An experience of five years using parallel programming contests for teaching

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The contest Teaching experiences Changes and Perspectives

... continuation of

The Spanish Parallel Programming Contest and its use as an educational resource

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Universidad de La Laguna

Parque Científico de Murcia
Outline

1. The contest
2. Teaching experiences
3. Changes and Perspectives
Spanish Parallel Programming Contest

Since 2011

It has evolved. In 2017:

- Individual participation, Spanish students no older than 28
- In the *Jornadas Sarteco* (Spanish Society of Computers Architecture), September 20th, Málaga
- Using systems of the CESGA (Supercomputing Center of Galicia)
- Problems to be solved with OpenMP, MPI, CUDA and XeonPhi (OpenMP, offload mode)
- A sequential solution is provided for each problem, and the score is calculated based on speed-up
- Automatic, real-time scoring using Mooshak
Spanish Parallel Programming Contest - Structure

- **Mooshak**: A tool for organization of contests. From the University of Porto, Portugal.
- Adapted to work in the cluster and to calculate scoring based on speed-up.
- Instructions and examples through mooshak.cesga.es and luna.inf.um.es
- The participants send their solution to mooshak, which compiles and links it with a schema (used for I/O, validation and scoring), sends the compiled program to be executed, collects the result and execution time, validates the output and calculates scores.
Examples from the qualification contest, 2017:

- **Displaced additions on a vector of floats.**
  We consider a vector $v$ of float numbers. The value at each position $i$ of vector $v (v[i])$ is updated by adding to this value those entries in $v$ at a distance from position $i$ a multiple of $\text{fabs}(v[i]/100) + 2$. The multiple can be positive or negative: positions before and after $i$ are considered. A given number of steps is carried out.

- **Medians and multiples.**
  We consider a matrix $n \times n$ of integers. The medians of each row are obtained, and for each median the number of its multiples in all the matrix is obtained. For a median with value 0 the value is 0.

**Simple problems.** Sequential solutions provided. Solved with well-known algorithmic schemas.
But it is necessary to adapt them to the system to obtain high speed-ups $\Rightarrow$ the effort is centered on parallelization.
## Spanish Parallel Programming Contest - Evolution

<table>
<thead>
<tr>
<th>Year</th>
<th>City</th>
<th>Problems</th>
<th>System</th>
<th>Modality</th>
<th>Groups</th>
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<tbody>
<tr>
<td>2011</td>
<td>La Laguna</td>
<td>MPI+OMP 5</td>
<td>CSC-FPC Murcia</td>
<td>in situ</td>
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<td>OMP+CUDA 3</td>
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<td>2015</td>
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<td>CUDA 2</td>
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<td>MPI</td>
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<td>2017</td>
<td>Málaga</td>
<td>OMP</td>
<td>CESGA</td>
<td>qualification</td>
<td>individual</td>
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</table>

- Problems: MPI+OMP 5, MPI+OMP 3, OMP 2, MPI+OMP 2, CUDA 2, OMP+CUDA 3, OMP+OMP 2 x 6 cores
- System: CSC-FPC Murcia 4 x 8 cores, SCPP-Murcia OMP 24 cores, MPI+OMP 2 x 6 cores, CESGA OMP 24 cores, MPI 4 x 24 cores
- Modality: in situ, online, regular exhibition, qualification in situ
- Groups: 3 students, 2 students, individual
Spanish Parallel Programming Contest - Resources

- **Website**: luna.inf.um.es
- **Modifications to Mooshak**: it has been adapted to send jobs to a cluster and for scoring based on speed-ups.
- **Problems**: are available on the website.
- **Programs**: solutions in the records table.
- **Explanations**: comments on the improvements for new records.
- **Open contests**:
  - calisto.inf.um.es
    - quadcore, University of Murcia
    - OpenMP, MPI and MPI+OpenMP problems of all the editions
  - mooshak.cesga.es
    - systems of CESGA: warmup, contest 2011, qualification contest of 2017
    - OpenMP, MPI, CUDA, Xeon Phi (OpenMP, offload mode)
Teaching experiences

- Parallelism in Informatics in Vocational Studies

- Degree:
  - Methodology of Parallel Programming
  - Multicore and Manycore Programming

- Early Adopters Program:
  - Fall-11: TCPP Curriculum: Adoption in the second year of the undergraduate Degree in Computer Science at the University of Murcia
  - Fall-14: TCPP Curriculum in Parallel Programming courses of the Degree in Computer Science at the University of Murcia

- Master: Parallel Programming and High Performance Computing

- Extracurricular courses
Parallelism in Informatics in Vocational Studies

- Project University of Murcia-Secondary School Juan de la Cierva (http://dis.um.es/~domingo/FP14.html, in Spanish)
  (Autogyro: “Invented by the Spanish engineer Juan de la Cierva to create an aircraft that could fly safely at low speeds”)

- Identification of parallelism topics in Informatics in Vocational Studies:
  Development of Multiplatform Applications
  Development of Web Applications
  Technology of Information and Communication (Secondary Studies)

- A contest (basico in calisto.inf.um.es) with basic examples
  Matrix multiplication, Sorting
  OpenMP, MPI+OpenMP, CUDA
Early Adopters Fall-11. TCPP Curriculum: Adoption in the second year of the undergraduate Degree in Computer Science at the University of Murcia

- Three departments + One supercomputing center
- Second year of Computing Science Degree
- Four compulsory courses:
  - Fundamentals of Operating Systems
  - Advanced Computer Architecture
  - Algorithms and Data Structures
  - Concurrent and Distributed Programming
- In ADS, use of basic examples from the contest

