Extreme Scale Mesh Generation For Big-Data Medical Images

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Input from BigBrain Project
https://bigbrain.loris.ca

Courtesy of MIT Technology Review

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Motivation: From Health-Care & Aerospace Engineering

Explore New-Frontiers:

- Human Brain has 85-100 billion neurons – 1TB (20 μm resolution)
  - 1000 elements per neuron:
  - 100 trillion elements
  - 10PB (100 bytes/elm)

  Library of Congress (1PB)

  ANL MIRA: 3.1 million cores
  768TB memory, 35PB disk

- Today we could generate:
  - In core: 320 billion elements
  - Out-of-core 10PB

Replace Physical Training Settins with Virtual Faster and Cheaper Simulators


Slotnick & Khodaboust (Boeing), Alonso (Stanford), Darmofal (MIT), Gropp (UIUC), Lurie (Pratt & Whitney) and Mavriplis (Univ. of Wyoming)
Current and Emerging Hardware & Software

Today:
Pittsburgh Supercomputing Center (PSC):
Blacklight: 2,048 core cc-NUMA

Future (Exascale-era):

Hardware: A billion-way concurrency
- About 1K cores per chip
- Core/memory ratio will change
- Out-of-core more prominent role for algorithm design and programming

Software: Programming
Hybrid programming model:
- Shared memory + message passing
- OCR (Intel), Argo (ANL), other?
- PREMA [1]

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We observed 50% overhead due to memory contention, for a mesh of about 2B elements on 176 cores (11 nodes or about a 10th of the machine size)
Overview: CRTC’s efforts on parallel meshing

Data Decomposition
- Tightly Coupled
- Partially Coupled
- Decoupled

Domain Decomposition

Concurrency:
- Today: 2D
  - 2x10^2 (0.7 pef)
- 3D
  - 3x10^2 (0.7 pef)

ACM ICS04 & ICS08, FEAD10, SIAM SISC11, SISC12
ACM TOMS08 [870,872]
SIAM SISC06, SISC08
ACM SoCG02, CGTA04, ISVD10, IMR12,
ACM ICS13, CGTA14, JPDC14, IMR15 and PC16
Telescopic Approach for Extreme-Scale Parallel Mesh Generation

Data Decomposition

18M elms/sec using about 256 cores @ PSC
Summary

- Map parallel mesh generation methods according to their communication/synchronization requirements in architectures with deep memory/network hierarchies and so far achieve three orders of magnitude performance improvements:

<table>
<thead>
<tr>
<th></th>
<th>CGAL</th>
<th>Tetgen</th>
<th>GSH3D</th>
<th>PODM</th>
<th>PDR.PODM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tets/sec (using N cores)</td>
<td>37K(1 core)</td>
<td>143K(1 core)</td>
<td>49K(1 core)</td>
<td>12.3M(144 cores)</td>
<td>18M(256 cores)</td>
</tr>
</tbody>
</table>

Existing Sequential Methods

- Achieve the same and sometimes better quality and fidelity to known sequential methods:

<table>
<thead>
<tr>
<th></th>
<th>Knee/Abdominal/Neck Atlas</th>
<th>Brain Atlas</th>
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</thead>
<tbody>
<tr>
<td><strong>Quality</strong></td>
<td>CGAL</td>
<td>TetGen</td>
</tr>
<tr>
<td>Min</td>
<td>1.6°-2.8° n/a</td>
<td>4.7° 169°</td>
</tr>
<tr>
<td>Max</td>
<td>--</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Fidelity</strong></td>
<td>HDmm</td>
<td>0.5</td>
</tr>
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</table>

- Future Work
  - By 2018 we should reach to about \(10^6\) concurrency (with about 0.7 to 0.8 pef) for 3D images!

(*) For some methods angle quality varies depending on the complexity of individual tissues.