An experience of early initiation to parallelism in the Computing Engineering Degree at the University of Murcia, Spain

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Centro de Supercomputación, Fundación Parque Científico, Murcia

EduPar Workshop, Shanghai, May 21, 2012
Outline

1. The context
2. The project
3. The topics
4. Perspectives
Parallel Computing today

- Computational systems are parallel: laptops, desktops, clusters, supercomputers, GPUs...
- But parallel computing is not sufficiently included in Computing Science studies, at least in Spanish universities, and in particular at the University of Murcia.
- This Early Adopters project (Fall 2011) aims at improving this situation in the Computing Science Degree at the University of Murcia.
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University of Murcia

- Generalist University
- Approximately 31000 students

Computer Science school

- Computing Science Degree
  appr. 800 students + 80 teachers
- Master and PhD
  appr. 60 students
- 3 computing departments
Parallelism in System courses from the third semester.

Basic concepts of concurrency and distributed computing in a programming course in the fourth semester.

Algorithmic aspects are not studied in any compulsory course.

Intensification in parallelism in some specializations, but parallelism is not included in all the specializations.

⇒ Computer Science students at the University of Murcia can obtain their degree without having developed and optimized any parallel code.
Parallelism at the University of Murcia - the project

- Four compulsory courses in the second year of the degree.
  - Two courses already included parallelism (ACA and CDP).
  - Two courses include topics of parallelism for the first time (FOS and ADS).
- Systems (ACA and FOS) and Programming (CDP and ADS) courses, with topics in the four parallelism aspects of the IEEE TCPP curriculum.
- Three departments and a Computing Centre: coordinated treatment of the topics + use of a range of computational systems in the practicals.
Courses involved

- Fundamentals of Operating Systems
  Processes, Memory, Files, I/O, Security, Shell Scripts, Users Management, File systems, Backups, Monitoring

- Advanced Computer Architecture
  Performance Analysis, Pipelining, Control Dependencies, Static and Dynamic Scheduling of Instructions, Memory System Organisation and Performance

- Algorithms and Data Structures
  Analysis of Algorithms, Complexity, Greedy Algorithms, Backtracking, Branch & Bound, Game Trees, Divide and Conquer, Dynamic Programming

- Concurrent and Distributed Programming
  Loosely and Strongly Coupled Systems Programming, Classic Programming Paradigms in Distributed Systems
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- **Act-1**, FOS: threads management and monitoring. (Practicals)
- **Act-2**, FOS+ACA+SCC: computing centre. (Visit)
- **Act-3**, FOS+CDP: performance management of threads and processes. (Practicals)
- **Act-4**, ACA+ADS: influence of memory hierarchy on performance. (Practicals)
- **Act-5**, ADS: parallel algorithmic schemes and cost of parallel algorithms. (Seminars)
- **Act-6**, CDP: basic shared-memory and message-passing constructors. (Theory and practicals)
- **Act-7**, CDP+ADS+SCC: shared-memory programming. (Practicals)
- **Act-8**, CDP+ADS+SCC: message-passing programming. (Practicals)
The project

The topics

Perspectives

Tasks

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Most of the architecture topics were studied in ACA.

A few topics are included, and others are treated more in depth and in collaboration with different courses.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Previous</th>
<th>First semester</th>
<th>Second semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACA</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Shared memory</td>
<td>12</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Distributed memory</td>
<td>12</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Client server</td>
<td>0.5</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Task/thread spawning</td>
<td>2.5</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>SPMD</td>
<td>2</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Shared memory notations</td>
<td>10</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Language extensions</td>
<td>1</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Libraries</td>
<td>10</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>SPMD notations</td>
<td>3</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>MPI</td>
<td>3</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Semantic tasks and threads</td>
<td>5.5</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Synchronization</td>
<td>2</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Critical regions</td>
<td>2.5</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Producer-consumer</td>
<td>1.5</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Monitors</td>
<td>4</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Deadlocks</td>
<td>0.5</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Memory models</td>
<td>0.5</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Scheduling and comp.</td>
<td>2</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Decomposition strategies</td>
<td>1</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Loop fusion</td>
<td>0.5</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Scheduling and mapping</td>
<td>3</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Performance monitoring</td>
<td>2</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Performance metrics</td>
<td>1.5</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Speed-up</td>
<td>2</td>
<td>K</td>
<td>X</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>C</td>
<td>X</td>
</tr>
<tr>
<td>Amdahl’s law</td>
<td>1</td>
<td>C</td>
<td>X</td>
</tr>
</tbody>
</table>

- Most of the programming topics were studied in CDP.
- Programming topics are put in practice.
### Algorithms

