SYLLABUS

1. Data about the program of study

1.1 Institution	Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Electronics, Telecommunications and Information Technology
1.3 Department	Communications
1.4 Field of study	Electronic Engineering, Telecommunications and Information Technologies
1.5 Cycle of study	Master of Science
1.6 Program of study / Qualification	Telecommunications / Master Multimedia Technologies / Master Artificial Intelligence and Signal Processing in Electronics and Telecommunications / Master
1.7 Form of education	Full time
1.8 Subject code	TC-E11.20

2. Data about the subject

2.1 Subject name	Machine Learning Applications for Wireless Communications						
2.2 Subject area	Theoretical area Methodological area Analytic area						
2.3 Course responsible	Professor Emanuel PUSCHITA – Emanuel.Puschita@com.utcluj.ro						
2.4 Teacher in charge with seminar / laboratory / project	Professor Emanuel PUSCHITA – Emanuel.Puschita@com.utcluj.ro						
2.5 Year of study	1	2.6 Semester	2	2.7 Assessment	E	2.8 Subject category	DA/DO

3. Estimated total time

3.1 Number of hours per week	4	of which: 3.2 course	2	3.3 laboratory	1
3.4 To Total hours in the curriculum	42	of which: 3.5 course	28	3.6 laboratory	14
Distribution of time					hours
Manual, lecture material and notes, bibliography					20
Supplementary study in the library, online specialized platforms and in the field					12
Preparation for seminars / laboratories, homework, reports, portfolios and essays					20
Tutoring					3
Exams and tests					3
Other activities:					

3.7 Total hours of individual study	58
3.8 Total hours per semester	100
3.9 Number of credit points	4

4. Pre-requisites (where appropriate)

4.1 curriculum	Cellular Radiocommunications, Communication systems
4.2 competence	N. A.

5. Requirements (where appropriate)

5.1. for the course	Amphitheatre, Cluj-Napoca
5.2. for the seminars / laboratories / projects	Laboratory, Cluj-Napoca

6. Specific competences

Professional competences	**C4. Conception, implementation and operation of data, voice, video, multimedia services, based on the understanding and application of fundamental notions in the field of communications and information transmission.** C4.3 Explanation and interpretation of the main requirements and specific approach techniques for data, voice, video, multimedia transmissions. **C5. Selection, installation, configuration and operation of fixed or mobile telecommunications equipment and equipping a site with the usual telecommunications networks.** C5.2 Explanation and interpretation of fundamental technologies and protocols for integrated fixed and mobile communication systems. **C6. Solving specific problems for broadband communication networks: propagation in different transmission media, circuits and equipment for high frequencies (microwave and optical).** C6.3 Solving practical problems using microwave circuit design methods, planning, coverage, selection and placement of transmission and reception equipment. **C7. Understanding the principles and techniques of machine learning, deep learning, optimization** C7.1 Design, implementation, testing and exploitation of neural networks. C7.2 Design, implementation, testing and exploitation of deep neural networks. C7.3 Design, implementation, testing and exploitation of convolutional neural networks. C7.4 Use of Matlab, Python environments for application development.
Cross competences	N.A.

7. Discipline objectives (as results from the key competences gained)

7.1 General objective	The development of professional skills in the field of wireless communication applications assisted by machine learning techniques.
7.2 Specific objectives	1. Application of theoretical concepts of wireless networks, use of professional software tools for design, testing and measurements (Matlab, QualNet, LabView). 2. Developing skills and competencies for planning, implementing, testing and evaluating wireless systems.

8. Contents

8.1 Lecture (syllabus)	Teaching methods	Notes
1. Introductory course on Machine Learning (ML)	The discipline content and the acquired skills agree with the expectations of the professional	Use of .ppt presentations, video projector, blackboard.
2. Supervised learning. k-Nearest neighbors' method. Decision tree. Perceptron		
3. Unsupervised learning. k-Means. Density-based spatial clustering of applications with noise. Clustering by fast search and find of density peaks. Relative core merge clustering algorithm. Gaussian mixture models and EM algorithm. Principal component analysis. Autoencoders		
4. Reinforcement learning. Markov decision process. Model-based methods. Model-free methods. Deep reinforcement learning		
5. Machine-learning-enabled channel modeling and estimation		
6. Channel prediction based on machine-learning algorithms		
7. Machine and Reinforcement Learning for Resource Allocation in Cognitive Radio Networks.		
8. Channel State Information Prediction for 5G Wireless Communications.		
9. Machine Learning–Based Coverage and Capacity Optimization.		
10. Machine Learning for Spectrum Access and Sharing.		
11. Machine Learning–Based Adaptive Modulation and Coding (AMC) Design.		
12. Signal identification in cognitive radios using machine learning.		
13. Signal and modulation classification based on ML techniques.		
14. ML based MIMO Communications		

1. Fa-Long Luo (Editor), Machine Learning for Future Wireless Communications, Wiley-IEEE Press, 2020, ISBN: 978-1-119-56225-2.
2. Yonina C. Eldar et al., Machine Learning and Wireless Communications, Cambridge University Press & Assessment, 2022, ISBN: 9781108832984
3. E.S. Gopi, Machine Learning, Deep Learning and Computational Intelligence for Wireless Communication, Springer Verlag, Singapore, 2021, ISBN: 9811602883.
4. Ruisi He, Zhiguo Ding, Applications of Machine Learning in Wireless Communications, The Institution of Engineering and Technology, 2019, ISBN 978-1-78561-657-0 (hardback).
5. V. K. Garg, Wireless communications and networking, Elsevier, 1st ed., ISBN: 978-0-12-373580-5, 2007.
6. Randy L. Haupt, Wireless Communications Systems: An Introduction, Wiley-IEEE Press, ISBN: 9781119419174, 2020.
7. Mishra, Ajay R., Fundamentals of network planning and optimisation 2G/3G/4G: evolution to 5G, ISBN: 9781119331704, Wiley, 2018.

