UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Course guide
205204 - HPCAE - High Performance Computing for Aerospace Engineering

Last modified: 11/04/2025

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN AEROSPACE VEHICLE ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Manel Soria
Miró Jané, Arnau

Others: Soria Guerrero, Manuel
Miró Jané, Arnau

PRIOR SKILLS

Good programming skills in C (preferably) or Fortran. Basic knowledge of interpreted languages such as Matlab or Python. Familiarity with Linux operating systems.

TEACHING METHODOLOGY

The course will be developed through theoretical lectures and hands-on sessions where the students will implement fragments of high performance computing codes for aerospace applications, and study the practical behaviour of new and classic parallel computers.

LEARNING OBJECTIVES OF THE SUBJECT

Understand the need of high performance computing for aerospace engineering applications.
Understand the different computer architectures currently in use for high performance computing.
Understand why only some algorithms can run in parallel.
Understand the different parallel programming models.
Acquire hands-on experience in parallel programming using OpenMP.
Acquire hands-on experience in parallel programming using MPI.
Acquire hands-on experience in parallel programming using CUDA/OpenACC.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	40.00
Self study	45,0	60.00

Total learning time: 75 h

CONTENTS

Module 1: Introduction to high performance computing for aerospace engineeering applications

Description:
* Motivations
* Limitations of the sequential processors
* Examples of problems in need of high performance computing
* Introduction to parallel computer architectures
* Shared and distributed memory models
* Introduction to Linux
* Review of C programming

Specific objectives:
The main goal of this module is to show the student what are the main limitations of serial computing and what are the main applications of parallel computing in the context of engineering. The student will develop a solid background in Linux and C programming.

Related activities:
Case study one: parallel algorithms for image processing
Case study two: genetic algorithms for optimization
Case study three: interplanetary trajectory analysis

Full-or-part-time: 25h
Theory classes: 10h
Self study : 15h

Module 2: HPC standards - OpenMP, MPI and OpenACC/CUDA

Description:
* Optimization of serial code, vectorization
* Description of the most prominent parallel standards: OpenMP and MPI
* Applications of parallel programming to engineering problems
* Analysis of parallel codes
* Novel parallelization methodologies: GPU programming

Specific objectives:
The goal of this module is to familiarize the student with the main parallel standards and give a broad overview of their capabilities. The aim is also to show the students the main challenges of parallel programming through real examples when possible.

Related activities:
* Seminar: GPU programming with OpenACC and CUDA
* Seminar: real HPC case study
* Visit to MareNostrum V facilities

Full-or-part-time: 25h
Theory classes: 10h
Self study : 15h

Module 3: Guided project

Description:
* The students will select a topic for their project in agreement with the professor.
* The professor will also propose feasible topics of projects for the students to develop.

Specific objectives:
The main goal of this module is to consolidate the topics exposed in the course through a student driven project.

Full-or-part-time: 25h
Theory classes: 10h
Self study : 15h

GRADING SYSTEM

Class participation: 30%
Exercises: 30%
Project: 40%

Students with a grade below 5.0 in any of the previous items will be able to take an additional written exam covering all the subject, which will take place the date fixed in the calendar of final exams. The grade obtained in this test will range between 0 and 10, and will replace that of the part or parts below 5.0 only in case it is higher, up to a maximum of 5.0 points.

BIBLIOGRAPHY

Basic:
- Chandrasekaran, Sunita; Juckeland, Guido. OpenACC for programmers: concepts and strategies. Boston: Addison-Wesley, 2018. ISBN 9780134694283.
- Nielsen, Frank. Introduction to HPC with MPI for data science. Cham; Heidelberg u.a: Springer, 2016. ISBN 9783319219028.
- Gropp, William [et al.]. Using advanced MPI: modern features of the Message-Passing Interface [on line]. Cambridge, Massachusetts: MIT Press, 2014 [Consultation: 28/05/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3339899. ISBN 9780262527637.
- Chandra, Rohit. Parallel programming in OpenMP [on line]. San Francisco, CA: Morgan Kaufmann, 2001 [Consultation: 28/05/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=296696. ISBN 9781558606715.