National PhD in Artificial Intelligence – Health and Life Sciences area
Training activities - year 2025

	Title	Number of hours	Institution	Location	Attendance mode	Lecturer(s)	Academic year(s)	Semester	Timetable	Abstract
1	Mathematics, Deep Learning and Deep Reinforcement Learning	30	Università di Chieti-Pescara	Dipartimento di matematica, Firenze	Ibrido	Maurizio Parton	2023/2024, 2024/2025	2	Every Tuesday and Friday, 5h per day, 11:00-13:00 and 15:00-18:00. First lecture on Tuesday, January 14, and last lecture on Friday, January 31.	The last few years have seen impressive accomplishments of artificial intelligence. Without a doubt, Deep Learning DL and Deep Reinforcement Learning DRL are the techniques that contributed most to these successes. Despite the extremely diverse areas involved (image recognition, games, biology, natural language processing, to name a few), we are still a long way from truly understanding the mathematics behind DL and DRL. Along with its theoretical interest, this would further increase their performance and fields of application. This course is addressed to mathematicians who aim to understand the relationship between DL/DRL and mathematics, in both directions. How can mathematicians contribute to the mathematical foundations of DL/DRL? How can DL/DRL be used by mathematicians in their everyday research field? After introducing DRL and DL in the first part of the course, we will provide (very partial) answers to the above questions by introducing some of the recent topics that in my opinion enlight this beautiful link between DL/DRL and mathematics, see bibliography. I will do my best to make this course accessible to the average mathematician. In particular, 2/3 of the course will be devoted to fundamentals of DRL and DL, so that no prior knowledge of DL or DRL is required. A basic knowledge in probability, algebraic geometry, differential geometry and/or Python could be helpful, but is not essential.
4	AI in Computer-aided drug design	15	SCITEC-CNR	Online or CNR p.le A. Moro, Roma	Online and in presence	Maria Cristina De Rosa, Davide Pirolli, Benedetta Righino	2024/2025	1	The course will be held in 2/3 weeks between March and July 2025; definitive dates will be delivered to enrolled students.	Drug discovery is an expensive and time-consuming process that is often assisted by computational methods to speed up and guide the design of new compounds. In the last decade, many studies have applied artificial intelligence in computer-aided drug design to obtain more accurate models and accelerate the design process. This course provides an overview of implementation of machine learning and deep learning algorithms in several drug discovery processes such as prediction of the target protein structure, structure-based and ligand-based drug design, evaluation of drug toxicity and physiochemical properties, quantitative structure–activity relationship. Specific case studies, related to applications of AI in drug development, will be discussed and used to ease the comprehension of the course arguments.
5	Multi-scale Applications of Mathematics to Medicine	15	UNIGE	online and in presence	online and in presence	Michele Piana, Anna Maria Massone, Sara Garbarino	2024/2025	2	First week of July, definitive dates will be delivered to enrolled students.	The course will discuss data simulation and processing methods for three biomedicine problems characterized by three different scales. At a cellular scale, we will describe a signalling network model for colon-rectal cancer and illustrates both formal and computational methods for its reduction. At a tissue scale, we will discuss parametric imaging approaches for the interpretation of nuclear medicine data. At an organ scale, we will describe some pattern recognition approaches for the extraction of radiomics features from both morphological and funcional images. The methodological topics will include inverse problems theory, dynamical systems, and artificial intelligence.
6	Behavioural biometrics for healthcare, security and related fields	15	Università degli studi di Bari Aldo Moro Campus Universitario	DIB Bari - online	online	Donato Impedovo, Vincenzo Dentamaro	2024/2025	2	April 14, h14-17; April 16, h09-12; April 17, h09-12; April 18, h09-12; April 30, h09-12	Behavioural biometrics for healthcare seek solutions to discover, classify, monitor, recognize diseases that are measurable only when the patient performs an action. This action could be walk, talk, write, type on the touchscreen and many more. Behavioral biometrics are, thus, interested in non directly measurable physical properties, but patterns that are recognized only when the patient performs a particular behavior. In general, it is the way the human being responses to natural events around him/her. In this course PhD students will learn shallow learning and deep learning techniques for recognizing pathological conditions using handwriting, gait analysis, speech analysis and many more.
10	Introduction to Neuromorphic Computing	12	Universita degli Studi di Roma Tor Vergata	online	online and in presence	Andrea Duggento	2021/2022, 2022/2023, 2023/2024, 2024/2025	2	Monday 10/03/2025, 8:00-10:00. Tuesday 11/03/2025 8:00-10:30. Thursday 13/03/2025, 8:00-10:30. Monday 17/03/2025, 8:00-10:30. Tuesday 18/03/2025, 8:00-10:30.	The mammalian brain is a very sophisticated, highly efficient biocomputer from which technology has begun to draw inspiration for developing artificial neural networks. However, this biology-to-technology translation is still in its infancy. Spiking neural networks based on neuromorphic architectures are emerging as a more biologically-inspired artificial minds which will likely underlie next-generation AI paradigms. This course will explore the biological – in silico correspondence at all levels, introducing key concepts of neuronal membrane potential dynamics, neuroanatomy and chemical neuromodulation, neural tissue energy demands, theory of evolution and principles of cognition. For each topic, its state-of-the-art neuromorphic engineering application counterpart will be presented. All major aspects of spiking neural network applications will be introduced, from training strategies (including principles of reinforcement learning, synaptic plasticity and multi-agent evolutionary artificial neural networks) to software and hardware implementation, e.g. including CMOS neuromorphic chips and memristor-based neuromorphic computers.
11	AI in medical image analysis	40	Istituto Nazionale di Fisica Nucleare	Sapienza Università di Roma and online	online and in presence	S. Giagu, C. Voena, A. Lonardo, F. Giove, A. Retico	2022/2023, 2023/2024, 2024/2025	2	May, 2, h14-17 May, 9 , h14-17 May, 16, h14-17 May, 23, h14-17 May, 30, h14-17, June 6 h14-17, March 3 h16-18, March 8 h16-18, March 12 h16-18, Macrh 15 h16-18, March 18 h10-12, March 20 h16-18, March 25 h10-12, April 8 h10-12, April 10 h10-12, April 15 h16-18, April 16 h16-18, April 22 h10-12, April 24 h10-12, April 29 h10-12, April 29 h16-18, April 30 h16-18, May 6 h14-16, May 13 h14-16, May 20 h14-16, May 27 h14-16	Medical digital images (Computed Tomography, Magnetic Resonance Imaging. etc.) play a key role in personalized therapy management, and are used in the diagnosis, treatment planning and monitoring of the disease and AI-driven solutions are emerging world-wide as a support in the clinical decision process. Deep Neural Networks, especially Convolutional Neural Networks, have opened up new avenues with the possibility of increasing accuracy in the detection and characterization of tumor tissues. Radiomic analysis, i.e. the extraction of a large number of quantitative features from the images and their combination through machine learning algorithms, is promising in several tasks, like predicting patient response to treatments. Students will acquire skills in modelling problems in medical image analysis, through AI based techniques, and be able to practically apply the learned techniques in some common use cases. Explainability techniques of the algorithms, as well as key concepts related to hardware and software architectures of modern computing devices will also be part of the course.
12	Modeling and managing medical processes	18	Università del Piemonte Orientale	Università del Piemonte Orientale	online and in presence	Alessio Bottrighi, Giorgio Leonardi, Stefania Montani, Luca Piovesan, Manuel Striani, Paolo Terenziani	2022/2023, 2023/2024, 2024/2025	2	May, 5, h14-17 May, 8 , h14-17 May, 15, h14-17 May, 22, h14-17 May, 29, h14-17, June, 5, h14-17	The course will focus on medical processes, with specific emphasis on their representation and their management. Different representation models will be considered, for clinical guidelines, clinical trials, and medical workflows, as well as the main aspects concerning acquisition and\or mining, representation, and use (e.g., simulation, decision support). Finally, the case of the treatment of comorbid patients will be considered, as a prototype of complex context in which multiple models have to be reconciled.
13	Neural Models and Algorithms for Linguistic Recognition and Inference	12	Università degli Studi di Roma, Tor Vergata	Università degli Studi di Roma, Tor Vergata	online and in presence	Roberto Basili, Fabio Massimo Zanzotto	2023/2024, 2024-2025	1	In February 2025, final dates to be defined	Modern AI is growingly faced with complex problems, characterized by heterogeneous forms of structured evidences in input and complex decisions. In medicine historical data, biological phenomena or images manifest through streams of structured data, usually digitally represented into sequences, trees or graphs. Machine Learning methods for structured learning have been studied whereas some mathematical paradigms (such as dimensionality reduction, structured kernels or neural embedding) have been proposed as modelling tools. In Natural Language Processing, Machine Translation and other Natural Language Inference (NLI) tasks, such as Question Answering or Textual Entailment, have been approached via kernels or neural models of the input representation. These achieved accurate state-of-the-art classification and prediction capabilities by enabling the exploration of huge spaces of possible solutions (e.g. target sequences or decisions). In this way, they correspond to both enabling technologies and software tools as well as to models of investigation able to systematically select hypothesis and validate controversial theories about linguistic phenomena. The application of these empirical methodologies to other areas like biology, medicine and medical robotics is more than promising, given the similar complexity of the domains targeted by AI and Life Sciences. The course will try promote this interesting research perspective in Deep Learning to PhD students with a specific focus, but not limited to, Life Science phenomena.
14	Federated learning: how it will protect our privacy in everyday life	10	Università Campus Bio-Medico di Roma	Università Campus Bio-Medico di Roma/(link Microsoft Teams)	phygital	Ermanno Cordelli	2022/2023, 2023/2024, 2024/2025	1	February 2025: Tuesday 4 - 15:00 to 17:00 Friday 7 - 15:00 to 17:00 Tuesday 11 - 15:00 to 17:00 Friday 14 - 15:00 to 17:00 Wednesday 19 - 15:00 to 17:00	How is it possible to allow multiple private data users to collaboratively train and use a shared prediction model, ensuring that their data never leaves their sole possession? By following a more classical machine learning approach, one needs to have a common data centre, which has the responsibility of extracting high-level information from the data of all users, but with the risk of violating data privacy and confidentiality laws. On the other hand, the European Union's General Data Protection Regulation (GDPR) is a prime example of a fully privacy-compliant approach to data that needs to be adhered to in order to continue to have access to global information across multiple users. In this course, federated machine learning will be described, showing the main innovative solutions combining distributed machine learning, cryptography and security, and the design of systems capable of learning without mobilising user proprietary data and with a focus on the medical field. Through heterogeneous practical applications it will be highlighted how such a learning method can become the foundation of next generation machine learning in the AI world.
15	Sustainable Digital Innovation: from foundations to design	10	University Campus Bio-Medico of Rome	Università Campus Bio-Medico di Roma	In presence	Alberto Sangiovanni-Vincentelli & Marta Bertolaso	2024/2025	1	May 2024: Monday 12th of May: 10:00-13:00 – 14:00-16:00 Wednesday 14th of May: 10:00-13:00 – 14:00-16:00	The object of the course is increasing the awareness about the process of design and critical thinking that has a strong context dependency. Epistemological issues and engineering practices converge in robust digital/AI tools to yield sustainable product. Practical examples (from artificial life to smart environments) will be used to illustrate the methodological aspect of the course.

