Program	Type of studies (cycle)	Third cycle
	Name of the program	Doctoral Studies in Mathematical and Computer Science

COURSE

Course title	**Advanced Topics in Computer Science**			
Course code	Semester	Course status	ECTS credits	Contact hours
CS 601	I	elective	10	30

Aims and intended learning outcomes	The aim of this course is to deepen theoretical, algorithmic, systems-level, and applied knowledge in computer science, focusing on areas essential to doctoral studies. As an advanced core course, it bridges knowledge gaps from previous studies in algorithms, computer systems, programming paradigms, databases, machine learning, computer vision, cybersecurity, and parallel computing. Upon completion, students will be able to explain key computer science concepts; analyze algorithmic complexity and program performance; relate computer architecture and parallelism to implementation efficiency; understand data management models; apply machine learning and computer vision techniques; address security and privacy challenges; and design and implement integrated technical solutions in advanced computer science.

Course content/topics

- **Advanced Algorithms, Data Structures, and Combinatorial Problems**: Complexity classes, NP-completeness, NP-hardness, approximation and randomized algorithms, advanced data structures, dynamic programming, and divide-and-conquer techniques.
- **Graph Algorithms, Optimization, and Computational Geometry**: Shortest paths, spanning trees, network flows, matchings, combinatorial optimization, triangulations, geometric searching, and covering problems.
- **Programming Languages, Paradigms, and Execution Models**: Imperative, object-oriented, generic, functional, and concurrent programming; data types, memory management, and program safety.
- **Computer Systems, Performance, and Parallel Computing**: Computer architecture, memory hierarchy, operating systems, processes, threads, synchronization, performance analysis, parallelism, vectorization, and GPU computing.
- **Distributed Systems, Cloud/Edge Computing, and Data Management**: Distributed models, scalability, reliability, cloud and edge computing, relational databases, SQL, transactions, NoSQL systems, and data processing pipelines.
- **Machine Learning, Deep Learning, and Computer Vision**: Supervised, unsupervised, and reinforcement learning; generalization, model evaluation, neural networks, deep learning, image processing, segmentation, object detection, CNNs, and vision transformers.
- **Trustworthy Artificial Intelligence, Security, and Scientific Computing**: Explainable AI, interpretability, robustness, uncertainty, bias, adversarial examples, cryptography, cybersecurity, privacy, numerical methods, simulations, and an integrative technical project.

LITERATURE

[1] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein: Introduction to Algorithms, 4th ed., MIT Press, 2022.
[2] Randal E. Bryant, David R. O'Hallaron: Computer Systems: A Programmer's Perspective, 3rd ed., Pearson, 2015.
[3] Abraham Silberschatz, Henry F. Korth, S. Sudarshan: Database System Concepts, 7th ed., McGraw-Hill, 2019.
[4] Stuart Russell, Peter Norvig: Artificial Intelligence: A Modern Approach, 4th ed., Pearson, 2020.
[5] Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.
[6] Richard Szeliski: Computer Vision: Algorithms and Applications, 2nd ed., Springer, 2022.
[7] William Stallings, Lawrie Brown: Computer Security: Principles and Practice, 5th ed., Pearson, 2024.
[8] Martin Kleppmann: Designing Data-Intensive Applications, O'Reilly Media, 2017.

Grading

	Criterion	Points	Cut-off points
1.	Assignments	30	17
2.	Project	30	17
3	Final exam	40	22
	T o t a l	100	55