The Performance Model of SilkRoad – A Multithreaded DSM System for Clusters

Presented by Weng-Fai Wong

Department of Computer Science
School of Computing
National University of Singapore
Background - Cilk

- Cilk is an efficient multithreaded runtime system for SMPs and Clusters developed at MIT.
- Cilk is good at Divide-and-Conquer paradigm.
- Cilk is using a work stealing scheduler for load balancing.
- There is no user level shared memory in (distributed) Cilk because of the nature of D-&-C.
Introduction to SilkRoad

- SilkRoad system is a variant of Cilk
- SilkRoad extends the memory consistency model of Cilk, which results in RC_dag consistency model
- SilkRoad provides user level shared virtual memory
- SilkRoad supports more paradigms and wider applications
The memory consistency model in SilkRoad - RC_dag

- RC_dag memory consistency model is extended from location consistency (LC).
- RC_dag permits the interactions via mutual exclusion (e.g. locks) between sibling threads.
- RC_dag also allows global synchronization (e.g. barriers) between threads.
RC_dag consistency in SilkRoad

- inherited work-stealing scheduler and thread migration of Cilk,
- improved the existing implementation of LC by eliminating the “home” and trigger the diff transferring with thread stealing and return.
- included the semantics of Lazy Release Consistency (LRC), and
- implemented barrier and lock.
Performance Analysis (1)

\[ T_p = T_c + T_s + T_{\text{sync}} \]

- \( T_c \) is the computation time
- \( T_s \) is the scheduling overhead
- \( T_{\text{sync}} \) is the overhead caused by global synchronization
Performance Analysis (2)

- In Cilk, the execution time on $P$ processor
  \[ T_p = O(T_1 / P + T_\infty) \]
  where $T_1$ is the execution time on one processor and $T_\infty$ is the execution time on infinite processors.

- In SilkRoad,
  \[ T_p \approx c_1(T_1 / P) + c_\infty T_\infty + P T_s(N) \]
  where $c_1$ and $c_\infty$ are constants.
Experimental Framework

- Cluster of eight 500MHz Pentium III PCs
- Connected by 100 Mbps Ethernet
- Six applications
  - Matrix multiplication
  - N-queen problem
  - Barnes-Hut
  - LU Decomposition
  - TSP
  - Embarassing parallel application
### Experimental Results

<table>
<thead>
<tr>
<th>Applications</th>
<th>sequential execution</th>
<th>2 processors</th>
<th>4 processors</th>
<th>8 processors</th>
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</thead>
<tbody>
<tr>
<td>matmul</td>
<td>512 x 512</td>
<td>9.81s</td>
<td>5.79s</td>
<td>5.03s</td>
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<tr>
<td></td>
<td>1024 x 1024</td>
<td>84.66s</td>
<td>38.41s</td>
<td>28.08s</td>
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<tr>
<td>nqueen</td>
<td>12</td>
<td>14.64s</td>
<td>6.99s</td>
<td>3.61s</td>
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<tr>
<td></td>
<td>13</td>
<td>76.61s</td>
<td>39.94s</td>
<td>19.75s</td>
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<td></td>
<td>14</td>
<td>528.34s</td>
<td>310.31s</td>
<td>155.03s</td>
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<tr>
<td>lu</td>
<td>512 x 512</td>
<td>18.16s</td>
<td>5.23s</td>
<td>4.82s</td>
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<tr>
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<td>1024 x 1024</td>
<td>83.56s</td>
<td>28.28s</td>
<td>21.74s</td>
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<tr>
<td>barnes-hut</td>
<td>16384</td>
<td>144.2s</td>
<td>112.4s</td>
<td>96.68s</td>
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<td>tsp</td>
<td>19b</td>
<td>11.58s</td>
<td>6.85s</td>
<td>5.49s</td>
</tr>
<tr>
<td>ep</td>
<td>2^{24}</td>
<td>23.02s</td>
<td>11.66s</td>
<td>6.01s</td>
</tr>
</tbody>
</table>

Table 1. Timing of the SilkRoad applications.
Performance of 13 Queens

- $T_1$ and $T_\infty$ are 79.64s and 0.03s respectively (calculated by the runtime system)
- The constants $c_1$ and $c_\infty$ are 1.03 and 10 respectively (adjusted according to experimental results)
- $T_s(N)$ is 0 since there is no lock operations
  So, $T_p \approx 1.03 \left( \frac{T_1}{P} \right) + 10 \ T_\infty$

And the coefficient of determination is 0.996.
Modeling Performance (1)

The performance model of Nqueen problem
Performance of TSP

- $T_1$ and $T_\infty$ are 11.94s and 2.35s respectively (calculated by the runtime system)
- The constants $c_1$ and $c_\infty$ are 0.962 and 0.085 respectively, $T_s(N)$ is 0.421 (adjusted according to experimental results)

So, $T_p \approx 0.962 \left( \frac{T_1}{P} \right) + 0.085 \; T_\infty + 0.421P$, and the coefficient of determination is 0.98.
Modeling Performance (2)

The performance model of TSP
Conclusion

- SilkRoad’s performance analysis model is based on Cilk’s theoretical performance model plus the consideration of global synchronization overhead.
- The performance model of SilkRoad is close to experimental results.