16	Cloud and Cloud-Edge Continuum	24	Univerità degli Studi della Campania Luigi Vanvitelli	Dipartimento di Ingegneria - Università della Campania (Aversa) and online	Phygital - some of the lectures will be held in Italian language	Beniamino Di Martino, Dario Branco, Antonio Esposito	2024/2025	2	From March to June 2025	The main issue affecting Cloud-based services today is the need for more portability and interoperability between Cloud platforms at different service levels. The brokering, negotiation, management, monitoring, and reconfiguration of Cloud resources are challenging tasks for developers and users of Cloud applications due to the different business models associated with resource consumption and the variety of services and features offered by different Cloud providers. The emergent Distributed Architectural Scenario of Cloud-Edge Continuum, where distributed applications are deployed along the entire spectrum of Cloud-Fog-Edge computational devices (including 5G and IoT devices) and where computational components can be offloaded near the data sources, is particularly amenable for application domains such as E-Health, where locality of data-streams processing, ultra-low latency, and privacy requirements are paramount. This course offers a comprehensive and up-to-date overview of the most important methodologies, technologies, and standards related to the portability, interoperability, deployment, and orchestration of Cloud and Cloud-edge distributed applications and services, illustrated by several use cases representing a variety of scenarios; relevant Cloud and Cloud-Edge Architectural Patterns will be illustrated. Examples and case studies from relevant application domains, such as Federated Learning and AR / VR collaborative environments, will be illustrated. Emphasis is placed on their application in the healthcare domain, where the integration of sensors and distributed machine learning further accentuates their significance.
17	Assessing the understandability of AI solutions in psychiatry	30	Universita' degli Studi di Bari Aldo Moro	Dipartimento di Biomedicina Traslazionale e Neuroscienze (DiBraiN), Bari.	Online and in presence	Cristina Berchio	2024/2025	2 semester	Days of Classes: -09/01/2025 h 14-18; -16/01/2025 h 14-18; -23/01/2025 h 14-18; -30/01/2025 h 14-18; -06/02/2025 h 14-18; -13/02/2025 h 14-18; -20/02/2025 h 14-18; -21/02/2025 h 14-17. Place: Dipartimento di Informatica, Campus Universitario, Bari.	This course aims at assessing the understandability of AI solutions in Psychiatry by investigating whether embedding clinical, behavioral and pathophysiological information into AI models reduces uncertainty and generates more clinically relevant decisions. Psychiatric disorders show highly variable characteristics and risk factors. Therefore, AI prognostic and diagnostic solutions are fed with a wide variety of patient related information (e.g., symptoms, behaviors, brain-related data). Because different diagnostic categories are often associated with drastically different clinical manifestations and neurobiological substrates, explaining clinical phenomena with AI is challenging. We will address this challenge by presenting algorithms that discriminate between psychiatric diagnoses based on multimodal data informed by biological and clinical priors. We will show AI solutions that are interpretable in clinical settings, besides generating a more comprehensive view of the pathophysiology of psychiatric conditions.
18	Law and Science	30	Università Campus Bio-Medico di Roma and NLAB RESEARCH CENTER at NIGUARDA HOSPITAL	Phygital	Online and in presence	Stefano Regondi	2023/2024, 2024/2025	2 semester	Wednesday 05/03/2025 h 11.00-13.00 Phygital Wednesday 12/03/2025 h 11.00-13.00 Phygital Wednesday 19/03/2025 h 10.00-13.00 (Dr. Regondi is avalaible at Campus Biomedico) Wednesday 26/03/2025 h 10.00-13.00 Phygital Wednesday 09/04/2025 h 11.00-13.00 Phygital Wednesday 16/04/2025 h 11.00-13.00 Phygital Wednesday 23/04/2025 h 10.00-13.00 (Dr. Regondi is avalaible at Campus Biomedico) Wednesday 30/04/2024 h 10.00-13.00 Phygital Wednesday 07/05/2025 h 11.00-13.00 Phygital Wednesday 14/05/2025 h 11.00-13.00 Phygital Wednesday 21/05/2025 h 10.00-13.00 Phygital Wednesday 28/05/2025 h 10.00-13.00 Final exam (Dr. Regondi is available at Campus Bio-medico) Students who wish to attend the course are invited to contact the lecturer to enroll in the course.	In an era where science and technology rapidly evolve, the interplay between law and these domains becomes increasingly significant. This course offers a comprehensive exploration of the legal, ethical, and policy issues at the intersection of law, science, and technology. The curriculum focuses on how legal frameworks adapt to and shape advancements in several scientific fields, particularly genetics, biotechnology, artificial intelligence (AI), and robotics. This course aims to equip students with a profound understanding of the legal challenges posed by scientific and technological advancements. Through a blend of theoretical and case-based learning, students will gain insights into the dynamic legal landscape surrounding cutting-edge technologies, preparing them to navigate and shape the future of law in the age of technology.
19	Quantum Artificial Intelligence	10	Università degli Studi di Firenze	Online	Online	Filippo Caruso	2024/2025	2 semester	- Monday 07/04/2025 h 9.00-12.30 - Tuesday 08/04/2025 h 9.00-12.30 - Wednesday 09/04/2025 h 9.00-12.00	Quantum Artificial Intelligence (Quantum AI) is a very young but rapidly developing research field combining AI with the huge power of quantum computers that today are becoming available via cloud and even on the market. This intensive short course sheds light on this new Quantum AI framework presenting an overview of the basic elements of quantum computing and quantum machine learning, where supervised and unsupervised ML, reinforcement learning algorithms, and generative AI models can be generalized to the quantum world, running on real, very powerful, quantum processing units.
20	Big Data in Healthcare	25	Università Campus Bio-Medico di Roma/Università Campus Bio-Medico di Roma	Università degli Studi di Messina	online	Antonio Celesti	2024/2025	2	**2nd Semester academic year 2024-2025** -Thursday, June 5th, 2025 h. 11:00-13:00 -Tuesday, June 10th, 2025 h. 14:00-17:00 -Thursday, June 12th, 2025 h. 11:00-13:00 -Tuesday, June 17th, 2025 h. 14:00-17:00 -Thursday, June 19th, 2025 h. 11:00-13:00 -Tuesday, June 24th, 2025 h. 14:00-17:00 -Thursday, June 26th, 2025 h. 11:00-13:00 -Tuesday, July 8th, 2025 h. 14:00-17:00 -Thursday, July 10th, 2025 h. 11:00-13:00 -Tuesday, July 15th, 2025 h. 14:00-17:00	The use of Big Data in biomedical and health sciences has received a lot of attention in recent years. These pieces of data present a significant opportunity for the improvement of the diagnosis, treatment and prevention of various diseases, and to interventions to improve health outcomes. The objective of the course is to provide the basic knowledges to understand, design, develop Big Data Systems. Morevover, particular attention will be given to methodologies and software tool for Big Data Storage, Warehousing and advanced Machine Learning based Analytics. In the end, case studies on the adoption of Big Data in healthcare will be discussed.
21	Knowledge Engineering	25	Univerità degli Studi della Campania Luigi Vanvitelli	Dipartimento di Ingegneria - Università della Campania (Aversa) and online	Phygital - most of the lectures will be held in Italian language; part of the course will be held asynchronously, through a MOOC platform	Beniamino Di Martino, Luigi Colucci Cante, Mariangela Graziano	2024/2025	2	From September to December 2025	The course introduces the topics and concepts of the field of Artificial Intelligence that deals with the Representation and Management of Knowledge, through methods and techniques based mainly on Logic and the production of rules. After an introduction, focused on the presentation of concrete examples of Intelligent Systems based on Rule-based techniques, we start with an overview of Problem-Solving techniques based on Research in State Spaces. The main models for the Representation of Knowledge are then introduced, with an in-depth study dedicated to the architecture and languages of the Semantic Web. We then move on to models and techniques of automated reasoning based on deduction and inference, in particular models based on Logic, with particular attention to the language of inference for the Semantic Web – SWRL. Finally, important fields of application of the methods illustrated are presented: Natural Language Processing, Process Mining and Semantic Web Services. Some of the lectures will be given in Italian.
23	Hands-on Machine Learning & Deep Learning	20	Università Campus Bio-Medico di Roma	Università Campus Bio-Medico di Roma/online	phygital	Valerio Guarrasi	2023/2024, 2024/2025	2	March 2025	In this course, students will gain an understanding of Machine Learning and Deep Learning concepts, algorithms, and applications. They will learn how to develop and implement various Machine Learning models using Python and acquire the skills to choose the appropriate models for different types of problems. Building intuition for these models and their practical uses is a key objective, along with mastering the skills for making accurate predictions and robust analyses.
25	Etica Personalista Applicata all'Intelligenza Artificiale	7	Università Campus Bio-Medico di Roma	Università Campus Bio-Medico di Roma		Vittoradolfo Tambone, Nicola Di Stefano, Francesco De Micco	2024/2025	tbd	to be defined	Contenuti: Introduzione all'Etica Personalista, L'AI alla Luce del Personalismo, Principi Etici Personalisti Applicati all'uso della AI, Casi Studio Personalisti sull'AI in Life Science

26	Introduction to Bioinformatics and Artificial Intelligence for Multi-Omics Sciences	25	University of Siena	online	Online	Fabrizio Celesti	2024/2025	2	Every Tuesday h. 09:00 - 11:00 and Thursday h. 09:00 - 12:00 from May 6th, 2025 to June 5th, 2025.	The course provides an exploration of the intersection of bioinformatics and artificial intelligence (AI) within the context of Multi-Omics Sciences, including genomics, transcriptomics, proteomics, and epigenomics. The course is designed to equip students with theoretical knowledge and practical skills to analyse and integrate large-scale biological data using cutting-edge computational tools and AI-driven methods. Key topics include an overview of basic concepts of biology, Multi-Omics data types and technologies, statistical and computational methods for data processing and integration, and the role of AI in uncovering complex biological patterns. Special emphasis is placed on approaches for biomarkers discovery, precision medicine, and network-based Multi-Omics analysis. Students will also gain hands-on experience with software tools and programming languages (e.g., R). By the end of the course, participants will be able to design and execute advanced computational workflows for Multi-Omics data, critically evaluate AI models for biological research, and contribute to innovative solutions in systems biology and personalised medicine. This course is ideal for students with backgrounds in biology, biotechnology, bioinformatics, computer science, or related disciplines who aim to advance their expertise in the rapidly evolving field of bioinformatics and AI applied to Multi-Omics Sciences.
27	Network Science and Applications in Biology, Health Sciences, and Neuroscience	12	Università di Bari	online	Online	Nicola Pedreschi, Giulio Pergola	2024/2025	2	•Monday 12/05/2025, 11:00-13:00 •Thursday 15/05/2025, 11:00-13:00 •Monday 19/05/2025, 11:00-13:00 •Thursday 22/05/2025, 11:00-13:00 •Monday 26/05/2025, 11:00-13:00 •Thursday 29/05/2025, 11:00-13:00 •Thursday 05/06/2025, 10:00-13:00 (Final Exam)	This course integrates Network Science with a focus on its applications in biology, health sciences, and neuroscience. Participants will explore how complex biological systems, such as (among others) gene co-expression networks and neural networks, can be modeled through network theory. The course aims to equip students with the tools to analyze biological networks and apply network-based approaches to address multifaceted research challenges.

In the case a course reports a time interval rathern than specific dates, Students are encpuraged to contact the Lecturers as detailed in the specific course presentation

In general, Students have to contact in advance the Lecturers to enroll in the course

Title: Mathematics, Deep Learning and Deep Reinforcement Learning

Number of hours: 30

Institution(s): Università di Chieti-Pescara

Location(s): Dipartimento di matematica, Firenze

Type: Ph.D. course

Attendance Mode: Hybrid

Final Exam: Yes

Lecturer(s): Maurizio Parton

Responsible Expert(s)\email: Maurizio Parton, Università di Chieti-Pescara, maurizio.parton@unich.it

Academic Year: 2021/2022, 2022/2023, 2023/2024, 2024/2025

Semester: 2 (please consider that the course can be selected by the student in the first or in the second year of the PhD)

Timetable: January 2025, dates to be decided. Students who wish to attend the course are invited to contact the lecturer by the mid of July 2024. Specific dates will be communicated to interested students.

Abstract: The last few years have seen impressive accomplishments of artificial intelligence. Without a doubt, Deep Learning DL and Deep Reinforcement Learning DRL are the techniques that contributed most to these successes. Despite the extremely diverse areas involved (image recognition, games, biology, natural language processing, to name a few), we are still a long way from truly understanding the mathematics behind DL and DRL. Along with its theoretical interest, this would further increase their performance and fields of application.

This course is addressed to mathematicians who aim to understand the relationship between DL/DRL and mathematics, in both directions. How can mathematicians contribute to the mathematical foundations of DL/DRL? How can DL/DRL be used by mathematicians in their everyday research field?

After introducing DRL and DL in the first part of the course, we will provide (very partial) answers to the above questions by introducing some of the recent topics that in my opinion enlight this beautiful link between DL/DRL and mathematics, see bibliography.

I will do my best to make this course accessible to the average mathematician. In particular, 2/3 of the course will be devoted to fundamentals of DRL and DL, so that no prior knowledge of DL or DRL is required. A basic knowledge in probability, algebraic geometry, differential geometry and/or Python could be helpful, but is not essential.

