

SYLLABUS

1. Information on the study programme

1.1. Higher education institution	Universitatea de Vest din Timisoara				
1.2. Faculty	Matematică și Informatică				
1.3. Department	Informatică				
1.4. Study program field	Informatică				
1.5. Study cycle	master				
1.6. Study programme / Qualification	Artificial Intelligence and Distributed Computing				

2. Information on the course

2.1. Course title	Dynamical Systems in Machine Learning / Sisteme dinamice în învățarea automată				
2.2. Lecture instructor	Prof.dr. Eva Kaslik				
2.3. Seminar / laboratory instructor	Prof.dr. Eva Kaslik				
2.4. Study year	1	2.5. Semester	1	2.6. Examination type	E
				2.7. Course type (Mandatory/Elective)	Elective

3. Estimated study time (number of hours per semester)

3.1. Attendance hours per week	3	out of which: 3.2 lecture	2	3.3. seminar / laboratory	1
3.4. Attendance hours per semester	42	out of which: 3.5 lecture	28	3.6. seminar / laboratory	14
Distribution of the allocated amount of time*					
Study of literature, course handbook and personal notes					35
Supplementary documentation at library or using electronic repositories					8
Preparing for laboratories, homework, reports etc.					26
Exams					6
Tutoring					8
Other activities...					
3.7. Total number of hours of individual study	83				
3.8. Total number of hours per semester	125				
3.9. Number of credits (ECTS)	5				

4. Prerequisites (if it is the case)

4.1. curriculum	Calculus, Linear Algebra and Probability Theory / Calcul diferențial și integral, Algebră liniară și Teoria Probabilităților
4.2. competences	programming skills/ abilități de programare

5. Requirements (if it is the case)

5.1. for the lecture	Google Classroom and an online conferencing platform such as Google Meet / Teams / Webex Lecture hall with overhead projector / sală de curs cu videoproiector
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5.2. for the seminar / laboratory	Google Classroom and an online conferencing platform such as Google Meet / Teams / Webex Computer lab/ Sală de laborator cu calculatoare
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6. Specific acquired competences

Professional competences	<ul style="list-style-type: none"> Advanced knowledge of theoretical, methodological, and practical developments in computer science; / Cunoștințe avansate de natură teoretică, metodologică și practică în informatică Demonstrate advanced modeling skills for specific phenomena and processes by using fundamental mathematical, statistical, and computer science knowledge;/ Demonstrarea unor abilități avansate de modelare a unor fenomene și procese specific utilizând cunoștințe matematice, statistice și informaticce
Transversal competences	<ul style="list-style-type: none"> Ability to communicate knowledge within different professional environments on the description of algorithms specific to the various fields of activity/ Abilitatea de a comunica cunoștințe în medii profesionale și de a descrie algoritmi specifici diferitelor domenii de activitate Team work abilities, assuming different execution and leading roles, performing professional tasks with considerable amounts of autonomy and responsibility/ Abilități de lucru în echipă, asumarea rolurilor de execuție și coordonare, îndeplinirea sarcinilor profesionale în condiții de autonomie și responsabilitate

7. Course objectives

7.1. General objective	Familiarization with the basics of Dynamical Systems Theory with the aim understanding diverse concepts and tools related to Machine Learning / Familiarizarea cu concept de bază din teoria sistemelor dinamice cu scopul înțelegerei diferitelor concepte și instrumente correlate cu învățarea automată
7.2. Specific objectives	Providing specific knowledge related to Markov processes, Recurrent Neural Networks, Restricted Boltzmann Machines and Kaufman Boolean networks/ Furnizarea de cunoștințe specific correlate cu procese Markov, rețele neuronale recurente, mașini Boltzmann restrictionate și rețele booleene Kaufman

8. Content

8.1. Lecture	Teaching methods	Remarks, details
L.1-2 (4h). : Introduction to Dynamical Systems and Machine Learning. Fundamental concepts: state, trajectory, phase space, attractors. Relationship between differential equations and machine learning paradigms	Lecturing, conversation, demonstration/ prelegere, conversație, demonstrare	Each lecture is correlated with the corresponding lab/seminar for the achievement of established objectives/ Fiecare curs este corelat cu laboratorul corespunzător cu scopul de a atinge obiectivele enunțate

