Course guide
270610 - ADS - Advanced Data Structures

Last modified: 02/02/2024

Unit in charge:	Barcelona School of Informatics
Teaching unit:	723 - CS - Department of Computer Science.

Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Optional subject).

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

LECTURER

Coordinating lecturer: AMALIA DUCH BROWN

Others: Segon quadrimestre:
AMALIA DUCH BROWN - 10
CONRADO MARTÍNEZ PARRA - 10
SALVADOR ROURA FERRET - 10

PRIOR SKILLS

Basic knowledge of the C++ programming language (or any other programming language).
Basic knowledge of algorithm analysis methods (in particular asymptotic complexity).
Basic knowledge of elementary data structures such as stacks, queues, linked lists, trees, and graphs as well as of sorting methods such as insertion sort, heap sort, merge sort, and quick sort.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEE3.1. Capability to identify computational barriers and to analyze the complexity of computational problems in different areas of science and technology as well as to represent high complexity problems in mathematical structures which can be treated effectively with algorithmic schemes.
CEE3.2. Capability to use a wide and varied spectrum of algorithmic resources to solve high difficulty algorithmic problems.

Generical:
CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.
CG3. Capacity for mathematical modeling, calculation and experimental designing in technology and companies engineering centers, particularly in research and innovation in all areas of Computer Science.

Transversal:
CTR4. INFORMATION LITERACY: Capability to manage the acquisition, structuring, analysis and visualization of data and information in the area of informatics engineering, and critically assess the results of this effort.
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.

Basic:
CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.
CB8. Capability to communicate their conclusions, and the knowledge and rationale underpinning these, to both skilled and unskilled public in a clear and unambiguous way.
CB9. Possession of the learning skills that enable the students to continue studying in a way that will be mainly self-directed or autonomous.

TEACHING METHODOLOGY

The lectures are theoretical/practical merged sessions.
The lecturer will allocate the hours in accordance with the subject matter.

The theory hours take the form of lectures in which the lecturer sets
out new concepts or techniques and examples illustrating them.
Sessions will consist of a presentation of the main topics of each content's item,
mainly based in selected original research papers.
A high level of students' participation is expected at each session.
Current lines of research in each topic will be discussed at the end of each topics' presentation.

The practical classes are used to explain implementations and show the performance
of selected data structures. Students are required to take an active part in the class by
discussing the various possible solutions/alternatives in class.

LEARNING OBJECTIVES OF THE SUBJECT

1.Become acquainted with the main and classic data structures of central areas of computer science and identify their major properties.
2.Become familiar with the mathematical tools usually used to analyze the performance of data structures.
3.Examine ideas, analysis and implementation details of data structures in order to assess their fitness to different classes of problems.
4.Select, design and implement appropriate data structures to solve given problems.

STUDY LOAD

Type	Hours	Percentage
Hours large group	42,0	28.00
Hours medium group	12,0	8.00
Self study	96,0	64.00

Total learning time: 150 h

CONTENTS

Preliminaries.

Description:
Review of required previous knowledge: asymptotic notation, basic algorithm analysis, arrays, linked lists, stacks and queues, basics of hashing, binary search trees, AVL trees, red-black trees, heaps.

Hashing.

Description:
Hashing: Universal Hashing (construction of hash functions), Cuckoo Hashing (collision resolution strategies), Applications (Bloom Filters).

Heaps.

Description:
Heaps: Binomial Heaps.

Self-adjusting data structures.

Description:
Self-adjusting data structures: List updates, Splay trees.

Randomized data structures.

Description:
Randomized data structures: randomized BSTs, treaps.

Multidimensional and metric data structures, searching in metric spaces, associative retrieval and object representation.

Description:
Multidimensional and metric data structures, searching in metric spaces, associative retrieval and object representation: grid files, kd trees, point quad trees, PR quad trees, octrees.

Geometric and kinetic data structures.