Learning Outcomes: At the end of the course the student should be able to communicate DRL and DL concepts with a proper and sound language, and to read and partially understand textbooks and research papers on the topics.

Detailed lecture contents:
-) Machine learning techniques that to date have proved useful in theoretical mathematics: reinforcement learning, and deep learning combined with explainability.
-) Theoretical mathematics techniques useful for machine learning: geometric deep learning.
-) Elements of Colab, Python, and Keras.
-) Details on AlphaGo Zero and MCTS.

Teaching method: Slides in English, **lectures in Italian**.

Final Exam: oral presentation of topics from the course, or presentation of a research paper, or project.

Prerequisites: none.

Key Bibliography:

-) Constructions in combinatorics via neural networks, https://arxiv.org/abs/2104.14516.
-) Geometric deep learning, https://arxiv.org/abs/1611.08097.
-) The Calabi-Yau Landscape, https://arxiv.org/abs/1812.02893.
-) Constructing and Machine Learning Calabi-Yau Five-folds, https://arxiv.org/abs/2310.15966.
-) Principles of Riemannian Geometry in Neural Networks, https://papers.nips.cc/paper/2017/hash/0ebcc77dc72360d0eb8e9504c78d38bd-Abstract.html.
-) Advancing mathematics by guiding human intuition with AI, https://www.nature.com/articles/s41586-021-04086-x.
-) Finding Increasingly Large Extremal Graphs with AlphaZero and Tabu Search , https://arxiv.org/abs/2311.03583.
-) https://www.youtube.com/watch?v=inN8seMm7UI. Video, Colab 3m introduction.
-) https://colab.research.google.com/. Colab introduction, notebook.
-) https://colab.research.google.com/github/cs231n/cs231n.github.io/blob/master/python-colab.ipynb. Python crash course, perfect if you want to get the idea of this language in less than 1h.

Title: AI in Computer-aided drug design

Number of hours: 15

Institution: Istituto di Scienze e Tecnologie Chimiche "Giulio Natta" (SCITEC)-CNR

Location: CNR p.le A. Moro, Roma and online

Type: Ph.D. course

Attendance Mode: Online and in presence

Final Exam: Yes

Lecturers: Maria Cristina De Rosa (SCITEC-CNR), Davide Pirolli (SCITEC-CNR), Benedetta Righino (SCITEC-CNR)

Responsible Expert\email: Maria Cristina De Rosa, mariacristina.derosa@cnr.it

Academic Year: 2024/2025

Semester: 2 semester a.a. 2024/2025

Timetable: The course will be held between March and July 2024, definitive dates will be delivered to enrolled students. Students who wish to attend the course are invited to contact the lecturer by mid-February. Specific dates will be communicated to interested students.

Abstract: Drug discovery is an expensive and time-consuming process that is often assisted by computational methods to speed up and guide the design of new compounds. In the last decade, many studies have applied artificial intelligence in computer-aided drug design to obtain more accurate models and accelerate the design process. This course provides an overview of implementation of machine learning and deep learning algorithms in several drug discovery processes such as prediction of the target protein structure, structure-based and ligand-based drug design, evaluation of drug toxicity and physiochemical properties, quantitative structure–activity relationship. Specific case studies, related to applications of AI in drug development, will be discussed and used to ease the comprehension of the course arguments.

Learning Outcomes: The course is aimed to introduce basic concepts and to provide the basis of practical applications on the impact of Artificial Intelligence (AI) in computational chemistry. It will make participants familiar with a wide set of AI-driven computational approaches in the field of drug discovery and structural biology.

Detailed lecture contents:

1. Introduction on AI in drug discovery
2. AI in protein structure prediction
3. Augmenting virtual screening using AI
4. Accelerating lead identification
5. AI-based QSAR approaches
6. ADME/Tox prediction by AI

Teaching method: Powerpoint slides

Final Exam: Evaluations will be based on: i) student's participation in discussion during the classes; and ii) brief presentation of selected scientific articles related to the course. Final exam will be held during regular class times

Prerequisites: None

Key Bibliography:

1. Fleming N. How artificial intelligence is changing drug discovery. Nature. 2018 May; 557(7707):S55-S57. doi: 10.1038/d41586-018-05267-x
2. Paul D. Artificial intelligence in drug discovery and development. Drug Discovery Today. 2021 January 26(1):80-93. doi: 10.1016/j.drudis.2020.10.010
3. Crampon K et al. Machine-learning methods for ligand–protein molecular docking. Drug Discovery Today. 2022 January; 27(1):151-164. doi: 10.1016/j.drudis.2021.09.007

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Multi-scale Applications of Mathematics to Medicine

Number of hours: 15

Institution(s): Università di Genova

Location(s): Dipartimento di Matematica, Università di Genova and online

Type: Ph.D. course

Attendance Mode: In presence and Online

Final Exam: Oral presentation of a project concerning the topics illustrated in the course

Lecturer(s): Michele Piana, Anna Maria Massone, Sara Garbarino

Responsible Expert(s)\email: name, affiliation and email(s): Michele Piana, Dipartimento di Matematica Università di Genova, piana@dima.unige.it

Academic Year: 2024/2025

Semester: II semester

Timetable: First week of July, definitive dates will be delivered to enrolled students.

Abstract:
The course will discuss data simulation and processing methods for three biomedicine problems characterized by three different scales. At a cellular scale, we will describe a signaling network model for colon-rectal cancer and illustrate both formal and computational methods for its reduction. At a tissue scale, we will discuss parametric imaging approaches for the interpretation of nuclear medicine data. At an organ scale, we will describe some pattern recognition approaches for the extraction of radiomics features from both morphological and functional images. The methodological topics will include inverse problems theory, dynamical systems, and artificial intelligence

Learning Outcomes: knowledge of the main aspects of computational data analysis for biomedical data at different scales

Detailed lecture contents:

Cells

- Construction of signaling networks in cancer cells
- Computation of the proteomic equilibrium
- Uniqueness and sensitivity issues

Tissues

- Aspects of tracer kinetics in nuclear medicine

- Parametric imaging in nuclear medicine

Organs

- Extraction of radiomics features (geometry-based methods)
- Unsupervised clustering of radiomics features

Teaching method: Frontal lectures (with slides)

Final Exam: Oral presentation of a project concerning the topics illustrated in the course

Prerequisites: Some mathematics (numerical analysis, mathematical analysis)

Key Bibliography: slides, handouts and some papers concerned with the topics

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Behavioural Biometric for healthcare, security and related fields

Number of hours: 15

Institution(s): Università degli studi di Bari "Aldo Moro", dipartimento di informatica

Location(s): online

Type: Ph.D. course

Attendance Mode: online

Final Exam: Yes

Lecturer(s): Donato Impedovo, Vincenzo Dentamaro

Responsible Expert(s)\email: Donato Impedovo, donato.impedovo@uniba.it

Academic Year: 2024/2025

Semester: 2

Timetable: April 14, h14-17; April 16, h09-12; April 17, h09-12; April 18, h09-12; April 30, h09-12 2025. Students who wish to attend the course are invited to contact the lecturer by mid-March. Specific dates will be communicated to interested students.

Abstract: Behavioural biometrics for healthcare seek solutions to discover, classify, monitor, recognize diseases that are measurable only when the patient performs an action. This action could be walk, talk, write, type on the touchscreen and many more. Behavioral biometrics are, thus, interested in non directly measurable physical properties, but patterns that are recognized only when the patient performs a particular behavior. In general, it is way the human being responses to natural events around him/her. In this course PhD students will learn shallow learning and deep learning techniques for recognizing pathological conditions using handwriting, gait analysis, speech analysis and many more.

Learning Outcomes: At the end of the course the student should be able to conduct their own studies on behavioural biometrics as well as read and reproduce papers making use of behavioural biometrics in healthcare, security and related fields.

Detailed lecture contents:

Lecture 1: Introduction to behavioural biometrics in healthcare and security
Lecture 2: Introduction to shallow learning and Deep Learning techniques
Lecture 3: Neurodegenerative disease assessment through handwriting
Lecture 4: Neurodegenerative disease assessment through gait analysis
Lecture 5: Covid and other diseases assessment through sound

Teaching method:
The Teacher will project slides and may present some scientific paper on the topic.

Final Exam:
The student will prepare slides for a short seminar (20-30 minutes) on a topic related to those discussed during the course. The topic of the seminar will be either proposed by the teacher or chosen by the student. The date of the seminar will be agreed between the student and the teacher.

Prerequisites:
None

Key Bibliography:

- Impedovo, D., & Pirlo, G. (2018). Dynamic handwriting analysis for the assessment of neurodegenerative diseases: a pattern recognition perspective. *IEEE reviews in biomedical engineering*, *12*, 209-220.
- De Stefano, C., Fontanella, F., Impedovo, D., Pirlo, G., & di Freca, A. S. (2019). Handwriting analysis to support neurodegenerative diseases diagnosis: A review. *Pattern Recognition Letters*, *121*, 37-45.
- Dentamaro, V., Impedovo, D., & Pirlo, G. (2021, January). An Analysis of Tasks and Features for Neuro-Degenerative Disease Assessment by Handwriting. In *International Conference on Pattern Recognition* (pp. 536-545). Springer, Cham.
- Dentamaro, V., Giglio, P., Impedovo, D., & Pirlo, G. (2021, September). Benchmarking of Shallow Learning and Deep Learning Techniques with Transfer Learning for Neurodegenerative Disease Assessment Through Handwriting. In *International Conference on Document Analysis and Recognition* (pp. 7-20). Springer, Cham.
- Dentamaro, V., Impedovo, D., & Pirlo, G. (2020). Gait analysis for early neurodegenerative diseases classification through the kinematic theory of rapid human movements. *IEEE Access*, *8*, 193966-193980.
- Cicirelli, G., Impedovo, D., Dentamaro, V., Marani, R., Pirlo, G., & D'Orazio, T. (2021). Human gait analysis in neurodegenerative diseases: a review. IEEE Journal of Biomedical and Health Informatics.
- Convertini, N., Dentamaro, V., Impedovo, D., & Pirlo, G. (2021). Sit-to-Stand Test for Neurodegenerative Diseases Video Classification. International Journal of Pattern Recognition and Artificial Intelligence, 35(12), 2160003.
- Dentamaro, V., Giglio, P., Impedovo, D., Moretti, L., & Pirlo, G. (2022). AUCO ResNet: an end-to-end network for Covid-19 pre-screening from cough and breath. *Pattern Recognition*, 108656. doi:10.1016/j.patcog.2022.108656

Title: Introduction to Neuromorphic Computing

Number of hours: 12

Institution(s): University of Rome Tor Vergata

Location(s): Rome, University of Rome Tor Vergata, via Montpellier 1

Type: Ph.D. course

Attendance Mode: Online

Final Exam: Yes

Lecturer(s): Andrea Duggento

Responsible Expert(s)\email: Andrea Duggento andrea.duggento@uniroma2.eu

Academic Year: 2021/2022, 2022/2023, 2023/2024, 2024/2025

Semester: 2

Timetable:
Monday 10/03/2025, 8:00-10:00. Tuesday 11/03/2025, 8:00-10:30. Thursday 13/03/2025, 8:00-10:30. Monday 17/03/2025, 8:00-10:30. Tuesday 18/03/2025, 8:00-10:30.
Students who wish to attend the course are invited to contact the lecturer to enrol in the course.

Abstract: The mammalian brain is a very sophisticated, highly efficient biocomputer from which technology has begun to draw inspiration for developing artificial neural networks. However, this biology-to-technology translation is still in its infancy. Spiking neural networks based on neuromorphic architectures are emerging as a more biologically-inspired artificial minds which will likely underlie next-generation AI paradigms. This course will explore the biological – in silico correspondence at all levels, introducing key concepts of neuronal membrane potential dynamics, neuroanatomy and chemical neuromodulation, neural tissue energy demands, theory of evolution and principles of cognition. For each topic, its state-of-the-art neuromorphic engineering application counterpart will be presented. All major aspects of spiking neural network applications will be introduced, from training strategies (including principles of reinforcement learning, synaptic plasticity and multi-agent evolutionary artificial neural networks) to software and hardware implementation, e.g. including CMOS neuromorphic chips and memristor-based neuromorphic computers.

