| Teaching Guide | | | | |
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| Identifying Data | | | | 2024/25 |
| Subject (*) | HPC Tools | | Code | 614973105 |
| Study programme | Mestrado Universitario en Computación de Altas Prestacións / High Performance Computing (Mod. Virtual) | | | |
| Descriptors | | | | |
| Cycle | Period | Year | Type | Credits |
| Official Master's Degree | 1st four-month period | First | Optional | 6 |
| Language | English | | | |
| Teaching method | Non-attendance | | | |
| Prerequisites | | | | |
| Department | Departamento profesorado másterEnxeñaría de Computadores | | | |
| Coordinador | Padron Gonzalez, Emilio Jose | E-mail | emilio.padron@udc.es | |
| Lecturers | Andrade Canosa, Diego<br>Padron Gonzalez, Emilio Jose | E-mail | diego.andrade@udc.es<br>emilio.padron@udc.es | |
| Web | aula.cesga.es | | | |
| General description | The objective of this course is to get the students familiar with the most common types of application that are candidates to use HPC, besides being introduced to the main tools and implementations existing for them, understanding the challenges to be addressed for their parallelization and performance tuning. All this will allow the students to obtain a general knowledge about the HPC field and its different applications and use cases.<br><br>Furthermore, the students will learn what tools can be used to carry out the performance characterization and benchmarking tasks in HPC environments, and how these tools can be leveraged to drive the parallelization and performance tuning of an application on a specific platform. This will allow the students to be able to analyze the expected performance on that system, identifying the different hot spots and focussing the optimization efforts on them.<br><br>Finally, the students will learn different technological alternatives for a fast and efficient deployment of HPC applications. This will allow them to be able to easily and effectively deliver and execute HPC applications in different environments. | | | |

| Study programme competences / results | |
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| Code | Study programme competences / results |
| A1 | CE1 - Define, evaluate and select the most appropriate architecture and software to solve a problem |
| A2 | CE2 - Analyze and improve the performance of a given architecture or software |
| A3 | CE3 - Know the high performance computing basic concepts |
| A4 | CE4 - Deepen in the knowledge of different programming tools and programming languages in the field of the high performance computing |
| A5 | CE5 - Analyze, design and implement efficient parallel algorithms and applications |
| B1 | CB6 - Possess and understand the knowledge that give a baseline or opportunity to be original in the development and/or application of ideas, often in a research environment |
| B3 | CB8 - The students have to be able to integrate knowledge and face the complexity to make judgments from information, despite being partial and limited, includes reflexions about the social and ethical responsabilities linked to the application of their judgements and knowledge |
| B4 | CB9 - The students have to be able to communicate their conclusions, their knowledge and the reasons that hold them to specialized and non specialized audience in a clear and unambiguous manner |
| B6 | CG1 - Be able to search and select useful information to solve complex problems, using the bibliographic sources of the field |
| B8 | CG3 - Be able to maintain and extend properly funded theoretical hypothesis to allow the introduction and exploitation of novel and advanced technologies in the field |
| B9 | CG4 - Be able to plan and do research, development and innovation tasks in high performance computing related environments |
| C1 | CT1 - Use the basic technologies of the information and computing technology field required for the professional development and the long-life learning |

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| C4 | CT4 - Value the importance of research, innovation and the technological development in the socioeconomical and cultural advance of the society |

| Learning outcomes | | | |
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| Learning outcomes | Study programme competences / results | | |
| Students will know the most common types of applications in which HPC techniques are usually applied. | AJ1<br>AJ2 | BJ1<br>BJ6 | CJ1 |
| Students will learn to use tools to characterize and represent the performance of applications. | AJ3<br>AJ4 | BJ3<br>BJ9 | CJ4 |
| Students will learn to use tools to compile, generate and deploy software in HPC environments. | AJ3<br>AJ5 | BJ1<br>BJ4<br>BJ8 | CJ1 |

| Contents | |
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| Topic | Sub-topic |
| A survey of the main application types in HPC environments | For each type we will see:<br>1. Problem: formal description.<br>2. Parallelization and performance tuning challenges.<br>3. Existing approaches. |
| Tools for software compilation and optimization in HPC environments | 1. Code compilation, optimization and generation.<br>2. Code optimization with a compiler.<br>3. Automatic parallelization and vectorization.<br>4. Tools for software building automation. |
| Tools to measure, characterize and represent the performance of HPC applications | 1. Usage of performance characterization and benchmarking tools, such as software monitoring and hardware counters.<br>2. Hot spot detection to drive the optimization process.<br>3. Application of performance models to this process.<br>4. Tools for application performance representation |
| Tools for the deployment of AI applications in HPC environments | 1. Training and deployment of Deep Learning models in HPC environments.<br>2. Use of containers to ease the deployment of HPC applications. |