<table>
<thead>
<tr>
<th>Topic</th>
<th>Previous</th>
<th>First semester</th>
<th>Second semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACA</td>
<td>1 2</td>
<td>3 4 5 6 7 8</td>
</tr>
<tr>
<td>Asymptotics cost.</td>
<td>C</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Time</td>
<td>C</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Space</td>
<td>C</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Speed-up</td>
<td>C</td>
<td>X X X</td>
<td>X X X</td>
</tr>
<tr>
<td>Notions from scheduling</td>
<td>K</td>
<td>X</td>
<td>X X</td>
</tr>
<tr>
<td>Divide and Conquer</td>
<td>A</td>
<td>X X X</td>
<td></td>
</tr>
<tr>
<td>Broadcast</td>
<td>K</td>
<td>X</td>
<td>X X</td>
</tr>
<tr>
<td>Asynchrony</td>
<td>K</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Synchronization</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorting</td>
<td>A</td>
<td>x X X</td>
<td></td>
</tr>
<tr>
<td>Graph search</td>
<td>K</td>
<td>x x X</td>
<td></td>
</tr>
<tr>
<td>Specialized computations</td>
<td>K</td>
<td></td>
<td>X X X</td>
</tr>
</tbody>
</table>

- Most algorithmic topics are new.
- They are studied in CDP and joint practicals are done with ADS.
- Students develop and theoretically and experimentally analyse simple parallel programs in multicore and clusters.
## Cross Cutting

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<thead>
<tr>
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<th>Previous</th>
<th>First semester</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Why and what is PDC.</td>
<td>1 C</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Concurrency</td>
<td>1 C</td>
<td>X</td>
<td>4</td>
</tr>
<tr>
<td>Non-determinism</td>
<td>1 A</td>
<td>X</td>
<td>5</td>
</tr>
<tr>
<td>Power</td>
<td>0.5 K</td>
<td>X</td>
<td>6</td>
</tr>
<tr>
<td>Locality</td>
<td>1.5 C</td>
<td>X</td>
<td>7</td>
</tr>
<tr>
<td>Security in Dist. systems</td>
<td>1 K</td>
<td>X</td>
<td>8</td>
</tr>
</tbody>
</table>

- **Wider vision of different aspects of parallelism.**
- **Collaboration of the Supercomputing Centre, with a visit and presentation of the laboratory: security, management, configuration, applications...**
Courses - hours

Approximate number of hours devoted in each course to each part of the curriculum

Previously:

<table>
<thead>
<tr>
<th></th>
<th>Arch.</th>
<th>Prog.</th>
<th>Algor.</th>
<th>Cross Cut.</th>
<th>TOTAL</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ACA</td>
<td>21</td>
<td>13</td>
<td>0</td>
<td>2</td>
<td>36</td>
<td>60</td>
</tr>
<tr>
<td>CDP</td>
<td>1</td>
<td>42</td>
<td>2.5</td>
<td>3</td>
<td>48.5</td>
<td>78</td>
</tr>
<tr>
<td>ADS</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>22</td>
<td>55</td>
<td>2.5</td>
<td>5</td>
<td>84.5</td>
<td>12</td>
</tr>
</tbody>
</table>

With the project:

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<thead>
<tr>
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<th>Cross Cut.</th>
<th>TOTAL</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOS</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0.5</td>
<td>6.5</td>
<td>12</td>
</tr>
<tr>
<td>ACA</td>
<td>24</td>
<td>13</td>
<td>0</td>
<td>2.5</td>
<td>37.5</td>
<td>62</td>
</tr>
<tr>
<td>CDP</td>
<td>1.5</td>
<td>55</td>
<td>2.5</td>
<td>3</td>
<td>62</td>
<td>100</td>
</tr>
<tr>
<td>ADS</td>
<td>1.5</td>
<td>13.5</td>
<td>5.5</td>
<td>0</td>
<td>20.5</td>
<td>32</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26</td>
<td>86.5</td>
<td>8</td>
<td>6</td>
<td>126.5</td>
<td>19</td>
</tr>
</tbody>
</table>
## Evaluation

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<thead>
<tr>
<th>Act</th>
<th>Students</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act-1</td>
<td>laboratory + test</td>
<td>opinion and test satisfactory</td>
</tr>
<tr>
<td>Act-2</td>
<td>not assessed</td>
<td>high participation</td>
</tr>
<tr>
<td>Act-3</td>
<td>theory + laboratory</td>
<td>high participation</td>
</tr>
<tr>
<td>Act-4</td>
<td>laboratory + practicals</td>
<td>ongoing, high participation</td>
</tr>
<tr>
<td>Act-5</td>
<td>practicals</td>
<td>ongoing, high participation</td>
</tr>
<tr>
<td>Act-6</td>
<td>theory + laboratory</td>
<td>high participation</td>
</tr>
<tr>
<td>Act-7</td>
<td>laboratory + practicals</td>
<td>ongoing, students of the non participating group ask to participate</td>
</tr>
<tr>
<td>Act-8</td>
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Subjective appreciation

- Positive experience, with participation of the students in non compulsory activities.
- 2 of the 3 groups participate, for next year it could be interesting to extend the experience to all the groups.
- Difficulties with rigid Degree plan and teachers not familiar with parallel computing.
- But some teachers without previous experience in parallelism have joined the experience.
- Most activities non compulsory, so attendance at the activities is satisfactory, but the active participation (homework, practicals...) is low.
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A poster in the posters’ session: 16:15-18:00

The paper in the proceedings describes in more detail how each topic is treated.

Project website: http://www.um.es/earlyadopters

... or my e-mail domingo@um.es

... or questions here