Learning Outcomes: At the end of the course the student is expected to have acquired:

- A basic knowledge of the biological mechanisms that inspired the neuromorphic engineering field.
- The ability to conceptualize biologically plausible mechanisms into a neuronal simulation with learning capabilities.

Detailed lecture contents:
Lecture 1: Introduction, membrane potential, synapses, and chemical neuromodulation
Lecture 2: Spiking neural network in silico: models and simulation environments
Lecture 3: Hard-wired spiking neural network: CMOS vs Memristors
Lecture 4: Synaptic plasticity, neuromodulation strategies and learning.
Lecture 5: Chemical-modulated reinforcement learning and evolution: from biology to engineering

Teaching method:
Lectures based on whiteboard for analytical and qualitative concepts, slides for illustrating applications.

Final Exam:
The student will prepare a seminar on a topic to be agreed upon

Prerequisites:
Key Machine Learning Concepts

Key Bibliography:

- Principles of Neural Science, Sixth Edition, by Eric R. Kandel et Al., 2021
- Neuromorphic Engineering; The Scientist's, Algorithm Designer's, and Computer Architect's Perspectives on Brain-Inspired Computing, by Elishai Ezra Tsur, 2021
- Neuroscience, by D Purves et Al., 2018
- Selected articled from scientific literature.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

National PhD in Artificial Intelligence
Area of specialization: Health and Life Sciences

Title: AI in medical image analysis

Number of hours: please insert any multiple of 5 from 10: 40.

Institution(s): INFN & Centro Fermi.

Location(s): Sapienza Università di Roma and online.

Type: Ph.D. course.

Attendance Mode: online and in presence.

Final Exam: yes.

Lecturer(s): prof. S. Giagu (Sapienza & INFN Roma), dr.ssa C. Voena (INFN Roma), dr. A. Lonardo (INFN Roma), dr. F. Giove (Centro Fermi), dr.ssa A. Retico (INFN Pisa).

Responsible Expert(s)\email:
stefano.giagu@uniroma1.it.

Academic Year: 2024/2025

Semester: 2

Timetable: During the month of May 2025 (will be communicated)
Students who wish to attend the course are invited to contact the lecturer by mid-February. Specific dates will be communicated to interested students.

Abstract: Medical digital images (Computed Tomography, Magnetic Resonance Imaging. etc.) play a key role in personalized therapy management, and are used in the diagnosis, treatment planning and monitoring of the disease and AI-driven solutions are emerging world-wide as a support in the clinical decision process. Deep Neural Networks, especially Convolutional Neural Networks, have opened up new avenues with the possibility of increasing accuracy in the detection and characterization of tumor tissues. Radiomic analysis, i.e. the extraction of a large number of quantitative features from the images and their combination through machine learning algorithms, is promising in several tasks, like predicting patient response to treatments. Students will acquire skills in modelling problems in medical image analysis, through AI based techniques, and be able to practically apply the learned techniques in some common use cases. Explainability techniques of the algorithms, as well as key concepts related to hardware and software architectures of modern computing devices will also be part of the course.

Learning Outcomes: acquire skills in modelling problems in medical image analysis, through AI based techniques, and be able to practically apply the learned techniques in some common use-cases. Learn the fundamental elements of the hardware architecture (control, data-path, instruction parallelism, hierarchy

of memories) and system software and understand the impact they have on the performance of AI applications, enabling the conscious optimization of their implementation.

Detailed lecture contents: medical image modalities (CT, Xrays, MRI, PET). Image pre-processing and image normalization**.** Radiomic pipeline: radiomic features computation, feature selection and reduction, radiomic signatures. Machine learning algorithms for classification. Deep learning-based tissue segmentation algorithms: CNN, Visual Transformers. Data augmentation and knowledge transfer techniques. Explainability techniques for medical image applications. Introduction to computers: hardware organization, firmware and software, performance definition and measurement. Computer arithmetic: arithmetic and logical operations. Processor Architecture: functional units, registers, control unit, microprogramming; processing unit; pipelining, exceptions handling. Memory hierarchy: cache memory, virtual memory. Storage and I/O. Overview of multicore systems, multiprocessors and clusters: parallel processing, classification, examples of many-core computing architectures (GPU), dedicated architectures for AI.

Teaching method: about 60% of the course takes place with lectures supplemented by projections of slides in the classroom and/or electronically, designed to provide advanced knowledge of the course topics. The remaining 40% is based on hands-on computational practical experiences that provide some of the application skills necessary to independently develop and implement AI pipelines for segmentation of medical images and for radiomic analysis.

Final Exam: discussion about a topic treated in the course chosen by the student + 1 topic chosen by the teacher.

Prerequisites: elements of python programming and elements of machine learning and neural networks.

Key Bibliography: given the highly dynamic nature of the topics covered in the course, there is no single reference text. During the course the sources will be indicated and provided from time to time in the form of scientific and technical articles and book chapters.

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

Title: Modelling and managing medical processes

Number of hours: 18

Institution(s): University of Eastern Piedmont

Location(s): Alessandria\Online

Type: Ph.D. course

Attendance Mode: In presence (Alessandria) + Online

Final Exam: Yes

Lecturer(s): Alessio Bottrighi, Giorgio Leonardi, Stefania Montani, Luca Piovesan, Manuel Striani, Paolo Terenziani

Responsible Expert(s)\email:
Alessio Bottrighi, University of Eastern Piedmont, alessio.bottrighi@uniupo.it
Giorgio Leonardi, University of Eastern Piedmont, giorgio.leonardi@uniupo.it
Stefania Montani, University of Eastern Piedmont, stefania.montani@uniupo.it
Luca Piovesan, University of Eastern Piedmont, luca.piovesan@uniupo.it
Manuel Striani, University of Eastern Piedmont, manuel.striani@uniupo.it
Paolo Terenziani, University of Eastern Piedmont, paolo.terenziani@uniupo.it

Academic Year: 2024/2025

Semester: 2

Timetable:
May, 5, h14-17 May, 8 , h14-17 May, 15, h14-17 May, 22, h14-17 May, 29, h14-17, June, 5, h14-17.
Students who wish to attend the course are invited to contact the lecturer to enroll in the course.

Abstract:
The course will focus on medical processes, with specific emphasis on their representation and their management. Different representation models will be considered, for clinical guidelines, clinical trials, and medical workflows, as well as the main aspects concerning acquisition and\or mining, representation, and use (e.g., simulation, decision support). Finally, the case of the treatment of comorbid patients will be considered, as a prototype of complex context in which multiple models have to be reconciled.

Learning Outcomes:
The students will acquire knowledge about the main types of models for medical processes, and of operational facilities to acquire, represent and use them. The course will provide basic background knowledge about such topics, as well as hints about most advanced researches, and recent “hot topics”.

Detailed lecture contents:
Lesson 1. Introduction to clinical guidelines. Different representation methods. Guideline acquisition, representation and execution. Advanced decision support facilities.
Lesson 2. Introduction to comorbid patient problematics. Analysis of techniques and methodologies for safe and efficient reconciliation of multiple (medical) models.
Lesson 3. Introduction to data acquisition and management for clinical trials. Electronic Data Capture approaches and standards. AI approaches for the management of clinical trials.
Lesson 4. Introduction to workflow. Workflow perspectives (organisational, data-flow, control-flow) and relative workflow patterns. Brief introduction to Process Mining.
Lesson 5. From process traces to process models: process mining. The ProM tool. Uses of process mining. Improving process mining and process comparison through domain knowledge.
Lesson 6. Techniques and methodologies of NLP/LLMs applied to Process Mining to enhance the quality of healthcare processes.

Teaching method:
Lesson & slide online

Final Exam:
Student seminar about a topic agreed together with the teachers.

Prerequisites:
Basic knowledge about AI knowledge representation formalisms

Key Bibliography:

Robert A. Greenes, Clinical Decision Support: The Road to Broad Adoption, Academic Press; 2nd edition ISBN: 978-0-123-98476-0 (2014)

Wil van der Aalst, Process Mining: Data Science in Action, Springer, ISBN: 978-3-662-57041-8 (2016)

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

Title: Neural Models and Algorithms for Linguistic Recognition and Inference

Number of hours: 12

Institution(s): University of Roma, Tor Vergata

Location(s): Online

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Roberto BASILI, Fabio Massimo ZANZOTTO

Responsible Experts: basili@info.uniroma2.it, fabio.massimo.zanzotto@uniroma2.it

Academic Year: 2023/2024, 2024/2025.

Semester: 1

Timetable: In February 2025, final dates to be defined.
Students who wish to attend the course are invited to contact the lecturer to enroll in the course.

Abstract: Modern AI is growingly faced with complex problems, characterised by heterogeneous forms of structured evidence in input and complex decisions. In medicine historical data, biological phenomena or images manifest through streams of structured data, usually digitally represented into sequences, trees or graphs. Machine Learning methods for structured learning have been studied whereas some mathematical paradigms (such as dimensionality reduction, structured kernels or neural embedding) have been proposed as modelling tools. In Natural Language Processing, Machine Translation and other Natural Language Inference (NLI) tasks, such as Question Answering or Textual Entailment, have been approached via kernels or neural models of the input representation. These achieved accurate state-of-the-art classification and prediction capabilities by enabling the exploration of huge spaces of possible solutions (e.g. target sequences or decisions). In this way, they correspond to both enabling technologies and software tools as well as to models of investigation able to systematically select hypotheses and validate controversial theories about linguistic phenomena. The application of these empirical methodologies to other areas like biology, medicine and medical robotics is more than promising, given the similar complexity of the domains targeted by AI and Life Sciences. The course will try to promote this interesting research perspective in Deep Learning to PhD students with a specific focus, but not limited to, Life Science phenomena.

Learning Outcomes: Knowledge about the state-of-the-art neural inference methods through their applications to structured input (sequences, trees and graphs) for classification, transduction and

discovery tasks. The course will discuss fruitful integration of deep neural and kernel-based learning methods as modelling tools for complex structures.

Detailed lecture contents:

Lesson 1 (2+2 hours)**:** **Kernel Methods for Language Modeling (RB)**

Lesson 2 (2+2 hours): **Autoregressive Encoder-Decoders for Neural Natural Language Inference and Question Answering (RB)**

Lesson 3 (2+2 hours): **Neural Transducers for Biological sequences and for structures (FMZ)**

Teaching method: Presentation of mathematical and algorithmic contents via seminar-like teaching, and Lab exercises in Python to share experimental best practices about the main course topics.

Final Exam: Short Projects on specific datasets will be proposed to assess the acquired knowledge. A final presentation of the project results is expected to close the study.

Prerequisites: Basic knowledge of Machine Learning and Deep Learning methods, Basic knowledge on Natural Language Topics: Syntax and Semantics of Natural Languages, Text Classification and Textual Inference.

Key Bibliography:

- "On the properties of neural machine translation: Encoder-decoder approaches." Cho, Kyunghyun, et al. , *arXiv preprint arXiv:1409.1259* (2014).
- Deep Learning, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press, 2016.
- Attention is all you need. Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. In Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS'17). Curran Associates Inc., Red Hook, NY, USA, 6000–6010.
- "BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding", Jacob Devlin Ming-Wei Chang Kenton Lee Kristina Toutanova, Proceedings of NAACL-HLT 2019, pages 4171–4186, Minneapolis, Minnesota, June 2 - June 7, 2019.
- Making sense of kernel spaces in neural learning, D Croce, S Filice, R Basili, Computer Speech & Language 58, 51-75 (2019)
- Fabio Massimo Zanzotto, Andrea Santilli, Leonardo Ranaldi, Dario Onorati, Pierfrancesco Tommasino, and Francesca Fallucchi. 2020. KERMIT: Complementing Transformer Architectures with Encoders of Explicit Syntactic Interpretations. In Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing (EMNLP)
- Lorenzo Ferrone and Fabio Massimo Zanzotto, Symbolic, Distributed, and Distributional Representations for Natural Language Processing in the Era of Deep Learning: A Survey, Front. Robot. AI, 21 January 2020

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Federated learning: how it will protect our privacy in everyday life

Number of hours: 10 ore

Institution(s): University Campus Bio-Medico di Roma

Location(s): Via Álvaro del Portillo, 21, Roma/(link Microsoft Teams)

Type: Ph.D. course

Attendance Mode: The attendance mode will be Phygital.