L.3-4 (4h). Basics of Nonlinear Dynamical Systems. Introduction to nonlinear systems and their behaviours. Equilibrium points and stability analysis. Limit cycles, bifurcations, and chaos. Nonlinear system identification and modelling in machine learning contexts.	Lecturing, conversation, demonstration	
L.5-6 (4h) Continuous-Time Dynamical Systems in Machine Learning. Ordinary Differential Equations (ODEs) and their solutions. Numerical methods for solving ODEs (Euler, Runge-Kutta). Neural ODEs and their applications in continuous-time modelling.	Lecturing, conversation, demonstration	
L.7-8 (4h) Discrete-Time Dynamical Systems and Recurrent Neural Networks (RNNs). Introduction to discrete-time dynamical systems (maps). Stability analysis of discrete-time systems. Recurrent Neural Networks (RNNs) as discrete-time dynamical systems. Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) networks.	Lecturing, conversation, demonstration	
L. 9-10 (4h) Control Theory and Reinforcement Learning. Introduction to control theory concepts: controllability, observability. Dynamic programming and optimal control. • Model Predictive Control and its applications in machine learning. Reinforcement learning as a dynamical system optimization problem.	Lecturing, conversation, demonstration	
L. 11-12 (4h) Chaotic Dynamical Systems and Applications. Chaotic behaviour in dynamical systems and its implications. Chaotic attractors and their properties. Applications of chaos	Lecturing, conversation, demonstration	

theory in machine learning: secure communications, random number generation.		
L. 13-14. (4h) Review. Project presentations. Additional topics.	Lecturing, conversation, demonstration	

Recommended literature

- [1] ELAYDI, S. *An introduction to difference equations*. Springer Science & Business Media, 2005.
- [2] CULL, P.I.; FLAHIVE, M.; ROBSON, R. *Difference equations: from rabbits to chaos*. Springer, 2005.
- [3] MURPHY, K. P., Machine learning: A probabilistic perspective. MIT Press, 2012
- [4] DEVANEY, R. L. *An Introduction to Chaotic Dynamical Systems*, Westview Press, 2003.
- [5] GROS, C. *Complex and Adaptive Dynamical systems*. Springer, 2008.
- [6] BRUNTON, S., KUTZ, J.L. *Data-Driven Science and Engineering Machine Learning, Dynamical Systems, and Control* (2nd ed.), Cambridge University Press, 2021.

8.2. Seminar / laboratory	Teaching methods	Remarks, details
Labs 1-7 follow closely the topics discussed at the lectures. / Lab 1-7 în corelare cu tematica studiată la curs	Dialogue with students, cooperative learning, modeling, case studies/ Dialog, învățare cooperativă, modelare, studii de caz	For each lab, the students must read and be familiar with the materials presented in the corresponding lectures. / Pentru fiecare lab studenții trebuie să studieze materialele de la cursurile corespunzătoare și să fie familiarizați cu concepțele utilizate.

Recommended literature
The same as for the lectures. / Similar cu bibliografia de la curs

9. Correlations between the content of the course and the requirements of the professional field and relevant employers.

The course is consistent with similar ones from representative universities and covers the most important aspects regarding the theory of dynamical systems and their applications to machine learning./ Cursul este în acord cu cele similar predate la universități representative și acoperă cele mai importante aspect ale teoriei sistemelor dinamice și ale aplicării lor în învățarea automată.

10. Evaluation

Activity	10.1. Assessment criteria	10.2. Assessment methods	10.3. Weight in the final mark
10.4. Lecture	Knowledge of theoretical concepts Knowledge of specific methods and algorithms and use of suitable techniques to solve a practical problem / Cunoașterea conceptelor teoretice și a metodelor și algoritmilor specific precum și utilizarea tehnicilor adecvate în rezolvarea problemelor practice	Homework assessment / Temă de casă	20%
		Final project presentation / Prezentare proiect final	60%
10.5. Seminar / laboratory		Lab activity during the semester (oral evaluation)/ Activitate de laborator pe	20%

		parcursul semestrului (evaluare orală)	
10.6. Minimum needed performance for passing			
Minimal standards (for grade 5):			
<ul style="list-style-type: none"> ● Knowledge of basic concepts from Dynamical Systems theory as proved by the oral presentation of the final project; / Cunoașterea conceptelor de bază din teoria sistemelor dinamice - ilustrată prin prezentarea orală a proiectului ● 50% of homeworks are handed in correctly./ 50% din teme rezolvate corect <p>The final grade is the weighted average of grades obtained for components 10.4 and 10.5. The exam is passed if the final grade is at least 5 (it is not necessary for each grade to be greater than 5). For every exam session, the grade is computed by the same rule. / Nota finală este media notelor componentelor de la 10.4 și 10.5. Examenul e promovat daca media e cel puțin 5 (nu e necesar ca fiecare notă să fie cel puțin 5). Regula e valabilă pentru fiecare sesiune de examene.</p> <p>During the semester, students may attend tutoring hours, during which the teacher answers their questions and provides supplementary explanations regarding the lecture, lab applications and homework./ Pe parcursul semestrului studenții pot participa la orele de tutoriat, pe parcursul cărora cadrul didactic răspunde la întrebări și furnizează explicații suplimentare.</p>			

Date of completion
15.09.2023

Signature (lecture instructor)
Prof. Dr. Eva Kaslik

Signature (seminar instructor)
Prof. Dr. Eva Kaslik

Date of approval

Signature (director of the department)