Manuel E. Acacio, Javier Cuenca, Lorenzo Fernández, Ricardo Fernández-Pascual, Joaquín Cervera, Domingo Giménez, M. Carmen Garrido, Juan A. Sánchez Laguna, José Guillén, Juan Alejandro Palomino Benito, María-Eugenia Requena: An experience of early initiation to parallelism in the Computing Engineering Degree at the University of Murcia, Spain, Second NSF/TCPP Workshop on Parallel and Distributed Computing Education (EduPar-12), en 26th IEEE International Parallel & Distributed Processing Symposium, Shanghai, China, May 21, 2012
Early Adopters Fall-14. TCPP Curriculum in Parallel Programming courses of the Degree in Computer Science at the University of Murcia

- Two departments, two lecturers, two courses
- Final year of Computing Science Degree
  - Methodology of Parallel Programming
  - Multicore and Manycore Programming
- Analysis of introduction into the curricula of topics of the TCPP Curriculum
Methodology of Parallel Programming

- Fourth year of Computer Science Degree, first semester.
- In the previous semester a course on Parallel Architectures.
- In the second year a course on Principles of Concurrent and Distributed Programming.
- Compulsory for specialization in Software Engineering, optional for specialization in Computer Engineering.
- Medium size class, around 40 students.
- Practical approach, with problems and tools from the Spanish Parallel Programming Contest.
Methodology of Parallel Programming - Organization

Syllabus:

- Review of parallel architectures
- Parallel programming paradigms
- Parallel programming tools: OpenMP, MPI and CUDA
- Parallel algorithmic schemas
- Analysis of parallel algorithms
- Methodology of parallel programming

Practical-guided evaluation: basic practicals (contest) and final project.
Methodology of Parallel Programming - Evolution

<table>
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<tr>
<th>year</th>
<th>&lt;11</th>
<th>11-12</th>
<th>12-13</th>
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<td>CSC-FPC</td>
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</table>
Methodology of Parallel Programming - Practice cluster

- **XeonPhi**
  - 57

- **Xeon Phi**
  - 57

- **venus**
  - OpenMP
  - GPUs
  - 512, 512
  - 448, 448

- **jupiter**
  - 512, 512

- **saturno**
  - 2496

- **CUDA**
  - 512

- **marte**
  - GPU
  - MPI+OpenMP

- **mercurio**
  - GPU
  - 512

- **mooshak in HETEROSOLAR**
  - Shared file system

- **luna**
## Methodology of Parallel Programming - Evaluation change

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<td>Basic practicals $\approx 20%$</td>
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<td>Continuous $75%+25%$</td>
<td>Non Cont. $50%+50%$</td>
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<tr>
<td>project</td>
<td>$\approx 50%$</td>
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<td>$\approx 45%$</td>
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<td>$\approx 65%$</td>
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Methodology of Parallel Programming - Students’ opinion

The structure of the course preferred to the previous and the traditional. With higher workload?

Average workload similar to that estimated. With less study after the lectures and greater difficulty in the practicals.
Methodology of Parallel Programming - Students’ opinion

The structure of the course preferred to the previous and the traditional. With higher workload?

Average workload similar to that estimated. With less study after the lectures and more difficulty in the practicals.

But negative opinions of the students: too much practical workload, little time to understand the explanation of the lecturer, little guiding by the lecturer...
Methodology of Parallel Programming - Organization 2017-18

Continuous:
- Basic practicals, 25%
- Practicals control, 15%
- Programming exam, 15% + 15%
- Project, 30%

NON Continuous:
- Basic practicals, 20%
- Practicals revision
- Programming exam, 20% + 20%
- Project, 40%
Multicore and Manycore Programming

- Fourth year of Computer Science Degree, second semester.
- Optional for specialization in Computer Engineering.
- Few students, between 2 and 4.
- Personalized work.
- Evaluation based on practicals and projects.
- Some basic examples from the Spanish Parallel Programming Contest:
  - for students without previous knowledge of OpenMP / MPI.
  - for initiation to CUDA and Xeon Phi.
Parallel Programming and High Performance Computing

- Master
- Specialization in High Performance Architectures and Supercomputing, optional in others.
- Few students, between 2 and 6.
- Heterogeneous knowledge (mathematicians, physicists, communications engineers, industry engineers, computer scientists from various specialties...)
- Examples from the Spanish Parallel Programming Contest are used for homogenization: online, autonomous work with basic examples.
Extracurricular courses and others

Programming the Ben Arabí Supercomputer:

- In collaboration with the Supercomputing Center of Murcia.
- Two editions 2011 and 2012.
- For scientists and engineers, students, researchers and from industry.

Use of tools of the contest by other universities?

A university from Brazil has use of the Heterosolar cluster.

Questions from some universities about the problems and the system.

While the number of users is not growing very much, the open contests in mooshak.cesga.es and calisto.inf.um.es can be used for practice with problems from the contest.

Ben Arabí: “mystic, poet, and philosopher ... was born in Murcia”
Changes and Perspectives

- Inclusion of problems over Xeon Phi, until now only OpenMP in offload mode.
- More open contests.
- Automation of the updating of records?
- This year for the first time, a Programming Contest in EuroPar, Thursday 31st, three hours.

If you are not enrolled and want to participate, contact José Carlos Cabaleiro jc.cabaleiro@usc.es
in collaboration with

<table>
<thead>
<tr>
<th>University</th>
<th>2011</th>
<th>2012</th>
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<th>2014</th>
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Questions? Comments? Recommendations?

- domingo@um.es
- http://dis.um.es/~domingo
- SCPP Group: http://luna.inf.um.es/grupo_investigacion
- Contest: http://luna.inf.um.es