Final Exam: Yes

Lecturer(s): Ermanno Cordelli

Responsible Expert(s)\email: Ermanno Cordelli (e.cordelli@unicampus.it), University Campus Bio-Medico di Roma

Academic Year: The academic years will be 2024/2025.

Semester: Semester 1

Timetable: Classes will be held in February 2025 on the following dates:
Tuesday 4 - 15:00 to 17:00
Friday 7 - 15:00 to 17:00
Tuesday 11 - 15:00 to 17:00
Friday 14 - 15:00 to 17:00
Wednesday 19 - 15:00 to 17:00

Abstract: How is it possible to allow multiple private data users to collaboratively train and use a shared prediction model, ensuring that their data never leaves their sole possession? By following a more classical machine learning approach, one needs to have a common data centre, which has the responsibility of extracting high-level information from the data of all users, but with the risk of violating data privacy and confidentiality laws. On the other hand, the European Union's General Data Protection Regulation (GDPR) is a prime example of a fully privacy-compliant approach to data that needs to be adhered to in order to continue to have access to global information across multiple users. In this course, federated machine learning will be described, showing the main innovative solutions combining distributed machine learning, cryptography and security, and the design of systems capable of learning without mobilising user proprietary data and with a focus on the medical field. Through heterogeneous practical applications it will be highlighted how such a learning method can become the foundation of next generation machine learning in the AI world.

Learning Outcomes: Federated Learning in Supervised Learning, Unsupervised Learning and related applications

Detailed lecture contents:
Lesson 1:
Supervised and unsupervised learning an overview + Python crash Machine Learning course

Lesson 2:
Introduction to Federated Learning main idea + Python practical task construction (to be defined)

Lesson 3:
Main Federated Learning method presentation (in general and with medical focus): Vanilla FL, Vertical and Horizontal FL, U-Net FL, Consensus-driven FL and AE-FL

Lesson 4:
Practical implementation of best Federated Learning methods (related to the defined task)

Lesson 5:
Paper presentation (pitch session)

Teaching method: Classroom lessons (with slides support) and practical lessons (using own computer).

Final Exam: Each student will analyse a recent state of the art paper and present the relevant concepts understood during a pitch presentation.

Prerequisites: Python programming (basics)

Key Bibliography:
[1] Rieke, N., Hancox, J., Li, W., Milletari, F., Roth, H. R., Albarqouni, S., ... & Cardoso, M. J. (2020). The future of digital health with federated learning. NPJ digital medicine, 3(1), 1-7.

[2] Yuan, B., Ge, S., & Xing, W. (2020). A federated learning framework for healthcare iot devices. arXiv preprint arXiv:2005.05083.

[3] Wang, Y., Gui, G., Gacanin, H., Adebisi, B., Sari, H., & Adachi, F. (2021). Federated learning for automatic modulation classification under class imbalance and varying noise condition. IEEE Transactions on Cognitive Communications and Networking.

[4] Nguyen, D. C., Pham, Q. V., Pathirana, P. N., Ding, M., Seneviratne, A., Lin, Z., ... & Hwang, W. J. (2022). Federated Learning for Smart Healthcare: A Survey. *ACM Computing Surveys (CSUR)*, *55*(3), 1-37.

[5] Qayyum, A., Ahmad, K., Ahsan, M. A., Al-Fuqaha, A., & Qadir, J. (2021). Collaborative federated learning for healthcare: Multi-modal covid-19 diagnosis at the edge. arXiv preprint arXiv:2101.07511.

Title: **Sustainable Digital Innovation: from Foundations to Design**

Number of hours: 10

Institution(s): UCBM & CHIPSIT

Location(s): Via Alvaro del Portillo, 21 Rome

Type: Ph.D. course

Attendance Mode: in presence

Final Exam: critical report on case studies

Lecturers:

- **Prof. Alberto Sangiovanni Vincentelli** (co-presidente del comitato strategico, MIND, professore alla University of California, Berkeley, the Buttner Chair of Electrical Engineering and Computer Science, e Presidente di https://www.fondazione-chipsit.it/)
- **Prof. Marta Bertolaso** (UCBM) and

Responsible e-mail: Prof. Marta Bertolaso, m.bertolaso@unicampus.it

Academic Year: 2024/5

Semester: 2

Timetable:
Monday 12th of May: 10:00-13:00 – 14:00-16:00
Wednesday 14th of May: 10:00-13:00 – 14:00-16:00

*with the possibility of online connection for those who need it.

The language of delivery of the course: English; if the students enrolled will be only Italians it will be possible to deliver it in Italian.

Students who wish to attend the course are invited to contact the lecturer to enrol in the course.

Abstract:

The object of the course is increasing the awareness about the process of design and critical thinking that has a strong context dependency. Epistemological issues and engineering practices converge in robust digital/AI tools to yield sustainable product. Practical examples (from

artificial life to smart environments) will be used to illustrate the methodological aspect of the course.

Learning Outcomes:

- Enhancing modelling processes when inquiring or enhancing complex systems.
- Understanding the methodological and theoretical foundations of data management and model generation;
- Awareness of the relevance and impact of the human factor for sustainable innovation and AI;
- Awareness of the interactions between AI and complex issues in health sciences and technology;
- Critical thinking: ability to identify and to appropriately discuss concrete problems, processes and issues.

Detailed lecture contents:

- AI Technology and Its Evaluation. Machine Learning, Generative AI and adversarial networks and their limitations. (***Prof. Sangiovanni Vincentelli***).
-Applications of Machine Learning to design and data analysis in health, integrated circuits, autonomous driving (***Prof. Sangiovanni Vincentelli***).
- Platform-based design and applications to system design, rational drug design and living environment, (***Prof. Sangiovanni Vincentelli***)
- The Human Factor in the Digital Transitions: differences, integration and implementation strategies (***Prof. Bertolaso***)
- Understanding Complexity in the digital-biological interfaces: risk assessment and management (***Prof. Bertolaso***)

Teaching method:
Lectures and class discussions.

Prerequisites:
None.

Bibliography:

A Sangiovanni-Vincentelli, EDA meets biology! The bumpy road ahead

Ahmadi-Assalemi, G., Al-Khateeb, H., Maple, C., Epiphaniou, G., Alhaboby, Z. A., Alkaabi, S., & Alhaboby, D. (2020). Digital twins for precision healthcare. Cyber defence in the age of AI, Smart societies and augmented humanity, 133-158.

Alberto Sangiovanni Vincentelli, Quo vadis, SLD? Reasoning about the trends and challenges of system level design, Proceedings of the IEEE 95 (3), 467-506

Beneduce C, Bertolaso M (Eds) (2021), Personalized Medicine in the Making Philosophical Perspectives from Biology to Healthcare, in Human Perspectives in Health Sciences and Technology, Springer.

Bertolaso M, Sterpetti F (Eds) (2020), A Critical Reflection on Automated Science – Will Science Remain Human?, in Human Perspectives in Health Sciences and Technology, Springer

Bertolaso M., Capone L., Rodriguez-Lluesma C. (Eds.) (2022), Digital Humanism. A human-centric approach to digital technologies, Palgrave

Bertolaso M., Marcos A. (2023) Umanesimo tecnologico. Una riflessione filosofica sull'intelligenza artificiale, Carocci, Roma.

Bertolaso, M., and M. Rocchi (2020). Specifically Human: Human Work and Care in the Age of Machines. Business Ethics, the Environment and Responsibility 31(3): 888–898.

Bertolaso, M., Lo Storto, G. (Eds.) (2020) Etica Digitale, Verità, responsabilità e fiducia nell'era delle macchine intelligenti, Luiss Editore

Bertolaso, Sangiovanni Vincentelli (2024) Innovazione sostenibile in Lo spazio oltre lo spazio (Boschetto Ed), Rubettino ; https://www.store.rubbettinoeditore.it/catalogo/lo-spazio-oltre-lo-spazio/.

Daniel J Fremont, Edward Kim, Tommaso Dreossi, Shromona Ghosh, Xiangyu Yue, Alberto L Sangiovanni-Vincentelli, Sanjit A Seshia, Scenic: A language for scenario specification and data generation, Machine Learning 112 (10), 3805-3849, 2023

Edwards, I. R. (2018). Living with complexity and big data. Uppsala Reports, 78, 28–29.

European Commission, Proposal for a Regulation of the European Parliament and of the Council laying down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts, 2021, https://eurlex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0206.

High Level Expert Group on Artificial Intelligence, Ethics Guidelines for Trustworthy AI, 2019, https://digitalstrategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

Id., Policy and Investment Recommendations For Trustworthy AI, 2019, https://digitalstrategy.ec.europa.eu/en/library/policy-and-investment-recommendations-trustworthy-artificial-intelligence

IEEE Design & Test of Computers 29 (3), 49-50, 2012

Luca P Carloni, Fernando De Bernardinis, Claudio Pinello, Alberto L Sangiovanni-Vincentelli, and Marco Sgroi, Platform-based design for embedded systems, Embedded Systems Handbook, 1st ed.; CRC Press: San Francisco, CA, USA.

Michael I Jordan, Tom M Mitchell, Machine learning: Trends, perspectives, and prospects, Science 349 (6245), 255-260

Michael I. Jordan, Michael I. Jordan: An Alternative View on AI: Collaborative Learning, Incentives, and Social Welfare, Stanford Data Science, Aug 30, 2023.

Russell, S. J., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.

UNESCO, Recommendation on the ethics of artificial intelligence, 2021, https://en.unesco.org/artificial-intelligence/ethics

World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), Preliminary Study on the Ethics of Artificial Intelligence, 2019, https://en.unesco.org/themes/ethics-science-and-technology/comest

X He, J Wu, Z Huang, Z Hu, J Wang, A Sangiovanni-Vincentelli, C Lv, Fear-neuro-inspired reinforcement learning for safe autonomous driving, IEEE transactions on pattern analysis and machine intelligence, 2023

Roma, 25/11/2024

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

National PhD in Artificial Intelligence
Area of specialization: Health and Life Sciences

Title: Cloud-Edge Continuum

Number of hours: 25

Institution(s): Università della Campania "Luigi Vanvitelli"

Location(s): Dipartimento di Ingegneria – via Roma n. 29 – Aversa (CE) /Online

Type: Ph.D. course

Attendance Mode: Online/Phygital

Final Exam: Yes

Lecturer(s): Beniamino Di Martino, Dario Branco, Antonio Esposito, Salvatore D' Angelo

Responsible Expert(s)\email: Beniamino Di Martino, University of Campania "Luigi Vanvitelli" – beniamino.dimartino@unicampania.it – dario.branco@unicampania.it – antonio.esposito@unicampania.it – salvatore.dangelo@unicampania.it

Academic Year: 2023/2024

Semester: 2

Timetable: From March to June 2025. Final dates to be defined.
Students who wish to attend the course are invited to contact the lecturer by mid-February. Specific dates will be communicated to interested students.

Abstract:
The main issue affecting Cloud-based services today is the need for more portability and interoperability between Cloud platforms at different service levels. The brokering, negotiation, management, monitoring, and reconfiguration of Cloud resources are challenging tasks for developers and users of Cloud applications due to the different business models associated with resource consumption and the variety of services and features offered by different Cloud providers.
The emergent Distributed Architectural Scenario of Cloud-Edge Continuum, where distributed applications are deployed along the entire spectrum of Cloud-Fog-Edge computational devices (including 5G and IoT devices) and where computational components can be offloaded near the data sources, is particularly amenable for application domains such as E-Health, where locality of data-streams processing, ultra-low latency, and privacy requirements are paramount.
This course offers a comprehensive and up-to-date overview of the most important methodologies, technologies, and standards related to the portability, interoperability, deployment, and orchestration of Cloud and Cloud-edge distributed applications and services, illustrated by several use cases representing a variety of scenarios; relevant Cloud and Cloud-Edge Architectural Patterns will be illustrated. Examples and case studies from relevant application domains, such as Federated Learning and AR / VR collaborative environments, will be illustrated. Emphasis is placed on their application in the healthcare

domain, where the integration of sensors and distributed machine learning further accentuates their significance.

Learning Outcomes:

Detailed lecture contents:

Introduction to Cloud and Cloud-Edge Computing:

- Definition and exploration of Cloud Computing, emphasising key characteristics.
- Introduction to Cloud-Edge Computing, highlighting its significance and evolution.