<table>
<tr><td colspan="3">8. K. K. Singh, A. Singh, K. Cengiz, Dac-Nhuong Le, “Machine Learning and Cognitive Computing for Mobile Communications and Wireless Networks”, Wiley 2020</td></tr>
<tr><td>8.2 Laboratory</td><td>Teaching methods</td><td>Notes</td></tr>
<tr><td>1. Supervised learning. k-Means Clustering. Gaussian Mixture Models. Interpreting the Clusters</td><td rowspan="7">Didactic and experimental demonstrations, didactic exercises, simulations, teamwork.</td><td rowspan="7">Use of laboratory instrumentation, radio network simulators, computers</td></tr>
<tr><td>2. Classification methods. Nearest Neighbor Classification Classification Trees, Naive Bayes Classification, Discriminant Analysis, Support Vector Machines, Classification with Neural Networks.</td></tr>
<tr><td>3. Autoencoders for Wireless Communications.</td></tr>
<tr><td>4. Creating and training neural networks.</td></tr>
<tr><td>5. Modulation classification using ML.</td></tr>
<tr><td>6. Spectrum Sensing with Deep Learning to Identify 5G and LTE Signals.</td></tr>
<tr><td>7. ML Data Synthesis for 5G Channel Estimation.</td></tr>
<tr><td colspan="3">Bibliography
1. Ruisi He, Zhiguo Ding, Applications of Machine Learning in Wireless Communications, The Institution of Engineering and Technology, ISBN 978-1-78561-657-0 (hardback), 2019.
2. F. Perez Fontan, P. Marino Espineira, Modelling the Wireless Propagation Channel: A simulation approach with MATLAB, John Wiley & Sons Ltd, ISBN 978-0-470-72785-0, 2008.
3. V. K. Garg, Wireless communications and networking, Elsevier, 1st ed., ISBN: 978-0-12-373580-5, 2007.
Online references
4. ***, Deep Learning Onramp, Mathworks.com, https://matlabacademy.mathworks.com/details/deep-learning-onramp/deeplearning
5. ***, Machine Learning Onramp, Mathworks.com , https://matlabacademy.mathworks.com/details/machine-learning-with-matlab/mlml
6. ***, Spectrum Sensing with Deep Learning to Identify 5G and LTE Signals, Mathworks.com, https://www.mathworks.com/help/comm/ug/spectrum-sensing-with-deep-learning-to-identify-5g-and-lte-signals.html
7. ***, Autoencoders for Wireless Communications, Mathworks.com, https://www.mathworks.com/help/comm/ug/autoencoders-for-wireless-communications.html
8. ***, Modulation Classification with Deep Learning, Mathworks.com, https://www.mathworks.com/help/comm/ug/modulation-classification-with-deep-learning.html</td></tr>
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9. Bridging course contents with the expectations of the representatives of the community, professional associations, and employers in the field

The discipline content and the acquired skills are in agreement with the expectations of the professional Competences acquired will be used in the following COR occupations (Electronics Engineer; Telecommunications Engineer; Electronics Design Engineer; System and Computer Design Engineer; Communications Design Engineer) or in the new occupations proposed to be included in COR (Sale Support Engineer; Multimedia Applications Developer; Network Engineer; Communications Systems Test Engineer; Project Manager; Traffic Engineer; Communications Systems Consultant).

10. Evaluation

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Course	The level of acquired theoretical knowledge and practical skills	Written exam	50%
10.5 Seminar/ Laboratory	The level of acquired knowledge and abilities	Final test at the end of laboratory sessions	50%
10.6 Minimum standard of performance			

Qualitative point of view

Minimal theoretical and practical knowledge:

- ✓ To know fundamental concepts related to supervised, unsupervised learning, respectively learning by reward.
- ✓ To know radio channel modeling techniques and to estimate its parameters with the help of ML algorithms
- ✓ To know techniques for optimizing the capacity of radio networks with the help of ML algorithms.
- ✓ To know techniques for classifying radio signals and modulations using ML algorithms.
- ✓ To know ML techniques for resource allocation in cognitive radio networks.
- ✓ To know ML techniques for coding and adaptive modulations.

Minimal acquired competences:

- ✓ Knowledge of fundamental concepts related to computational intelligence / deep learning, supervised and unsupervised training,
- ✓ Knowledge of the radio cell concept, cell geometry and division, co-channel, and adjacent channel interference reduction techniques.
- ✓ Knowledge of spectral efficiency indicators and cellular traffic estimation models.
- ✓ Knowledge of the propagation mechanisms and the behavior of the radio channel in environments with mobility;
- ✓ Knowledge of indoor and outdoor propagation models, fading models;
- ✓ Knowing and creating minimal applications in the field of wireless communications using ML techniques.

Quantitative point of view

- ✓ Minimal mean at the exam 5
- ✓ Final mark = 0.5 x Exam + 0.5 x Mean of the marks at the lab tests

Date of filling in:	**Responsible**	**Title First name SURNAME**	**Signature**
19.06.2024	Course	Professor Emanuel PUSCHITA, Ph.D.	
	Applications	Professor Emanuel PUSCHITA, Ph.D.	

Date of approval in the Council of the Communications Department 10.07.2024	Head of Communications Department Prof. Virgil DOBROTA, Ph.D.
Date of approval in the Council of the Faculty of Electronics, Telecommunications and Information Technology 11.07.2024	Dean Prof. Ovidiu POP, Ph.D.