Methods and Tools for Energy Optimization

Piotr Łuszczek
## PLASMA and MAGMA Software Scope

<table>
<thead>
<tr>
<th>Symmetry</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>symmetric positive definite</td>
<td>Cholesky</td>
</tr>
<tr>
<td>symmetric, hermitian</td>
<td>LDL(^t)</td>
</tr>
<tr>
<td>non-symmetric</td>
<td>LU</td>
</tr>
<tr>
<td>overdetermined</td>
<td>QR</td>
</tr>
<tr>
<td>underdetermined</td>
<td>SVD</td>
</tr>
</tbody>
</table>

\[
Ax = b
\]

**Generalized**

\[
Ax = Bb
\]
BSP (fork-join) vs. DAG (dynamically scheduled)

- **Potrf**
- **Trms**
- **Syrk**
- **Gemm**

Cholesky factorization
Problem size: 4 by 4

- DAGs get big quickly: $N^3$
- Sliding window technique
- DAGs are composed at runtime
Column-major (LAPACK) vs. Tile Storage (PLASMA)
Solving Symmetric Positive Definite Systems (DPOSV)

SGI Altix UV, 2.0 GHz Intel Nehalem EX

Problem size

Gflop/s

384 cores

576 cores

768 cores

960 cores

1000 cores
Monitoring Power and Energy with PowerPack

- Watt's Up Pro
- ACPI

System: 397 W
CPU: 101 W
Memory: 34 W

Sampling rate: 10 ms - 100 ms

NI LabView

Power Supply

Cores

HyperTransport, QuickPath
### Power and Energy Metrics

- **Hardware inspired metrics**
  - **Total power**
  - **Energy delay product**
  - **Power delay product**
    - \( \frac{1}{\text{Power} \times \text{delay}} = \frac{1}{\text{Power} / \text{perf}} = \frac{\text{perf}}{\text{Power}} \) [Gflop/s per Watt]

### Benchmarks

<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>TOP500</th>
<th>Green500</th>
<th>Power</th>
<th>Hours</th>
<th>M W h</th>
<th>Mil. Cores</th>
<th>MiB/core</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sequoia</td>
<td>16.3</td>
<td>2069</td>
<td>7890</td>
<td>23.1</td>
<td>182</td>
<td>1.57</td>
<td>780</td>
</tr>
<tr>
<td>2</td>
<td>K Comp</td>
<td>10.5</td>
<td>830</td>
<td>12660</td>
<td>29.5</td>
<td>373</td>
<td>0.71</td>
<td>1525</td>
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<tr>
<td>5</td>
<td>Tianhe-1</td>
<td>2.6</td>
<td>635</td>
<td>4040</td>
<td>3.4</td>
<td>14</td>
<td>0.19</td>
<td>531</td>
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<tr>
<td>6</td>
<td>Jaguar</td>
<td>1.9</td>
<td>377</td>
<td>5142</td>
<td>24.2</td>
<td>124</td>
<td>0.31</td>
<td>972</td>
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<tr>
<td>160</td>
<td>JAXA</td>
<td>0.1</td>
<td>119</td>
<td>1020</td>
<td>55.3</td>
<td>56</td>
<td>0.01</td>
<td>6942</td>
</tr>
</tbody>
</table>
LU-based Inversion
8-cores, 2.8 GHz

DAG Composition
LU-based Inversion, Intel Core 2, 8-cores, 2.8 GHz

Watts

seconds

PLASMA

MKL

LAPACK
Tool Support for Power and Energy Measurement

Hardware-based solutions

- PowerPack
- PowerScope
- Energy Endoscope

Counter-based solutions

- PAPI-C
- Intel RAPL
- NVIDIA NVML
- VMware
- I/O
- KVM
- InfiniBand
- LM
Accuracy > 1 ms
MAGMA Power Profile on Fermi C2075 with PAPI and NVML

Sampling rate ~ 60 Hz
Collaborators

- Kirk Cameron, Virginia Tech
- Jack Dongarra, University of Tennessee
- Hatem Ltaief, KAUST
- Mathieu Faverge, ENSEIRB-Matmeca, INRIA, Bordeaux, France
- Jakub Kurzak, University of Tennessee
- Stanimire Tomov, University of Tennessee
- Vince Weaver, University of Maine