Characteristics and Reference Models:

- Examination of essential characteristics of Cloud Computing, including on-demand self-service and resource pooling.
- Comparison of Cloud service models (IaaS, PaaS, SaaS) and deployment models (public, private, hybrid, community).
- Analysis of distinct characteristics specific to Cloud-Edge Computing.

Virtualization:

- Explanation of virtualization and its role in Cloud Computing.
- Discussion of various virtualization types (server, network, storage) and their applications in Cloud environments.

Multi-Cloud and Cloud Interoperability:

- Definition of multi-Cloud architecture and its advantages.
- Discussion of challenges and solutions for achieving interoperability among different Cloud providers.

Reference Architectures and Open Source Frameworks:

- Overview of popular reference architectures for Cloud Computing.
- Overview of popular reference architectures for Cloud -Edge Computing.
- Introduction to open-source frameworks facilitating Cloud and Cloud-Edge development and deployment.

Cloud and Cloud-edge Patterns

- Discussion of design patterns for Cloud applications independent of specific providers.
- Exploration of patterns optimised for particular Cloud services.
- Discussion of patterns specific for Cloud-Edge Computing
    - Cloud Edge Architectural Patterns
    - Cloud Edge Orchestrational Patterns
    - Cloud Edge Computational Patterns
    - Cloud-Edge Deployment Patterns

Cloud and Cloud-Edge Application Deployment and Management Automation:

- Introduction to automation tools and frameworks for deploying and managing applications in Cloud and edge environments.

- Containers and Docker:
  - Definition of containerization and its advantages for application deployment.
  - Exploration of Docker as a widely-used containerization platform.
- **Infrastructure as Code (IAC):**
  - Discussion of orchestrators such as Kubernetes, Ansible, Chef, Juju, and OpenShift.
  - Exploration of their roles in managing and orchestrating containerized applications in Cloud and edge environments.
- TOSCA: Topology and Orchestration Specification for Cloud Applications - Illustration of the TOSCA standard and its role in describing complex Cloud application topologies.

Cloud-Edge Computing Scenarios:

- Centralized learning VS Decentralized learning: conceptual differences, advantages and disadvantages.
- Examination of examples of decentralized learning: Federated Learning VS Distributed Learning.
- Exploration of scenarios where applications are deployed at the edge for enhanced performance and efficiency.
- Application of Cloud and Cloud-Edge paradigms and technologies to real case studies and application domains, specifically E-health

Teaching method: Both lectures and laboratory sessions. A portion of the lectures will be conducted in the Italian language.

Final Exam: Completion of a home assignment, followed by oral discussion, constitutes an integral component of the final examination

Prerequisites: Fundamentals of Computing Architectures, and fundamentals of Software Engineering.

Key Bibliography:

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

Title: Assessing the understandability of AI solutions in psychiatry

Number of hours: 30

Institution(s): Universita' degli Studi di Bari Aldo Moro

Location(s): Online and in presence

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Dr. Cristina Berchio

Responsible Expert(s)\email: Cristina Berchio, Universita' degli Studi di Bari Aldo Moro, cristina.berchio@uniba.it

Academic Year: 2024-2025

Semester: 1/2

Timetable: January-February 2025. Course start date: 9 January 2025.
Students who wish to attend the course are invited to contact Dr. Berchio by January 9 th.

Days of Classes:
-09/01/2025 h 14-18;
-16/01/2025 h 14-18;
-23/01/2025 h 14-18;
-30/01/2025 h 14-18;
-06/02/2025 h 14-18;
-13/02/2025 h 14-18;
-20/02/2025 h 14-18;
-21/02/2025 h 14-17.

Place : Dipartimento di Informatica, Campus Biomedico, Bari.

Abstract:
This course aims at assessing the understandability of artificial intelligence (AI) solutions in Psychiatry by investigating whether embedding clinical, behavioral, pathophysiological, and genetic information into AI models reduces uncertainty and generates more clinically relevant decisions. Psychiatric disorders show highly variable characteristics and risk factors. Therefore, AI prognostic and diagnostic solutions are fed with a wide variety of patient related information (e.g., symptoms, behaviors, brain-related data). Because different diagnostic categories are often associated with drastically different clinical

manifestations and neurobiological substrates, explaining clinical phenomena with AI is challenging. We will address this challenge by presenting algorithms that discriminate between psychiatric diagnoses based on multimodal data informed by biological and clinical priors. We will show AI solutions that are interpretable in clinical settings, besides generating a more comprehensive view of the pathophysiology of psychiatric conditions.

Learning Outcomes:
Students will gain knowledge and understanding about:
- Basic elements of AI in the field of psychiatry and neurobiological research;
- Applicability of AI models to brain-related data, with a specific focus on electrophysiology;
- Applicability of AI models to cognitive assessment, with a specific focus on psychiatric disorders.

Detailed lecture contents:
-Introduction to the basic concepts of AI in the context of cognitive assessment in psychiatry;
-Neurobiological bases of cognitive functions, cognitive and neurobiological deficits in the psychiatric context, using AI to understand and model cognitive functions, cognitive assessment tools;
- Discussion of research studies integrating AI in cognitive assessment;
-Ethical considerations in the use of AI in cognitive assessment, transparency and interpretability of AI models in cognitive assessment, impact of privacy and data security in AI-enhanced cognitive assessment;
-Use of AI in the diagnosis and treatment of psychiatric disorders, AI-based cognitive assessment in specific populations (e.g., children, elderly, at high-risk individuals), challenges and opportunities in applying AI to cognitive assessment;
-Limitations and challenges in implementing AI in cognitive assessment, discussion of cases and practical applications, new directions and research opportunities in applying AI to cognitive assessment.

Teaching method:
Lectures and exercitations.

Final Exam:
Students present the content of 1/2 papers suggested by the teacher. Final exam will be held during regular class times.

Prerequisites:
None.

Key Bibliography:
Scientific articles and book chapters concerned with the topics.

Title: Law and Science

Number of hours: 30

Institution(s): Università Campus Bio-Medico di Roma and NLAB Research Center at ASST GOM NIGUARDA

Location(s): Phygital

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Dr. Stefano Regondi, email: stefano.regondi@nemolab.it

Responsible Expert(s)\email: Dr. Stefano Regondi, email: stefano.regondi@nemolab.it, Director NLAB Research Center at ASST GOM NIGUARDA

Academic Year: 2024-2025

Semester: 2

Timetable:

The course will be held in 3 months considering approximately 10 h a month for lectures. The proposed dates are:

Wednesday 05/03/2025 h 11.00-13.00 Phygital

Wednesday 12/03/2025 h 11.00-13.00 Phygital

Wednesday 19/03/2025 h 10.00-13.00 (Dr. Regondi is avalaible at Campus Biomedico)

Wednesday 26/03/2025 h 10.00-13.00 Phygital

Wednesday 09/04/2025 h 11.00-13.00 Phygital

Wednesday 16/04/2025 h 11.00-13.00 Phygital

Wednesday 23/04/2025 h 10.00-13.00 (Dr. Regondi is avalaible at Campus Biomedico)

Wednesday 30/04/2024 h 10.00-13.00 Phygital

Wednesday 07/05/2025 h 11.00-13.00 Phygital

Wednesday 14/05/2025 h 11.00-13.00 Phygital

Wednesday 21/05/2025 h 10.00-13.00 Phygital

Wednesday 28/05/2025 h 10.00-13.00 Final exam (Dr. Regondi is available at Campus Bio-medico)
Students who wish to attend the course are invited to contact the lecturer to enroll in the course.

Abstract:
In an era where science and technology rapidly evolve, the interplay between law and these domains becomes increasingly significant. This course offers a comprehensive exploration of the legal, ethical, and policy issues at the intersection of law, science, and technology. The curriculum focuses on how legal frameworks adapt to and shape advancements in several scientific fields, particularly genetics, biotechnology, artificial intelligence (AI), and robotics.
This course aims to equip students with a profound understanding of the legal challenges posed by scientific and technological advancements. Through a blend of theoretical and case-based learning, students will gain insights into the dynamic legal landscape surrounding cutting-edge technologies, preparing them to navigate and shape the future of law in the age of technology.

Learning Outcomes:

1. Understanding AI and Legal Frameworks: Students will gain a comprehensive understanding of the legal frameworks governing AI research, including international and national regulations, data protection laws, and intellectual property rights.
2. Ethical Principles in AI Research: Students will learn the fundamental ethical principles guiding AI research, including respect for autonomy, beneficence, non-maleficence, and justice. They will be able to identify ethical challenges specific to AI, such as bias, transparency, and accountability.
3. Protocol Development for Ethical Committees: The course will equip students with the skills to develop and submit scientifically rigorous and ethically sound research protocols to Ethical Committees. This includes the ability to articulate the research's purpose, methodology, potential impacts, and ethical considerations.
4. Critical Analysis of AI in Healthcare: Students will critically analyze the use of AI in healthcare, evaluating the ethical implications of AI-driven diagnostics, treatment planning, and patient data management.
5. Case Study Analysis: Through the examination of real-world case studies, students will learn to apply legal and ethical frameworks to practical scenarios, enhancing their problem-solving and decision-making skills.
6. Interdisciplinary Collaboration: Students will understand the importance of interdisciplinary collaboration between legal experts, computer scientists, ethicists, and healthcare professionals in conducting responsible AI research.

Detailed lecture contents:
The study of how law interacts with science and technology is more critical and relevant now than before. In the course we will examine these following topics:

I. Ethics and law in Genetics / Biotechnology and law / Biobanks, DNA and research: "Legal regulation of genome editing with the CRISPR/Cas9 technology as an example".

II. Medical Artificial Intelligence: Ethics, Law, & Policy

III. Legal Analytics and AI for Health Sources

IV. Computational models of legal and ethical reasoning: Guidelines and Recommendations for Data Integration and Model Validation / Formal Models of Norms and Legal Reasoning Logic-based models of norms and legal knowledge / Case Reports: Leveraging electronic medical records to extract experiential clinical knowledge for forensic medicine: an automated approach; Artificial intelligence in cancer: bridging the gap between computational power and clinical decision-making; building computational models of mental ill health for decision making;

V. Normative Multi-Agent Systems and e-Institutions Regulatory Compliance

VI. Regulation of Robotics, AI-based robotic surgery and Related Ethical Issues

VII. Privacy and Security with New Technology Cybercrime and Computer Forensics / Computer forensics and security

VIII. IPR and New Medical Technology

IX. Regulation (EU) 2016/679 of 27 April 2016 on the protection of natural persons regarding the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) in research and clinical activities.

X. Regulation (EU) 2017/745 of 5 April 2017 on the use of medical devices.

XI. Regulation (EU) 2017/746 of 5 April 2017 on the use of diagnostic devices.

XII. Regulation (EU) on the use of AI (AI ACT).

XIII. Artificial Neural Networks, Deep Learning, and generative language models for an intelligent and ethical healthcare professional

XIV. Legal cases

Teaching method:
The course is structured with some theoretical lessons supported by slides provided by the lecturer and with some practical lessons regarding legal cases.

Final Exam:
The student will prepare slides solving or discussing a topic related during the course (min 10 slides/max 20slides). The topic will be either proposed by the teacher or chosen by the student.

Prerequisites:
None

Key Bibliography:

- 1. *Genome Editing and Engineering* (pp.421-463), Publisher: Cambridge University Press, Publication Year: 2018, Link to the book
- 2. *Artificial Intelligence Law*, Publisher: Intersentia, Publication Year: 2023, Link to the book

- 3. *Artificial Intelligence and Legal Analytics*, Publisher: Cambridge University Press, Publication Year: 2017, Link to the book
- 4. *Robotics, AI and the Future of Law*, Series: Perspectives in Law, Business and Innovation, Publisher: Springer, Publication Year: 2018, Link to the book

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Quantum Artificial Intelligence

Number of hours: 10

Institution: Università Campus Bio-Medico di Roma

Location(s): Online

Type: Ph.D. course

Attendance Mode: Online

Final Exam: Yes

Lecturer: Prof. Filippo Caruso

Affiliation: Physics and Astronomy Department, Florence University, filippo.caruso@unifi.it

Academic Year: 2024/2025

Semester: 2

Timetable:
- Monday 07/04/2025 h 9.00-12.30
- Tuesday 08/04/2025 h 9.00-12.30
- Wednesday 09/04/2025 h 9.00-12.00

Students who wish to attend the course are invited to contact the lecturer to enroll in the course.

