visualization of raw large turbulence data is challenging
- The Johns Hopkins Turbulence database (JHTDB) simplifies access to over 230 Terabytes of direct numerical simulation data through commodity hardware
- A demand exists for a visualization framework that adds high-speed remote visualization for large datasets

Contributions

- Remote visualization support and additional compute capabilities were added to the database cluster
- Wavelet compression was introduced at the data-level to reduce access cost, bandwidth, and improve visualization latency
- Wavelet compression used to reduce memory footprint of datasets for visualization

JHTDB: http://turbulence.pha.jhu.edu/
Remote visualization is achieved through Paraview and Paraview Web integration

JHTDB: http://turbulence.pha.jhu.edu/
JHTDB API (Matlab, C++, HTML, etc)
Tests and Results

Remote Visualization

- Web (HTML 5) interface
Tests and Results

Efficiency (Performance)

- Scenario: A single $512^3$ grid size subset of a $1024^3$ dataset is accessed and visualized by a single user.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Original (512)</th>
<th>Scale 1 (256)</th>
<th>Scale 2 (128)</th>
<th>Scale 3 (64)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelet decompose</td>
<td>0 s</td>
<td>17.8 s</td>
<td>20.6 s</td>
<td>20.8 s</td>
</tr>
<tr>
<td>Wavelet reconstruct</td>
<td>0 s</td>
<td>23.3 s</td>
<td>23.2 s</td>
<td>23.3 s</td>
</tr>
<tr>
<td>Visualize volume</td>
<td>25.7 s</td>
<td>3.01 s</td>
<td>0.22 s</td>
<td>0.02 s</td>
</tr>
<tr>
<td>Visualize isosurfaces</td>
<td>171.0 s</td>
<td>12.1 s</td>
<td>0.91 s</td>
<td>0.15 s</td>
</tr>
<tr>
<td>Total time</td>
<td>196.7 s</td>
<td>56.21 s</td>
<td>44.93 s</td>
<td>44.27 s</td>
</tr>
<tr>
<td>RAM used</td>
<td>4526 MB</td>
<td>865 MB</td>
<td>308 MB</td>
<td>178 MB</td>
</tr>
<tr>
<td>Est. Concurrent users</td>
<td>&lt;14</td>
<td>&lt;75</td>
<td>&lt;212</td>
<td>&lt;368</td>
</tr>
</tbody>
</table>

Intel Xeon E5440 @ 2.83 Ghz / 64GB RAM
Tests and Results

Efficiency (Performance)

- Scenario: A single $512^3$ grid size subset of a $1024^3$ dataset is accessed and visualized by a single user.

- ... and these are only Serial wavelet results, parallel benchmarks will be better!!

<table>
<thead>
<tr>
<th>Operation</th>
<th>Intel Xeon E5440 @ 2.83 Gtz</th>
<th>Estimate Concurrent Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic B-spline wavelets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wavelet decompression</td>
<td>196.2 s</td>
<td>&lt;14</td>
</tr>
<tr>
<td>Wavelet reconstruction</td>
<td>56.8 s</td>
<td>&lt;75</td>
</tr>
<tr>
<td>Visualize volume</td>
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</tbody>
</table>

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Tests and Results

Quality

- Density component of a dataset is decomposed into 6 scales using cubic B-spline wavelets
Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Original
Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 2
Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 3
Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 4
Tests and Results

Scale-based wavelet analysis

- Reconstruction of individual scales

Scale 6
Questions? Thank you!