| Planning | | | | |
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| Methodologies / tests | Competencies / Results | Teaching hours (in-person & virtual) | Student?s personal work hours | Total hours |
| Workbook | A3 B1 C4 | 0 | 23 | 23 |
| Laboratory practice | A1 A2 A4 A5 C1 | 4 | 66 | 70 |
| Supervised projects | B3 B4 B6 B8 B9 | 0 | 54 | 54 |
| Mixed objective/subjective test | B4 B6 | 2 | 0 | 2 |
| Personalized attention | | 1 | 0 | 1 |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. | | | | |

| Methodologies | |
|---|---|
| Methodologies | Description |
| Workbook | Reading educational material, watching videos and use multimedia resources. Instruction guided by teaching materials, especially designed for an autonomous and asynchronous learning. |
| Laboratory practice | Asynchronous and autonomous lab sessions, monitored by teachers, allowing students to become familiar from a practical standpoint with the issues discussed in the workbook. |

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| Supervised projects | Guided task fulfillment: students apply the acquired knowledge to solve different problems autonomously. |
| Mixed objective/subjective test | Written test/exam to show that the students have acquired the Degree's competences trained in this course by answering theoretical questions and solving exercises. |

| Personalized attention | |
|---|---|
| **Methodologies** | **Description** |
| Laboratory practice<br>Supervised projects | Personalized attention is guaranteed during the development of the laboratory practices and supervised projects, being essential to guide students in the fulfillment of their tasks. This personalized attention is also useful to validate and evaluate the work carried out throughout the different development stages, until finished.<br><br>Furthermore, it is recommended for students to leverage the teacher's office hours as a complementary assistance tool. |

| Assessment | | | |
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| **Methodologies** | **Competencies / Results** | **Description** | **Qualification** |
| Mixed objective/subjective test | B4 B6 | Written test/exam to show that the students have acquired the Degree's competences trained in this course by answering theoretical questions and solving exercises. | 30 |
| Supervised projects | B3 B4 B6 B8 B9 | Guided task fulfillment: students apply the acquired knowledge to solve different problems autonomously. | 70 |

| Assessment comments |
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| All aspects related to "academic exemption", "study dedication",<br>"continuation", and "academic fraud" shall be governed by the current academic regulations of the UDC." |

| Sources of information | |
|---|---|
| **Basic** | [1] Computer Architecture: A Quantitative Approach (5th or 6th Ed.). John L. Hennessy, David A. Patterson. Morgan Kaufmann. ISBN 978-0123838728 (5th Ed. 2011) 978-0128119051 (6th Ed. 2017)[2] Performance Tuning of Scientific Applications. David H. Bailey, Robert F. Lucas, Samuel Williams. CRC Press. ISBN 978-1439815694[1] Computer Architecture: A Quantitative Approach (5th or 6th Ed.). John L. Hennessy, David A. Patterson. Morgan Kaufmann. ISBN 978-0123838728 (5th Ed. 2011) 978-0128119051 (6th Ed. 2017)[2] Performance Tuning of Scientific Applications. David H. Bailey, Robert F. Lucas, Samuel Williams. CRC Press. ISBN 978-1439815694 |
| **Complementary** | [3] Intel® C++ Compiler Developer Guide and Reference https://software.intel.com/cpp-compiler-developer-guide-and-reference[4] A Guide to Vectorization with Intel® C++ Compilers https://software.intel.com/sites/default/files/m/4/8/8/2/a/31848-CompilerAutovectorizationGuide.pdf[5] Intel® VTune? Amplifier Help https://software.intel.com/en-us/vtune-amplifier-help[6] Free Software Foundation, Inc.: Using the GNU Compiler Collection (GCC). https://gcc.gnu.org/onlinedocs |

| Recommendations |
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| **Subjects that it is recommended to have taken before** |
| Parallel Programming/614473102 |
| **Subjects that are recommended to be taken simultaneously** |
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| **Subjects that continue the syllabus** |
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| **Other comments** |

Because of the strong interrelation between the lectures and the lab sessions, and the progressive presentation of concepts very related each other in the lectures, it is recommended to dedicate enough time to a daily study or review.This course will leverage online communication tools in quite an intensive way: videoconference, e-mail, chat, etc.According to the various applicable regulations for university teaching, this course incorporates a gender perspective (non-sexist language, promoting the participation of male and female students in class...).Efforts will be made to identify and modify sexist, racist, or xenophobic prejudices and attitudes, and actions and measures will be proposed to correct them.