DEGREE CURRICULUM

HIGH PERFORMANCE COMPUTING

Coordination: GINE DE SOLA, FRANCESC

Academic year 2020-21

HIGH PERFORMANCE COMPUTING 2020-21

Subject's general information

<table>
<tr><td>Subject name</td><td>HIGH PERFORMANCE COMPUTING</td></tr>
<tr><td>Code</td><td>103084</td></tr>
<tr><td>Semester</td><td>2nd Q(SEMESTER) CONTINUED EVALUATION</td></tr>
<tr><td>Typology</td><td>
<table>
<tr><th>Degree</th><th>Course</th><th>Character</th><th>Modality</th></tr>
<tr><td>Master's Degree in Informatics Engineering</td><td>1</td><td>COMPULSORY</td><td>Attendance-based</td></tr>
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<tr><td>Course number of credits (ECTS)</td><td>4.5</td></tr>
<tr><td>Type of activity, credits, and groups</td><td>
<table>
<tr><th>Activity type</th><th>PRALAB</th><th>TEORIA</th></tr>
<tr><th>Number of credits</th><td>3</td><td>1.5</td></tr>
<tr><th>Number of groups</th><td>1</td><td>1</td></tr>
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<tr><td>Coordination</td><td>GINE DE SOLA, FRANCESC</td></tr>
<tr><td>Department</td><td>COMPUTER SCIENCE AND INDUSTRIAL ENGINEERING</td></tr>
<tr><td>Teaching load distribution between lectures and independent student work</td><td>30% of the time is leaded by the teacher and 70% is based on autonomous work. The hours of work leaded by the teacher will be distributed between face-to-face and non-face-to-face sessions (synchronous videoconferences) depending on the type of activity to be carried out.</td></tr>
<tr><td>Important information on data processing</td><td>Consult this link for more information.</td></tr>
<tr><td>Language</td><td>English</td></tr>
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HIGH PERFORMANCE COMPUTING 2020-21

Teaching staff	E-mail addresses	Credits taught by teacher	Office and hour of attention
GINE DE SOLA, FRANCESC	francesc.gine@udl.cat	3	
LERIDA MONSO, JOSEP LLUIS	joseplluis.lerida@udl.cat	1,5	

Subject's extra information

To follow this course, the student should have solid knowledge of structured programming in C language and Architecture and Computer Technology. Specifically, it is important that the student has good knowledge of concepts of memory hierarchy and pipelining.

Learning objectives

- Knowledge the use of benchmarking tools applied to the high performance computing environments.
- Capacity for analysis and understanding the computer perfomance.
- Knowledge of the parallel programming paradigms.
- Implementation and debugging of parallel applications using the OpenMP and MPI paradigms.
- Knowledge and understanding of the cloud computing paradigm.
- Practical use of frameworks and cloud computing technologies.
- Knowledge and understanding the architecture and operation for the most common HPC Infrastructures most booming in the market.
- Solving numerical algorithms using a Hybridization of OpenMP and MPI technologies and evaluating its performance.
- Communication of ideas and concepts in english in an understandable way, writing and speaking.

Competences

University of Lleida strategic competences

- UdL1: Appropriate skills in oral and written language.
- UdL2: Command of a foreign language.

Cross-disciplinary Competences EPS

- EPS3: Capacity to convey information, ideas, problems and solutions to both a specialized and no specialized public.
- EPS4: Capacity to conceive, design and implement projects and/or contribute to new solutions, using engineering tools.

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General Competences

- CG1: Capacity to project, calculate and design products, processes and installations in all fields of Computer Engineering.
- CG8: Capacity to apply the knowledge acquired for solving problems in new and unfamiliar situations within broader and more multidisciplinary contexts, and to be capable of integrating this knowledge.

Basic Competences

- CB1: Possess knowledge and understanding that provide a basis or opportunity for originality in developing and / or applying ideas, often in a research context.
- CB2: That the students can apply their knowledge and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their field of study

Degree-specific competences

- CE10: Capacity to understand and apply advanced knowledge in high-performance computing and numerical or computational methods to problems of engineering.

- CE12: Capacity to apply mathematical, statistical and artificial intelligence methods, design and develop applications, services, intelligent systems and systems based on knowledge.

Subject contents

1. Introduction: High Performance Computing (2h F+4h NF)
2. Introduction to the parallel processing and Benchmarking(4h F+12h NF)
    - Introduction
    - Concepts
    - Parallel programming models
    - Design of parallel applications
    - Limits of the parallel processing
    - Benchmarking Tools
3. Shared-memory Parallel Programming with OpenMP (8h F+20h NF)
    - Main Characteristics
    - Parallel Regions
    - Data Scoping
    - OpenMP worksharing for loops
    - Reductions
    - Loop Scheduling
    - Synchronization
4. Distributed-memory Parallel Programming with MPI (10h F+30h NF)
    - Main Characteristics
    - Messages and Point-to-point communications
    - Collective communication
    - Grouping Data for communication
    - Communicators and Topologies
5. Cloud Computing (4h F+10h NF)
    - Cloud Essentials
    - Anatomy of the cloud
    - Oportunities
    - OpenNebula
6. Parallel computers (2h F+6h NF)
    - Types of parallel computers
    - Analysis of main supercomputers located in TOP500.