Description:
Geometric and kinetic data structures: interval, segment and partition trees, sweep lines.
Data structures for points in motion.

Strings.

Description:
Strings: tries, Patricia tries, suffix trees, suffix arrays, BW-transform, FM-index

External memory / cache oblivious.

Description:
External memory / cache oblivious: models, B-trees, ordered-file maintenance, van Emde-Boas layout.

Succinct Data Structures.

Description:
Succinct rank and select operations.

Miscellaneous.

Description:
Miscellaneous: concurrent, distributed, augmented, persistent data structures.

ACTIVITIES

Development of syllabus topics.

Description:
Development of syllabus topics.

Specific objectives:
1, 2, 3, 4

Related competencies :
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Full-or-part-time: 76h
Theory classes: 38h
Self study: 38h

Deliverables.

Description:
Deliverables.

Specific objectives:
1, 2, 3, 4

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Full-or-part-time: 10h
Self study: 10h

Final Work.

Description:
Presentation or deliberation of the Final Work (resulting from the Research Assignment).

Specific objectives:
1, 2, 3, 4

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Full-or-part-time: 12h
Guided activities: 2h
Self study: 10h

Summaries of classmates presentations.

Description:
Summaries of classmates presentations.

Specific objectives:
1, 2, 3, 4

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Full-or-part-time: 2h
Self study: 2h

Research Assignment.

Description:
Research Assignment.

Specific objectives:
1, 2, 3, 4

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CB9. Possession of the learning skills that enable the students to continue studying in a way that will be mainly self-directed or autonomous.
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Full-or-part-time: 17h
Guided activities: 2h
Self study: 15h

Reading of research papers.

Description:
Reading of research papers.

Specific objectives:
1, 2, 3

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Full-or-part-time: 21h
Practical classes: 6h
Self study: 15h

> **Case studies and problem solving.**
>
> **Description:**
> Case studies and problem solving.
>
> **Specific objectives:**
> 1, 2, 3, 4
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> **Related competencies :**
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> CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.
> CEE3.2. Capability to use a wide and varied spectrum of algorithmic resources to solve high difficulty algorithmic problems.
> CEE3.1. Capability to identify computational barriers and to analyze the complexity of computational problems in different areas of science and technology as well as to represent high complexity problems in mathematical structures which can be treated effectively with algorithmic schemes.
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>
> **Full-or-part-time:** 24h
> Practical classes: 6h
> Self study: 18h

GRADING SYSTEM

Grade = FW + H + S

FW = Final Work (graded from 0 to 6) in which each participant is required to develop a research paper (previously assigned/authorised by the coordinator).
The delivery of the final work consists of either an oral presentation or a written document containing concrete explanations of the paper's motivation, topic's background, overview of the key ideas,
brief description of the most important details, demo of a program that implements the ideas introduced therein.

S = Summaries and participation (graded from 0 to 1) in which each participant is required to deliver a summary (1 page extent) of each others presentation and to participate (with questions and comments).

H = 3 Homeworks (graded from 0 to 1, each) to freely choose among several possibilities proposed by the lecturer as the following (but not limited to):

*Notes of one topic in latex (well explained and completed).
*Read and resume one research paper.
*Implement and prove experimentally one of the studied data structures.
*Add to Wikipedia a data structure that isn't.

BIBLIOGRAPHY

Basic:

- Cormen, T.H. [et al.]. Introduction to algorithms. 4th ed. Cambridge: MIT Press, 2022. ISBN 9780262046305.
- Brass, P. Advanced data structures. Cambridge: Cambridge University Press, 2008. ISBN 9780511436079.
- Gusfield, D. Algorithms on strings, trees, and sequences: computer science and computational biology. First edition.. Cambridge [England] ; New York: Cambridge University Press, 1997. ISBN 0521585198.
- Samet, H. Foundations of multidimensional and metric data structures. Amsterdam: Elsevier : Morgan Kaufmann, 2006. ISBN 0123694469.