Abstract:
Quantum Artificial Intelligence (Quantum AI) is a very young but rapidly developing research field combining AI with the huge power of quantum computers that today are becoming available via cloud and even on the market. This intensive short course sheds light on this new Quantum AI framework presenting an overview of the basic elements of quantum computing and quantum machine learning, where supervised and unsupervised ML, reinforcement learning algorithms, and generative AI models can be generalized to the quantum world, running on real, very powerful, quantum processing units.

Learning Outcomes: knowledge of the basic elements of quantum computing and quantum machine learning, understanding differences and advantages as compared to classical machine learning

Detailed lecture contents:
- Introduction to Quantum Computing
- Introduction to Quantum Machine Learning (QML)
- Parametric Quantum Circuits (PQC)
- Deterministic and Probabilistic QML models
- Quantum Kernel Theory

- Quantum Deep Learning
- Quantum Generative AI
- Applications on cloud-available real Quantum Processing Units (QPU)

Teaching method: Digital Whiteboard and/or Slides

Final Exam: Project work - written thesis and oral colloquium

Prerequisites: Basic knowledge of mathematical analysis and linear algebra

Key Bibliography: Machine Learning with Quantum Computers, M. Schuld and F. Petruccione, Springer Nature 2021.

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

Title: Big Data in Healthcare

Number of hours: 15

Institution(s):University of Messina

Location(s): Online

Type: Ph.D. course

Attendance Mode: Online

Final Exam: Yes

Lecturer(s): Prof. Antonio Celesti

Responsible Expert(s)\email: Prof. Antonio Celesti, University of Messina, email: acelesti@unime.it

Academic Year: 2024/2025

Timetable:

2nd Semester academic year 2024-2025
-Thursday, June 5th, 2025 h. 11:00-13:00
-Tuesday, June 10th, 2025 h. 14:00-17:00
-Thursday, June 12th, 2025 h. 11:00-13:00
-Tuesday, June 17th, 2025 h. 14:00-17:00
-Thursday, June 19th, 2025 h. 11:00-13:00
-Tuesday, June 24th, 2025 h. 14:00-17:00
-Thursday, June 26th, 2025 h. 11:00-13:00
-Tuesday, July 8th, 2025 h. 14:00-17:00
-Thursday, July 10th, 2025 h. 11:00-13:00
-Tuesday, July 15th, 2025 h. 14:00-17:00

Students who wish to attend the course are invited to contact the lecturer to enroll in the course.

Abstract: The use of Big Data in biomedical and health sciences has received a lot of attention in recent years. These pieces of data present a significant opportunity for the improvement of the diagnosis, treatment and prevention of various diseases, and to interventions to improve health outcomes. The objective of the course is to provide the basic knowledges to understand, design, develop Big Data Systems. Morevover, particular attention will be given to methodologies and software tool for Big Data Storage, Warehousing and advanced Machine Learning based Analytics. In the end, case studies on the adoption of Big Data in healthcare will be discussed.

Learning Outcomes:

-Understanding Big Data and how the way to manage information changes with respect to the past;
-Understanding NoSQL DBMS for Big Data;
-Acquire the skills to design and develop Big Data Warehouse systems;
-Acquire the skills to design and develop advanced Big Data Analytics systems based on Machine Learning;
-Understand how Big Data systems can be used to address healthcare problems.

Detailed lecture contents:

Introduction to Big Data. Understanding Big Data; Evolution of Big Data; Failure of Traditional Database in Handling Big Data; 3Vs of Big Data; Sources of Big Data; Different Types of Data; Big Data Infrastructure; Big Data Life Cycle; Big Data Technology; Big Data Storage; NoSQL DBMS; Driving Big Data with the Hadoop Technology; Big Data Applications; Big Data Use Cases.

Big Data Analytics. Terminology; Life Cycle; Analytics Techniques; Semantic Analysis; Visualanalysis; Business Intelligence; Real-Time Analytics Processing; Enterprise Data Warehouse; Machine Learning.

Improving Healthcare with Big Data. Big Data and Health; Big Data and Health in Low- and Middle-Income Countries; Analytical Challenges; Ethical Challenges;

Healthcare Data Analytics. Healthcare Data Sources and Basic Analytics (Electronic Health Records; Biomedical Image Analysis, Sensor Data Analysis, Biomedical Signal Analysis, Genomic Data Analysis, Clinical Text Mining, Mining Biomedical Literature, Social Media Analysis); Advanced Data Analytics for Healthcare (Clinical Prediction Models, Temporal Data Mining, Visual Analytics, Clinico–Genomic Data Integration, Information Retrieval, Privacy-Preserving Data Publishing); Applications and Practical Systems for Healthcare (Data Analytics for Pervasive Health, Healthcare Fraud Detection, Data Analytics for Pharmaceutical Discoveries, Clinical Decision Support Systems Computer-Aided Diagnosis, Mobile Imaging for Biomedical Applications); Extracting Disease Surveillance Information.

Teaching method:
The course is structured with four theorical lessons supported by slides provided by the lecturer and with one practical lesson focusing on the Apache Hadoop framework.

Final Exam: Knowledge gained during the course will be assessed with a pitch discussing a Big Data problem that can be addressed with a software tool of the Apache Hadoop framework chosen by the student. No additional time for the finalexam is needed, since it is already scheduled as part of the course.

Prerequisites: no prerequisite is required.

Key Bibliography:

1. Pouria Amirian, Trudie Lang, Francois van Loggerenberg. Big Data in Healthcare: Extracting Knowledge from Point-of-Care Machines. Springer Cham, eISBN: 978-3-319-62990-2.

2. Chandan K. Reddy, Charu C. Aggarwal. HealtHcare Data analytics. CRC Press, eISBN: 9780429183447
3. Sergio Consoli, Diego Reforgiato Recupero, Milan Petković. Data Science for Healthcare: Methodologies and Applications, Springer, eISBN 978-3-030-05249-2.
4. Rahul K., Banyal R.K., Arora N. A systematic review on big data applications and scope for industrial processing and healthcare sectors (2023) Journal of Big Data, 10 (1), art. no. 133
5. Venkatraman S., Parvin S., Mansoor W., Gawanmeh A. Big data analytics and internet of things for personalised healthcare: opportunities and challenges
6. (2023) International Journal of Electrical and Computer Engineering, 13 (4), pp. 4306 - 4316.
7. Arfaoui N. A new process for healthcare big data warehouse integration (2023) International Journal of Data Mining, Modelling and Management, 15 (3), pp. 240 - 254
8. Chao K., Sarker M.N.I., Ali I., Firdaus R.B.R., Azman A., Shaed M.M. Big data-driven public health policy making: Potential for the healthcare industry
9. (2023) Heliyon, 9 (9).
10. Alzaabi H.M., Alawadhi M.A., Ahmad S.Z. Examining the impact of cultural values on the adoption of big data analytics in healthcare organizations (2023) Digital Policy, Regulation and Governance , 25 (5), pp. 460 - 479
11. Sangaiah A.K., Rezaei S., Javadpour A., Zhang W. Explainable AI in big data intelligence of community detection for digitalization e-healthcare services
12. (2023) Applied Soft Computing, 136.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Knowledge Engineering

Number of hours: 25

Institution(s): University of Campania "Luigi Vanvitelli"

Location(s): Department of Engineering – via Roma n. 29 – Aversa (CE) / Online

Type: PhD Course

Attendance Mode: Online/Phygital

Final Exam: Yes

Lecturer(s): Beniamino Di Martino, Luigi Colucci Cante, Mariangela Graziano

Responsible Expert(s)\email: Beniamino Di Martino - Università della Campania "Luigi Vanvitelli" – beniamino.dimartino@unicampania.it – luigi.coluccicante@unicampania.it – mariangela.graziano@unicampania.it

Academic Year: 2024/2025

Semester: 2

Timetable: from September to December 2025. Students who wish to attend the course are invited to contact the lecturer by mid-February. Specific dates will be communicated to interested students.

Abstract:
The course introduces the topics and concepts of the field of Artificial Intelligence that deals with the Representation and Management of Knowledge, through methods and techniques based mainly on Logic and the production of rules. After an introduction, focused on the presentation of concrete examples of Intelligent Systems based on Rule-based techniques, we start with an overview of Problem-Solving techniques based on Research in State Spaces. The main models for the Representation of Knowledge are then introduced, with an in-depth study dedicated to the architecture and languages of the Semantic Web. We then move on to models and techniques of automated reasoning based on deduction and inference, in particular models based on Logic, with particular attention to the language of inference for the Semantic Web – SWRL. Finally, important fields of application of the methods illustrated are presented: Natural Language Processing, Process Mining and Semantic Web Services.

Learning outcomes:

Detailed lecture contents:

Introduction to AI

Genesis and Challenges of Artificial Intelligence

Intelligent Systems: Examples from the Past and Present

Models and Techniques for Knowledge's Representation

Introduction to Knowledge Based Systems

Classical Models of Knowledge Representation: Semantic Networks, Conceptual Graphs, Frames, Scripts, Triple OAV

Wordnet, an example of a Semantic Network

Semantic Web

Introduction to Semantic Web and its Stack

RDF and RDFS Metadata Description Languages

Open Data and Linked Open Data

OWL: a Semantic Web Language for managing ontologies

Creation of OWL ontologies with Protege Tool

Semantic Web Services with OWLS

Reasoning and related languages for the Semantic Web

Logic-based reasoning models

An RDF/OWL Query Language: SPARQL

An Inference Language for the Semantic Web: SWRL

Process Mining and Multi-agent Systems

Introduction to Process Mining as a Link between Data Science and Process Science

Process Mining Techniques

Overview of main Process Models

Algorithms for Process Mining Discovery

Representational Bias, Noise, Incompleteness and Quality Assessment of Discovered Process Models

Algorithms for Process Mining Conformance Checking

Additional Perspectives of Process Mining: Organizational Mining (Social Network Analysis and Role Discovery), Case Perspective (Decision Mining), Time Perspective

Introduction to Process Mining Operation Support

Process Mining Tool: Introduction to ProM

Introduction to agents

Multi-agent systems

Semantic Agents

Natural Language Processing

Introduction to Text Mining, Natural Language Processing Levels and NLP Pipeline

Text Pre-Processing Techniques: stopwords removal, lemmatization, stemming, regex

Text Analysis Techniques: Named Entity Recognition and POS-Tagging

Natural Language Processing Libraries: NLTK and SPACY illustration

Text Vectorization Techniques: Bag of Word, TF-IDF

Word Embedding algorithms: Word2Vec (Skip-Gram and CBOW architectures) and GloVe

Semantic Annotation of Text, with illustration by Open Source and Free Annotators

Application of Deep Learning to NLP

A Text Generation overview: Recurrent Neural Network (RNN), Transformers, Generative Adversarial Networks (GAN)

Teaching method: lectures and lab. Most of the lectures will be given in Italian Language, and part of them will be teached asynchronously, through a MOOC platform.

Final exam: Home assignment and oral discussion of it

Prerequisites: Procedural Programming skills, notions of Boole Algebra, Graphs and databases

Key bibliography:

George F. Luger – Artificial Intelligence: Structures and Strategies for Complex Problem Solving – Addison Wesley
Grigoris Antoniou et al. – A Semantic Web Primer – MIT Press
Leon Sterling, Ehud Shapiro – The Art of Prolog – MIT press
Wil M. P. van der Aalst - Process Mining - Discovery, Conformance and Enhancement of Business Processes
Steven Bird, Ewan Klein, and Edward Loper - Natural Language Processing with Python – Analyzing Text with the Natural Language Toolkit

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Hands-on Machine Learning & Deep Learning

Number of hours: 20

Institution(s): Università Campus Bio-Medico di Roma

Location(s): Università Campus Bio-Medico di Roma, Via Álvaro del Portillo, 21, 00128 Roma

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Valerio Guarrasi

Responsible Expert(s)\email: Valerio Guarrasi, valerio.guarrasi@unicampus.it

Academic Year: 2023/2024, 2024/2025

Semester: 2 semester a.a. 2023/2024, 2024/2025

Timetable: The course will be held in 6 lectures during the second half of March. Students who wish to attend the course are invited to contact the lecturer by mid-February. Specific dates will be communicated to interested students.