F: Face to Face or on-line class (It will depend of the evolution of the pandemic of COVID-19)

NF: Homework

Methodology

Every week, each student will receive:

- **Two hours of class leaded by the teacher.** These lectures can be carried out both face-to-face and non-face-to-face, depending on the evolution of the COVID-19 pandemic.
- **Face-to-face lectures** will be done in the lab explaining the contents in a more practical way. As a support material of the class, we will follow the slides for the course.
- **Non-face-to-face lectures** will be done by synchronous video-conferences, explaining the theoretical content of the course, accompanied by illustrative examples and problem solving. Classes recording will be at student's disposal.
- Support materials to follow the subject in a non-attendance way.

The evaluation is continuous throughout the semester and consists of four different parts:

- Four practices: Benchmarking, openMP, MPI-Hybrid and Comparison Hybrid (only if you don't take the supercomputing report).
- A report about a supercomputing infraestructure (this is optional instead of the Comparison practice).

Development plan

Week	Description	Activities leaded by teacher*	Autonomous Activity	Autonomous Hours
1	Introduction: High Performance Computing	Exhibition events and methodology Lecture and participatory classes	Teaching Plan Review Study & homework	4
2	Introduction to parallel processing and Benchmarking	Lecture and participatory classes	Case study resolution Benchmarking	6
3	Introduction to parallel processing and Benchmarking	Lecture and participatory classes	Case study resolution Benchmarking	6
4	Parallel code optimization seminar using Intel tools	Seminar	Practical execicises resolution in lab. Case study resolution Benchmarking	5
5	Shared-memory Parallel Programming with OpenMP	Lecture and participatory classes	Study and Exercises resolution Case study resolution OpenMP	9
6	Shared-memory Parallel Programming with OpenMP	Lecture and participatory classes	Study and Exercises resolution Case study resolution OpenMP Submission Practice Benchmarking	5
7	Shared-memory Parallel Programming with OpenMP	Lecture and participatory classes	Study and Exercises resolution Case study resolution OpenMP	5
8	Distributed-memory Parallel Programming with MPI HPC PROJECT	Lecture and participatory classes	Study and Exercises resolution Case study resolution OpenMP	6
9	Distributed-memory Parallel Programming with MPI	Lecture and participatory classes	Study and Exercises resolution Submission OpenMP Practice Case study resolution MPI	10
10	Holiday	No Lecture	Case study resolution MPI	3

11	Distributed-memory Parallel Programming with MPI	Lecture and participatory classes	Study and Exercises resolution Case study resolution MPI	6
12	Distributed-memory Parallel Programming with MPI	Lecture and participatory classes	Case study resolution MPI	6
13	Distributed-memory Parallel Programming with MPI	Lecture and participatory classes	Study and Exercises resolution Case study resolution MPI	6
14	Holiday	Holiday	Study and Exercises resolution Submission MPI Practice	3
15	Cloud Computing	Lecture and participatory classes	Practice OpenNebula Case study resolution Hybrid OpenMP+MPI	5
16		Tutorial class	Submission Hybrid Practice Study and Analysis of a parallel computing Infrastructure	7
17		Tutorial class	Analysis and Comparison of Hybrid Practices Study and Analysis of a parallel computing Infrastructure	7
18		Tutorial class	Submission Parallel Computer work or Hybrid Analysis	8
19	parallel Computers	Oral Presentation	Preparattion	3

*The activities leaded by teacher may be carried out in face-to-face way, as an on-line mode (synchronous video conferences), as a function of the evolution of the COVID-19 pandemic.

Evaluation

There is a continous evaluation consisting in the following activities with the corresponding percentage of the final mark of the course:

Objectives	Evaluation activities	%	Dates	M/V (1)	I/G (2)	Remarks
Continous assesment Topics 1 & 2	First practice benchmarking	15	Week 4	M	G	
Continous assesment Topics 1 & 2 & 3	Second practice OpenMP	25	Week 9	M	G	
Continous assesment Topics 1 & 2 & 3 & 4	Third practice MPI-Hybrid	40	Week 16	M	G	
Continous assesment Topics 1 & 2 & 3 & 4	Hybrid application Performance Analysis	15	Week 18	M	G	Students choose the activity
Continous assesment Topics 1 & 2 & 5 & 6	Writing Work Supercomputers - Cloud Computing	15	Week 18			
Continous assesment Topics 3 & 4 & 5 & 6	Oral Presentation	5	Week 19	M	G	

Objectives	Evaluation activities	%	Dates	M/V (1)	I/G (2)	Remarks
Recovery assesment. Topics 1 & 2 & 3	Recovery assesment**		Week 19	V	I	Recoveries Week

(1) Mandatory / Voluntary
(2) Individual / Group

Therefore, the final mark for the course will be:

Final grade = 15% Benchmarking + 25% OpenMP + 40% MPI-Hybrid + 15% Supercomputer Work or 15% Hybrid application Performance Analysis + 5% Oral Presentation
The practices of the previous year can be recognized retaining the same result obtained in the previous year.

Students who participate actively in the subject, carrying out extra activities proposed throughout the course, will be able to aim for an additional point on the Final Note of the subject.

**Students who fail the continuous assessment with a score lower than 5 shall be entitled to recover the tests with a weight higher than 15%.

Bibliography

F. Giné & J.L. Lérida

Slides of the Subject

Lleida, 2020

P.S. Pacheco,

Parallel Programming with MPI,

Morgan Kaufmann Publishers , 1997

-R. Chandra, L. Dagum, D. Kohr,

Parallel Programming in OpenMP,

Morgan Kaufmann Publishers , 2001