National University of Engineering (UNI)
School of Computer Science
Syllabus 2026-I

1. COURSE

CS312. Advanced Data Structures (Mandatory)

2. GENERAL INFORMATION

2.1 Course	:	CS312. Advanced Data Structures
2.2 Semester	:	6^{th} Semester.
2.3 Credits	:	4
2.4 Hours	:	2 HT; 4 HP;
2.5 Duration of the period	:	16 weeks
2.6 Type of course	:	Mandatory
2.7 Learning modality	:	Face to face
2.8 Prerrequisites	:	CS212. Analysis and Design of Algorithms. (5^{th} Sem)

3. PROFESSORS

Meetings after coordination with the professor

4. INTRODUCTION TO THE COURSE

Algorithms and data structures are a fundamental part of Computer Science that allow us to organize information efficiently. For any professional in the field, a solid foundation in this area is crucial. This course focuses on advanced structures such as Multidimensional Access Methods, Spatio-Temporal Access Methods, and Metric Access Methods, which are essential for high-performance applications in search engines, geographic information systems (GIS), and big data processing.

5. GOALS

- Understand, design, and implement innovative data structures for multidimensional data.
- Apply similarity search techniques and metric indexing to complex data types.
- Analyze the ”Curse of Dimensionality” and its impact on search efficiency.
- Research and present contemporary indexing methods for Big Data in English.

6. COMPETENCES

AG-C08) Problem Analysis: Identifies, formulates, and analyzes complex computing problems. (Usage)

AG-C12) Uses systemic approaches to select, develop, apply, integrate, and manage secure computing technologies to achieve user objectives. (Usage)

7. TOPICS

Unit 1: Programación Orientada a Objetos II: Encapsulación, Subtipado y Reflexión (12 hours)	
Competences Expected: AG-C08,AG-C12	
Topics	**Learning Outcomes**
• Static and dynamic implementation techniques. • Data abstraction and encapsulation. • Abstract Data Types (ADT). • Compile-time vs. Runtime polymorphism. • Generic data structures and C++ Templates. • Reusable components and design patterns for data structures.	• Evaluate the impact of static and dynamic techniques on data structure design [Evaluar]. • Implement generic and reusable data structures using advanced programming paradigms [Usar]. • Analyze performance trade-offs between different implementation strategies [Evaluar].
Readings : [Cua+04], [Knu97], [Gam+94], [VJG18]	

Unit 2: Multidimensional Access Methods (Part I) (8 hours)	
Competences Expected: AG-C08,AG-C12	
Topics	**Learning Outcomes**
• Introduction to multidimensional data. • Vector space representation. • The Curse of Dimensionality: theoretical foundations. • Impact of high dimensionality on traditional indexing. • Real-world applications in search engines and pattern recognition.	• Explain the significance of multidimensional data representation [Familiarizarse]. • Analyze the complexity and performance degradation in high-dimensional spaces [Usar]. • Discuss real-world scenarios where dimensionality impact is critical [Usar].
Readings : [GG98], [Sam06]	

Unit 3: Multidimensional Access Methods (Part II) (20 hours)	
Competences Expected: AG-C08,AG-C12	
Topics	**Learning Outcomes**
• Spatial data structures: Quadtree and Octree. • Point Access Methods: Kd-Tree. • Region Access Methods: R-Tree (Guttman), R+ tree, R* tree. • Variations of R-trees and their relation to paging and block size. • Advanced structures: X-tree and SS-tree.	• Implement spatial data structures for high-volume data indexing [Usar]. • Evaluate the limitations of tree-based spatial structures in specific domains [Evaluar]. • Implement range search and Nearest Neighbor (k-NN) strategies [Usar].
Readings : [Sam06]	

Unit 4: Metric Access Methods (12 hours)	
Competences Expected: AG-C08,AG-C12	
Topics	**Learning Outcomes**
• Metric Spaces: definitions and properties. • Similarity search vs. Exact search. • Vantage Point Tree (VP-Tree). • Slim-Tree and M-Tree. • Pivot-based indexing.	• Model similarity search problems using metric space properties [Usar]. • Compare metric access methods against multidimensional methods for non-vector data [Evaluar].
Readings : [Sam06], [Zez+07]	

Unit 5: Comunicación Técnica y Profesional (12 hours)	
Competences Expected: AG-C08,AG-C12	
Topics	**Learning Outcomes**
• Seminar on recent research papers (SIGMOD, VLDB, ICDE). • Indexing for Big Data and streaming data. • Compact data structures and succinct representations. • Future trends in similarity search.	• Research new methods for indexing large volumes of complex data [Usar]. • Present and lead technical discussions in English on state-of-the-art methods [Evaluar]. • Identify potential thesis topics within the advanced data structures domain [Familiarizarse].
Readings : [Nav16], [Tra+00]	

8. WORKPLAN

8.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

8.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

8.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

9. EVALUATION SYSTEM

********* EVALUATION MISSING ********

10. BASIC BIBLIOGRAPHY

[Gam+94] Erich Gamma et al. *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley Professional, 1994.

[Knu97] Donald E. Knuth. *The Art of Computer Programming, Volume 1: Fundamental Algorithms*. 3rd. Addison-Wesley Professional, 1997.

[GG98] Volker Gaede and Oliver Günther. "Multidimensional Access Methods". In: *ACM Computing Surveys* 30.2 (1998), pp. 170–231.

[Tra+00] C. Traina Jr et al. "Slim-Trees: High Performance Metric Trees Minimizing Overlap between Nodes". In: *Advances in Database Technology - EDBT 2000*. Springer, 2000.

[Cua+04] Ernesto Cuadros-Vargas et al. "Implementing data structures: An incremental approach". Available at: http://socios.spc.o 2004.

[Sam06] Hanan Samet. *Foundations of Multidimensional and Metric Data Structures*. Elsevier/Morgan Kaufmann, 2006.

[Zez+07] Pavel Zezula et al. *Similarity Search: The Metric Space Approach*. Springer, 2007.

[Nav16] Gonzalo Navarro. *Compact Data Structures*. Cambridge University Press, 2016.

[VJG18] David Vandevoorde, Nicolai M. Josuttis, and Doug Gregor. *C++ Templates: The Complete Guide*. Addison-Wesley Professional, 2018.