PhD AI – Health and Life Sciences area

Training activities - year 2023

ID	Title	Number of hours	Institution	Location	Attendance mode	Lecturer(s)	Academic year(s)	Semester	Timetable	Abstract
1	Reinforcement Learning	30	università di Chieti-Pescara	Dipartimento di matematica, Firenze	Online and in presence	Maurizio Parton	2021/2022, 2022/2023	2	September-November 2023	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.
2	Can we trust AI? Opening the black box	15	Università Campus Bio-Medico di Roma	Università Campus Bio-Medico di Roma/online	phygital	Rosa Sicilia	2022/2023, 2023/2024	1	**1 semester a.a. 2022/2023** - Wednesday 18/01/2023 h 11.00-13.00 - Thursday 19/01/2023 h 11.00-13.00 - Monday 23/01/2023 h 11.00-13.00 - Thursday 26/01/2023 h 11.00-13.00 - Monday 30/01/2023 h 10.00-12.00 - Thursday 02/02/2023 h 11.00-13.00 - Thursday 09/02/2023 h 10.00-13.00 (final exam) **1 semester a.a. 2023/2024** - Monday 15/01/2024 h 11.00-13.00 - Thursday 18/01/2024 h 11.00-13.00 - Monday 22/01/2024 h 11.00-13.00 - Thursday 25/01/2024 h 11.00-13.00 - Monday 29/01/2024 h 11.00-13.00 - Thursday 01/02/2024 h 11.00-13.00 - Thursday 08/02/2024 h 10.00-13.00 (final exam)	The pervasiveness of Artificial Intelligence (AI) in our daily lives has raised the need to understand and trust the outputs of the learning models, especially when involved in decision processes. This intensive short course sheds light on the new and wide world of eXplainable Artificial Intelligence presenting an overview of the state-of-the-art methodologies to explain and interpret different aspects involved in an AI decision process, i.e. data, outcome and the model.
3	Probabilistic Graphical Models in Intelligent Systems	20	Università del Piemonte Orientale	UPO Alessandria/ online	phygital	Luigi Portinale	2022/2023	1	nov-23	The course aims at introducing notions and algorithms for Probabilistic Graphical Models (PGM) in Artificial Intelligence (AI). PGMs are the the main AI formalism for dealing with uncertain knowledge and reasoning; they are grounded on both probability calculus and graph theory and represent an effective tool for the construction of intelligent decision support systems. After a short review of probability calculus and of the interpretation of probability, we will discuss different types of PGMs, namely directed models like Bayesian Belief Networks and undirected models like Random Markov Fields. Both representational and algorithmic issues will be discussed, as well as aspects concerning extensions to dynamic models, sensitivity analysis and learning
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	2022/2023	1	The course will be held in 1/2 weeks between March and May 2023; 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 garbariono	2023/2024	TBD	TBD	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 funciontal 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	2022/2023	2	Apr/May 2023	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.
7	Machine Learning for Edge Computing	15	Univerità degli Studi della Campania Luigi Vanvitelli	online	online	Antonio Esposito, Beniamino Di Martino	2023/2024	1	2023/2024 06/10/2023 Lecture 1: 10:00-12:00 Lecture 2: 12:00-14:00 13/10/2023 Lecture 3: 10:00-12:00 Lecture 4: 12:00-14:00 20/10/2023 Lecture 5: 10:00-12:00 Lecture 6: 12:00-14:00 27/10/2023 Lecture 7: 10:00-11:00 Lecture 8: 11:00-13:00	Machine learning is one of the fundamental applications of Artificial Intelligence, providing artificial systems the potentiality to automatically learn and improve from experience without being explicitly programmed. The learning process starts with the observations of data, used to identify patterns in data and to make future decisions based on the examples provided. Through machine learning approaches, the computing systems are allowed to learn automatically without the human intervention. A Machine Learning system automatically learns facts during a training phase, on the basis of provided examples, and then it is able to generalize and abstract the acquired knowledge to manage new data and situations, within the same application domain. Many Machine Learning algorithms are currently run locally, in specialized devices that collect data and learn from them, in order to provide immediate action and eventually correct any "incorrect" behaviour. Edge Computing plays a fundamental role in providing the computational resources to support such algorithms, and specific Federated Learning approaches have been defined for this reason. The objective of this course is to introduce artificial intelligence techniques, involving in particular Machine Learning, providing both a theoretical base and a practical insight on the matter. Furthermore, it will present the Edge Computing paradigm and will focus on Federated Learning approaches and algorithms.
8	Approximate Bayesian computation	15	Universita di Firenze	online and in presence	online and in presence	Fabio Corradi, Cecilia Viscardi	2022/2023	2	June/July 2023	The course introduces Approximate Bayesian Computation (ABC) - a class of likelihood-free methods for Bayesian inference. Topics presented during this course: ABC as an explanation of how Bayes rule works; Generative models; ABC with no approximation; Sources of approximation in ABC; Rejection ABC and its convergence to exact Bayesian computation; Limits in the use of Rejection ABC by examples; Examples from network analysis and Population genetics; Trade-off between level of approximation and computational efficiency; Importance Sampling ABC; Markov Chain Monte Carlo ABC. Sequential methods: Population MC and Sequential MC. At the end of the course, we provide an introduction to some more advanced topics, possibly related to students' research interests, to be further developed in a presentation given by the students during the last lecture.
9	Bayesian methods for high-dimensional data	10	Universita di Firenze	online and in presence	online and in presence	Francesco Stingo	2021/2022	2		Bayesian approaches for model selection and inference in the context of: Linear regression, GLM, Semi-parametric regression and other topics (e.g., mixtures, graphical models). With applications in bio-medicine, with a particular focus on genomics.

