

SYLLABUS

1. Data about the program of study

1.1 Institution	The Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Automation and Computer Science
1.3 Department	Computer Science
1.4 Field of study	Computer Science and Information Technology
1.5 Cycle of study	Master
1.6 Program of study / Qualification	Artificial Intelligence and Vision
1.7 Form of education	Full time

2. Data about the subject

2.1 Subject name	Introduction in Quantum Machine Learning			Subject code	5.00
2.2 Course responsible / lecturer	Dr. fiz. Zârbo Liviu - Liviu.Zarbo@itim-cj.ro				
2.3 Teachers in charge of seminars / Laboratory / project	Dr. fiz. Levente Mathe – levente.mathe@itim-cj.ro				
2.4 Year of study	I	2.5 Semester	1	2.6 Type of assessment (E - exam, C - colloquium, V – verification)	E
2.7 Subject category	Formative category: DA – advanced, DS – speciality, DC – complementary				DA
	Optionality: DI – imposed, DO – optional (alternative), DF – optional (free choice)				DI

3. Estimated total time

3.1 Number of hours per week	2	of which:	Course	1	Seminars	1	Laboratory	-	Project	-
3.2 Number of hours per semester	42	of which:	Course	28	Seminars	14	Laboratory	-	Project	-
3.3 Individual study:										
(a) Manual, lecture material and notes, bibliography										10
(b) Supplementary study in the library, online and in the field										10
(c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays										10
(d) Tutoring										0
(e) Exams and tests										3
(f) Other activities:										0
3.4 Total hours of individual study (suma (3.3(a)...3.3(f)))					72					
3.5 Total hours per semester (3.2+3.4)					100					
3.6 Number of credit points					4					

4. Pre-requisites (where appropriate)

4.1 Curriculum	Linear Algebra Mathematical Analysis Physics Programming
4.2 Competence	

5. Requirements (where appropriate)

5.1. For the course	
5.2. For the applications	

6. Specific competence

6.1 Professional competences	Basic knowledge of linear algebra and calculus, first year undergraduate student level Basic programming knowledge, first year undergraduate student level
6.2 Cross competences	

7. Expected Learning Outcomes

Knowledge	Qubits, quantum circuits, basic quantum algorithms, quantum machine learning algorithms
Skills	Implementing a quantum algorithm on a quantum platform (e.g. Uranium); Being able to utilize frameworks (e.g. Qiskit) for implementing quantum algorithms.
Responsibilities and autonomy	

8. Discipline objective (as results from the *key competences gained*)

8.1 General objective	Developing general knowledge relevant to applications in the field of quantum computation and quantum machine learning
8.2 Specific objectives	1. Assimilating the basics of quantum computation: qubits, quantum gates, quantum circuits, quantum algorithms 2. Developing the basic skills for developing quantum algorithms 3. Understanding the basics of quantum machine learning.

9. Contents

9.1 Lectures	Hours	Teaching methods	Notes
1. Introductory notions. - From classical to quantum computing - The dual behavior of the quantum objects - Tunneling - Double slit experiment	2	Blackboard, video-lectures, discussions of examples, problem solving	
2. Quantum states - Notations - Probabilities - Matrix and vector representation of quantum states - Qubits - Pure states and mixed states	2		

3. Observables and quantum measurement 1	2		
• Observables and operators • The Heisenberg principle • Projective measurements • The Stern-Gerlach experiment			
4. Observables and quantum measurement 2	2		
• Quantum state vectors. • Observables and operators, the density matrix. • Probabilities and expectation values. • Partial measurements			
5. Qubits	2		
• The two-level system and real life examples • Quantum gates • Superpositions and entanglement of qubits • The Bloch sphere.			
6. Quantum measurement and applications 1.	2		
• The no-cloning theorem • Quantum teleportation • Quantum sensing • Quantum tomography			
7. Quantum measurement and applications 2.	2		
• Quantum random number generation • Quantum communication protocols (BB84). • Quantum cryptography notions • Quantum communication networks.			
8. Quantum circuits and algorithms	2		
• Quantum circuits • Density matrices, noise • Entanglement • Computational complexity.			
9. Quantum algorithms 1.	2		
• Deutsch-Josza algorithm. • Grover algorithm			
10. Quantum algorithms 2.	2		
• Quantum Fourier transform • RSA and Shor's algorithm			
11. QML 1	2		
• Encoding classical data into quantum states • Parametrized quantum circuits • Hybrid models			
12. QML2	2		
• Variational quantum algorithms • Quantum kernel methods			
13. QML3	2		
• HHL, QGAN algorithms			
14 Applications & outlook	2		
• Current hardware limits • Where QML might realistically help			
Bibliography: • Nielsen and Chuang, Quantum Computation and Quantum Information, Cambridge University Press (2010). • David McIntyre, Quantum Mechanics: A Paradigms Approach, Pearson Addison-Wesley (2012). • Cohen-Tannoudji, Quantum Mechanics, Wiley-VCH; 2nd edition (2019). • Maria Schuld & Francesco Petruccione, Machine Learning with Quantum Computers (Springer, 2021, 2nd ed.)			
9.2 Applications - Seminars/Laboratory/Project	Hours	Teaching methods	Notes

1. Visualising qubit operations: Bloch sphere, single qubit gates, destructive and constructive interference (Quantum Odyssey)	2	Lab work in INCDTIM Quantum Software lab, using tools such as Uranium, Quantum Odyssey, Google Colab.	
2. Quantum circuits in Uranium/Qiskit	2		
3. Generating entanglement in quantum circuits (quantum gates: CNOT, SWAP, Toffoli). Visualisation in Q. Odyssey, circuits on the Uranium platform.	2		
4. Deutsch algorithm/Grover algorithm	2		
5. Quantum Fourier Transform	2		
6. Variational algorithms	2		
7. HHL algorithm	2		
Bibliography			
• Nielsen and Chuang, Quantum Computation and Quantum Information, Cambridge University Press (2010). • David McIntyre, Quantum Mechanics: A Paradigms Approach, Pearson Addison-Wesley (2012). • Cohen-Tannoudji, Quantum Mechanics, Wiley-VCH; 2nd edition (2019). • Maria Schuld & Francesco Petruccione, Machine Learning with Quantum Computers (Springer, 2021, 2nd ed.)			

**Se vor preciza, după caz: tematica seminariilor, lucrările de laborator, tematica și etapele proiectului.*

9. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field

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10. Evaluation

Activity type	Assessment criteria	Assessment methods	Weight in the final grade
Course	Solving 2 problems + 1 theory set of questions	Written exam	60%
Seminar			
Laboratory	-	Periodic lab quizzes	40%
Project	-	-	-
Minimum standard of performance:			

Date of filling in: 01.09.2025	Responsible	Title First name Last name	Signature
	Course	Dr. Liviu Zarbo	
	Applications	Levente Mathe	

Date of approval in the department 17.09.2025	Head of department, Prof.dr.eng. Rodica Potolea
Date of approval in the Faculty Council 19.09.2025	Dean, Prof.dr.eng. Vlad Mureșan