Course guide
270068 - PAP - Parallel Programming and Architectures

Last modified: 30/01/2024

Unit in charge: Barcelona School of Informatics
Teaching unit: 701 - DAC - Department of Computer Architecture.

Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: EDUARD AYGUADÉ PARRA

Others: Segon quadrimestre:
EDUARD AYGUADÉ PARRA - 10

PRIOR SKILLS

Defined by the pre-requisites for the course

REQUIREMENTS

- Prerequisite PAR

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEC2.1. To analyse, evaluate, select and configure hardware platforms for the development and execution of computer applications and services.
CEC2.2. To program taking into account the hardware architecture, using assembly language as well as high-level programming languages.
CT8.7. To control project versions and configurations.

Generical:
G8. APPROPIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.

TEACHING METHODOLOGY

The theory lessons introduce the knowledge, techniques, and concepts using examples of real code or pseudo-code. These lessons will be complemented with the realization of problems in the practical lessons. The laboratory sessions put into practice the theoretical contents, and evaluate the behavior and performance of the solutions proposed.

The course assumes that part of the theoretical contents, or laboratory statements, will have to be developed by the student independently.

The course is mainly focused on cluster architectures, using the C programming language, the Pthreads library and the OpenMP and MPI programming models.

LEARNING OBJECTIVES OF THE SUBJECT

1.Ability to write and understand parallel programs that make use of the low-level Pthreads interface.
2.Ability to implement the basic functionalities in a library supporting the execution of parallel applications on a shared-memory architecture.
3.Ability to understand the main components used to build a multiprocessor architecture, and design on paper a system that fulfill certain design restrictions.
4.Ability to write simple applications using the MPI programming model, evaluate their performance and identify the critical parts that limit scalability.
5.Ability to assess the quality of a proposed solution to a specific problem
6.Ability to autonomously complete or expand knowledge and to perform a specific job even though the statement is incomplete or information relevant to the implementation is missing

STUDY LOAD

Type	Hours	Percentage
Hours large group	15,0	10.00
Hours medium group	15,0	10.00
Guided activities	6,0	4.00
Self study	84,0	56.00
Hours small group	30,0	20.00

Total learning time: 150 h

CONTENTS

MPI: parallel programming for distributed-memory architectures

Description:
This topic will introduce how to program parallel applications using MPI, a programming model based on message passing for distributed-memory cluster architectures.

Parallel programming using Pthreads

Description:
Introduction to the basic functionalities that are offered by the Pthreads low-level support library

Implementation of a shared-memory programming model: threads and synchronization, work sharing and tasking model

Description:
This topic presents how to design and implement a library supporting the execution of parallel programs in OpenMP, in particular the aspects related with thread management and synchronization, work sharing in the OpenMP worksharing constructs and the tasking model.

Components and design of a cluster architecture

Description:
This topic will introduce the main components in a cluster architecture we the objective of doing a design with certain performance/power trade-offs and budget.

ACTIVITIES

Parallel programming with message passing: MPI

Specific objectives:
4, 5, 6

Related competencies :
G8. APPROPIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.

Full-or-part-time: 58h
Theory classes: 5h
Practical classes: 5h
Laboratory classes: 12h
Self study: 36h

POSIX threads (Pthreads)

Specific objectives:
1

Full-or-part-time: 20h
Theory classes: 3h
Practical classes: 3h
Laboratory classes: 2h
Self study: 12h

Implementation of a shared-memory programming model

Specific objectives:
1, 2, 5, 6

Related competencies :
G8. APPROPIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.

Full-or-part-time: 50h
Theory classes: 2h
Practical classes: 2h
Laboratory classes: 16h
Self study: 30h

Components and design of a cluster architecture

Specific objectives:
3, 6

Related competencies :
G8. APPROPIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.

Full-or-part-time: 20h
Theory classes: 3h
Practical classes: 5h
Self study: 12h

Final Exam

Specific objectives:
1, 2, 3, 4

Related competencies :
G8. APPROPIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.

Full-or-part-time: 2h
Guided activities: 2h

GRADING SYSTEM

The grade for the course is calculated from 3 grades:
- theoretical contents grade;
- laboratory grade;
- autonomy and motivation grade.

The theoretical contents grade (T) is obtained from the marks contained in the midterm (50%) and final exam (50%). The laboratory grade (L) is obtained from the marks of the laboratory deliverables and monitoring of the laboratory sessions by the professor.

The grade of autonomy and motivation (A) evaluates the ability of students to face situations of lack of information and their motivation to explore additional topics or go beyond what is initially assigned. It is obtained from the results of those laboratory experiments that require the exploration of extra material and/or performing optional/free parts.

The final grade is calculated F = T * 0.4 + L * 0.4 + A * 0.2.

BIBLIOGRAPHY

Basic:
- Grama, A.; Karypis, G.; Kumar, V.; Gupta, A. Introduction to parallel computing. 2nd ed. Pearson Education, 2003. ISBN 0201648652.

Complementary:
- Ayguadé, Eduard. Unit 1: POSIX Threads (Pthreads) programming. Departament d'Arquitectura de Computadors, 2021.
- Ayguadé, Eduard. Unit 2: Build (on paper) your own cluster architecture. Departament d'Arquitectura de Computadors, 2021.

- Ayguadé, Eduard. Unit 3: MPI (Message Passing Interface). Departament d'Arquitectura de Computadors, 2021.
- Ayguadé, Eduard. Laboratory assignments: Lab 1 - OpenMP parallelisation of Eratosthenes Sieve. Departament d'Arquitecture de Computadors, 2023.
- Ayguadé, Eduard. Laboratory assignments: Lab2 - Implementing a minimal OpenMP runtime. Departament d'Arquitectura de Computadors, 2021.
- Ayguadé, Eduard ; Àlvarez, Lluc. Laboratory assignments: Lab 3 - Performance characteritzation of HPC clusters. Departament d'Arquitectura de Computadors, 2023.
- Ayguadé, Eduard ; Àlvarez, Lluc. Laboratory assignments: Lab 4 - Heat equation using MPI. Departament d'Arquitectura de Computadors, 2023.

RESOURCES

Hyperlink:
- https://www.openmp.org/specifications/- https://computing.llnl.gov/tutorials/mpi/- https://computing.llnl.gov/tutorials/pthreads/