Manufacturing Industry Simulation Trends and the Influence of High Performance Computing

Nvidia GTC 2013
Place of Simulation in Manufacturing

“... five large-scale trends that have been instrumental in the shift from traditional labor-intensive process to advanced technology-based processes

1. Ubiquitous role of information technology
2. **Reliance on modeling and simulation in the manufacturing process**
3. Acceleration of innovation in global supply-chain management
4. Move towards rapid changeability of manufacturing in response to customer needs
5. Acceptance and support of sustainable manufacturing

SIMULIA - The Dassault Systèmes brand dedicated to making…

Realistic Simulation

an *integral* business practice

to Explore, Discover, Understand, Improve

*product, life, & nature*
Growth in Simulation with HPC progress

Crash simulation mid 1990’s

Increased computational power

Improvements to software

Crash simulation 2010

Simulation runtime

Simulation is a valuable part of an engineering design process, but computational cost is significant.

- **Bottle Stacking**
  - Routine static analysis
  - Compute time of 4-6 hours on 4 x86 cores

- **Stent Expansion**
  - Complex static analysis
  - Compute time of 12-24 hours using between 8 and 32 x86 cores

- **Automotive Crash**
  - Large, complex dynamics model
  - Compute time of 2-5 days using between 16 and 32 x86 cores

- **Gasket Sealing**
  - Large static model
  - Compute time of 2-5 days using between 32 and 64 x86 cores

**Reducing compute cost is critical!**
Hardware Trends of the Past Decade

- Transition from increasing clock frequencies to more cores

10 years between 1993 and 2003 are characterized by constant increase in clock frequency

Around 2004 clock frequencies stop increasing, but the multi-core era begins
## Effect of HPC in Practice

- Timings for Abaqus/Standard benchmark problem t4-std

<table>
<thead>
<tr>
<th>Hardware</th>
<th>Year</th>
<th>Clock Speed (MHz)</th>
<th>1 Core Time (secs)</th>
<th>Cores</th>
<th>Time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBM Nighthawk II</td>
<td>2001</td>
<td>375</td>
<td>3780</td>
<td>4</td>
<td>1680</td>
</tr>
<tr>
<td>HP Keystone</td>
<td>2003</td>
<td>875</td>
<td>1896</td>
<td>16</td>
<td>756</td>
</tr>
<tr>
<td>Xeon “Woodcrest”</td>
<td>2006</td>
<td>3000</td>
<td>609</td>
<td>4</td>
<td>226</td>
</tr>
<tr>
<td>Xeon “Sandybridge”</td>
<td>2012</td>
<td>2800</td>
<td>342</td>
<td>16</td>
<td>58.5</td>
</tr>
</tbody>
</table>

- Gains of 29X in single server performance in past decade
HPC Enables

- Increase in model size from greater mesh refinement (and thus computational cost)
  - Increased fidelity of physics
  - Reduce cost to engineers

- Increasing complexity of physics being modeled (next slide)
Reach of simulation continues to expand

- Design for the human body is a new frontier
Heterogeneous Compute

Future Trends

- Using different computational units for different tasks
  - Pick the computational unit that does the best job

Current gains shown above for customer model

Still learning how to best leverage hardware and adapting code base to this end
Increasing Scope of Heterogeneous Computing

**Future Trends**

- **Abaqus/Standard** – first step in leveraging GPU
  - Compute time highly concentrated in (BLAS 3) linear algebra kernels

- **Abaqus/Explicit**
  - Computational costs spread out in large number of loops
  - Parallel in both instructions and data

### Number of Variables (DOF) | Total Solution Time (secs) | Time in Linear Equation Solver (secs) | fraction of total
---|---|---|---
720 KDOF | 1265 | 680 | 54%
5237 KDOF | 18684 | 15663 | 85%

```plaintext
do k = 1, groupsize
temp1(k) = in1(k) * in2(k)
do k = 1, groupsize
temp2(k) = temp1(k) * in3(k)
do k = 1, groupsize
out(k) = temp2(k) * x
```
“Democratization” of Simulation

*Future Trends*

- Changing simulation from an expert activity to part of the design process
  - Example of simulation done in SolidWorks

- Design of experiment, optimization, and stochastics using many “runs” for a single simulation in order to look at design space rather than single point and to improve design