Abstract:
In this course, students will gain an understanding of Machine Learning and Deep Learning concepts, algorithms, and applications. They will learn how to develop and implement various Machine Learning models using Python and acquire the skills to choose the appropriate models for different types of problems. Building intuition for these models and their practical uses is a key objective, along with mastering the skills for making accurate predictions and robust analyses.

Learning Outcomes:
Upon completion, students will have the practical knowledge to apply Machine Learning models to real-world problems, with a particular skill in selecting and applying the right model for each situation. They will be competent in handling and analyzing data, making predictions, and have proficiency in Deep Learning techniques for complex problem-solving. The course also aims to develop the capability to initiate, develop, test, and refine Machine Learning projects

Detailed lecture contents:
The Machine Learning Process (3h):

- Introduction to Machine Learning
- Data Preprocessing

Regression Models (4h):

- Simple Linear
- Multiple Linear
- Polynomial Regression
- Bias vs Variance, overfitting
- Support Vector Regression
- Decision Tree Regression
- Random Forest Regression
- Evaluating Regression Models

Classification Models (3h):

- Logistic Regression
- k-NN
- SVM
- Kernel SVM
- Naive Bayes
- Decision Tree Classification
- Random Forest Classification
- Evaluating Classification Models

Clustering Techniques (4h):

- K-Means
- Hierarchical Clustering
- DB-Scan
- Expectation-Maximization
- Evaluating Clustering Models

Deep Learning (6h):

- Artificial Neural Networks
- Convolutional Neural Networks
- Autoencoders

Teaching method:
Interactive Lectures: To introduce and explain key concepts.
Hands-on Tutorials: Python-based exercises for practical experience.
Case Studies: Real-life examples to illustrate the application of theories.

Final Exam:
Knowledge gained during the course will be assessed with a project work based on the development and performance of models in a practical project.

Prerequisites:
Basics of programming

Key Bibliography:
Bishop, Christopher M., and Nasser M. Nasrabadi. Pattern recognition and machine learning. Vol. 4. No. 4. New York: springer, 2006.

Etica Personalista Applicata all'Intelligenza Artificiale

Vittoradolfo Tambone, Nicola Di Stefano, Francesco De Micco

7h - A/A 2024-2025

1. Introduzione all'Etica Personalista

- **1.1 Fondamenti del Personalismo**
  - La persona umana.
  - Relazione persona-persona; persona-natura; persona-tecnologia.
  - Trascendenza.
- **1.2 Il Personalismo e l'Etica**
  - Persona umana e felicità.
  - Virtù relazionali.

2. L'AI alla Luce del Personalismo

- **2.1 Rilettura Personalista della Tecnologia**
  - La tecnologia come alterazione rafforzativa della persona.
  - Tecnologia come Atto Umano.
- **2.2 AI e Antropologia Personalista**
  - Differenza qualitativa tra persona e macchina.
  - Libertà della persona e gradi di libertà della macchina.
  - Correlazione e Interpretazione.

3. Principi Etici Personalisti Applicati all'uso della AI

  - Non esiste un'Etica della AI.
  - Oltre l'implicito economico e politico della progettazione di Algoritmi.
  - Distinguere il discorso analogico da quello identitario nella dinamica AI/HI.

4. Casi Studio Personalisti sull'AI in Life Science

  - Diagnosi assistite da AI: il falso confronto fra decisioni umane e algoritmiche.
  - Rinuncia all'uso della AI come Malpractice.
  - GAN Ibridi e Nuova Metodologia Clinica Ibrida.
  - Temperatura degli Algoritmi ed Evidence Based Medicine.

Metodologia Didattica

- **Lezioni frontali e dialogiche**: esplorazione dei fondamenti del personalismo e delle sue applicazioni (3h)
- **Analisi di casi studio**: rilettura di esempi reali attraverso la lente del personalismo (4h)

Valutazione

- Partecipazione attiva.
- Elaborati su casi di studio applicati ai principi personalisti.
- Progetto finale: proposta di un sistema di AI che rispetti i criteri etici personalisti.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Introduction to Bioinformatics and Artificial Intelligence for Multi-Omics Sciences

Number of hours: 25

Institution(s): University of Siena

Location(s): Online

Type: Ph.D. course

Attendance Mode: Online

Final Exam: Yes

Lecturer(s): Prof. Fabrizio Celesti

Responsible Expert(s)\email: Prof. Fabrizio Celesti, Department of Medicine, Surgery and Neurosciences, University of Siena, email: fabrizio.celesti@unisi.it.

Academic Year: 2024/2025

Timetable:

2nd Semester academic year 2024-2025.
Every Tuesday h. 09:00 - 11:00 and Thursday h. 09:00 - 12:00 from May 6th, 2025 to June 5th, 2025.

Abstract:
The course provides an exploration of the intersection of bioinformatics and artificial intelligence (AI) within the context of Multi-Omics Sciences, including genomics, transcriptomics, proteomics, and epigenomics. The course is designed to equip students with theoretical knowledge and practical skills to analyse and integrate large-scale biological data using cutting-edge computational tools and AI-driven methods.
Key topics include an overview of basic concepts of biology, Multi-Omics data types and technologies, statistical and computational methods for data processing and integration, and the role of AI in uncovering complex biological patterns. Special emphasis is placed on approaches for biomarkers discovery, precision medicine, and network-based Multi-Omics analysis. Students will also gain hands-on experience with software tools and programming languages (e.g., R).
By the end of the course, participants will be able to design and execute advanced computational workflows for Multi-Omics data, critically evaluate AI models for biological research, and contribute to innovative solutions in systems biology and personalised medicine. This course is ideal for students with backgrounds in biology, biotechnology, bioinformatics, computer science, or related disciplines who aim to advance their expertise in the rapidly evolving field of bioinformatics and AI applied to Multi-Omics Sciences.

Learning Outcomes:

- **Comprehensive understanding of biology foundations**. Acquire basic knowledge of biological concepts and understanding of biological data sources.
- **Comprehensive understanding of Multi-Omics data**. Gain a deep understanding of the principles, methodologies, and challenges related to Multi-Omics data.
- **Gain proficiency in Bioinformatics.** Develop expertise to analyse Multi-Omics data by using computer science tools.
- **Understanding how to use AI in Multi-Omics research**. Learn how to design, apply, and evaluate AI-based approaches for extracting meaningful insights from Multi-Omics data.
- **Understanding of how to develop Multi-Omics pipelines.** Acquire how to build and implement workflows for data preprocessing, normalization, integration, and interpretation, enabling robust and reproducible Multi-Omics research.
- **Acquire the knowledges to solve biological problems.** Gain awareness of how to use Multi-Omics pipelines to solve problems regarding biomarkers discovery, precision medicine, and systems biology.

Detailed Lecture Contents:

- **Introduction to Biological Data.** Definition and Sources of Biological Data; Characteristics of Biological Data; Applications of Biological Data; Challenges in Handling Biological Data.
- **Foundations of the Multi-Omics Science**. Introduction to Multi-Omics Data; Overview of Omics Layers (Genomics, Transcriptomics, Proteomics, Epigenomics); Technologies and Platforms Enabling Multi-Omics; Multi-Omics Workflow; Data Integration, Analysis and Interpretation.
- **Bioinformatics and AI applied to Multi-Omics.** Challenges in Multi-Omics Data Interpretation; Functional Annotation and Pathway Analysis; Application of Bioinformatics and AI Tools; Methodological Limitations.
- **Healthcare Application in Multi-Omics.** Understanding Biological Systems; Biomarkers Discovery; Early Disease Diagnosis; Precision Medicine and Personalized Healthcare; Challenges in Multi-Omics Research; Future Perspectives.

Teaching Method: The course is structured with theoretical and practical lessons supported by slides.

Final Exam: Knowledge gained during the course will be assessed with an oral exam. No additional time is needed since it is already scheduled as part of the course.

Prerequisites: No prerequisite is required.

Key Bibliography:

1. Manish Kumar Gupta, Pramod Katara, Sukanta Mondal, Ram Lakhan Singh. Integrative Omics: Concept, Methodology, and Application. Academic Press, eBook ISBN: 9780443160936.
2. Mario Cannataro, Pietro Hiram Guzzi, Giuseppe Agapito. Artificial Intelligence in Bioinformatics: From Omics Analysis to Deep Learning and Network Mining. Elsevier, eBook ISBN: 9780128229293.

3. Debmalya Barh, Vasco Ariston De Car Azevedo. Omics Technologies and Bio-engineering. Academic Press, eBook ISBN: 9780128047491.
4. Adam Bohr, Kaveh Memarzadeh. Artificial Intelligence in Healthcare. Academic Press, eBook ISBN: 9780128184394.
5. Loo Keat Wei. Computational Epigenetics and Diseases. Academic Press, eBook ISBN: 9780128145142.
6. Momiao Xiong. Big Data in Omics and Imaging: Association Analysis. Chapman and Hall/CRC, eBook ISBN 9781315370507.

Title: Network Science and Applications in Biology, Health Sciences, and Neuroscience

Number of hours: 12

Institution(s): Università di Bari

Location(s): Online

Type: Ph.D. course

Attendance Mode: Online

Final Exam: Yes

Lecturer(s): Nicola Pedreschi, Giulio Pergola

Responsible Expert(s)\email: Nicola Pedreschi, Università di Bari, nicola.pedreschi@uniba.it

Academic Year: 2024/2025

Semester: 2

Timetable: 2st semester a.a. 2024/2025

- Monday 12/05/2025, 11:00-13:00
- Thursday 15/05/2025, 11:00-13:00
- Monday 19/05/2025, 11:00-13:00
- Thursday 22/05/2025, 11:00-13:00
- Monday 26/05/2025, 11:00-13:00
- Thursday 29/05/2025, 11:00-13:00
- Thursday 05/06/2025, 10:00-13:00 (Final Exam)

Abstract:
This course integrates Network Science with a focus on its applications in biology, health sciences, and neuroscience. Participants will explore how complex biological systems, such as (among others) gene co-expression networks and neural networks, can be modeled through network theory. The course aims to equip students with the tools to analyze biological networks and apply network-based approaches to address multifaceted research challenges.

Learning Outcomes:
By the end of the course, students will be able to:

- Understand the foundational principles of Network Science
- Analyze biological phenomena using network models.
- Apply network analysis techniques to study neural connectivity and brain function.
- Interpret complex datasets through network analysis within biological and health contexts.
- Critically evaluate the implications of network-based approaches in both biological research and neuroscience.

Detailed lecture contents:

1. Introduction to Network Science (2h)
    - Overview of network theory and concepts
    - Importance of networks in biological contexts
2. Network Analysis Techniques (2h)
    - Statistical methods for network analysis
    - Tools and software for analyzing networks (NetworkX, graph-tool, Gephi, XGI)
3. Biological Networks (2h)
    - Types of biological networks (e.g., gene regulatory, protein-protein interaction networks, Structural and Functional Brain networks)
    - Case studies illustrating the application of networks in biology
    - Tutorial
4. Applications in Health Sciences (2h)
    - Use of networks in disease modeling and epidemiology
    - Network-medicine
    - Tutorial
5. Practical Sessions: Case Studies and Applications (4h)
    - Hands-on analysis of biological networks using real datasets

Teaching method:
The course is structured with theorical lessons supported by slides provided by the lecturer and practical examples/tutorials at the computer using Python language on free online environments.

Final Exam:
Assessment will be based on a presentation discussing a research paper or project related to network science and its applications in biology and health sciences.

Prerequisites:
Basic understanding of data analysis techniques and of the programing language Python are recommended. Familiarity with network theory is advantageous but not mandatory.

Key Bibliography:

- Newman, M. E. J. (2010). Networks: An Introduction. *Oxford University Press*.
- Sporns, O. (2011). Networks of the Brain. *MIT Press*.
- Barabási, A.-L., & Oltvai, Z. N. (2004). Network Biology: Understanding the Cell's Functional Organization. *Nature Reviews Genetics*
- Barabàsi, A.-L., Gulbahce N., Loscalzo J. (2010). Network Medicine: a network-based approach to huma disease. *Nature Reviews Genetics*