10	Introduction to Neuromorphic Computing	12	Universita degli Studi di Roma Tor Vergata	online	online and in presence	Andrea Duggento, Nicola Toschi	2021/2022, 2022/2023	2	from 13/03/2023 to 17/03/2023. 9:00-11:00 Every day	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. The course will be include a hands-on self contained project where the student will be asked to translate a biologically plausible mechanism into an artificial spiking neural network.
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	2	March/June 2023	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	15	Università del Piemonte Orientale	Università del Piemonte Orientale	online and in presence	Alessio Bottrighi, Giorgio Leonardi, Stefania Montani, Luca Piovesan, Paolo Terenziani	2022/2023	2	May,3,h14-17 May,10,h14-17 May,17,h14-17 May,24,h14-17 May,29,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	2022/2023	1	January 2024: 16-17-18 14.00 to 18.00	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	1	February 2023: Tuesday 14 - 15:00 to 17:00 Friday 17 - 15:00 to 17:00 Tuesday 21 - 15:00 to 17:00 Friday 24 - 15:00 to 17:00 Tuesday 28 - 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	AI complexity: open challenges on digital society	10	University Campus Bio-Medico of Rome	Università Campus Bio-Medico di Roma/online	online	Marta Bertolaso, Laura Corti	2022/2023	2	Wednesday 13 April 9-11 Wednesday 19 April 9-11 Wednesday 26 April 9-11 Wednesday 3 May 9-11 Wednesday 10 May 9-11 final test	The course aims at providing students with theoretical, ethical and epistemological knowledge and understanding of the fundamentals of Artificial Intelligence. Specifically, the course wants to develop a critical analysis of the open questions involved in AI and deepen the philosophical implications of the use of AI in building a 'good society'.

Title: Reinforcement Learning

Number of hours: 30

Institution(s): università di Chieti-Pescara

Location(s): Dipartimento di matematica, Firenze

Type: Ph.D. course

Attendance Mode: Online and in presence

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

Semester: 2 (please consider that the course can be selected by the student in the first or in the second year of the PhD. Hence, if it is possible, please consider that the course will be held both in 2022 and 2023)

Timetable: September-November 2023, to be decided.

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:

Teaching method:

Final Exam:

Prerequisites:

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.
-) 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.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

Title: Can we trust AI? Opening the black box

Number of hours: 15

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): Rosa Sicilia

Responsible Expert(s)\email: Rosa Sicilia, r.sicilia@unicampus.it

Academic Year: 2022/2023 - 2023/2024

Semester: 1 semester a.a. 2022/2023 – 1 semester a.a. 2023/2024

Timetable: The course will be held in 3 weeks considering approximately 4 h a week for lectures. The proposed dates for the two academic years are:

- 1 semester a.a. 2022/2023
  - Wednesday 18/01/2023 h 11.00-13.00
  - Thursday 19/01/2023 h 11.00-13.00
  - Monday 23/01/2023 h 11.00-13.00
  - Thursday 26/01/2023 h 11.00-13.00
  - Monday 30/01/2023 h 10.00-12.00
  - Thursday 02/02/2023 h 11.00-13.00
  - Thursday 09/02/2023 h 10.00-13.00 (final exam)
- 1 semester a.a. 2023/2024
  - Monday 15/01/2024 h 11.00-13.00
  - Thursday 18/01/2024 h 11.00-13.00
  - Monday 22/01/2024 h 11.00-13.00
  - Thursday 25/01/2024 h 11.00-13.00
  - Monday 29/01/2024 h 11.00-13.00
  - Thursday 01/02/2024 h 11.00-13.00
  - Thursday 08/02/2024 h 10.00-13.00 (final exam)

Abstract: The pervasiveness of Artificial Intelligence (AI) in our daily lives has raised the need to understand and trust the outputs of the learning models, especially when involved in decision processes.

This intensive short course sheds light on the new and wide world of eXplainable Artificial Intelligence presenting an overview of the state-of-the-art methodologies to explain and interpret different aspects involved in an AI decision process, i.e. data, outcome and the model.

Learning Outcomes: Students will gain knowledge and understanding about:

- Basic elements of XAI
- The main families of XAI algorithms
- State-of-the-art approaches explaining the data, the outcome and the model
- Principal Python libraries for XAI

Moreover the Students will be able to understand how to employ the presented techniques in a practical case, with the aim of critically analysing and evaluating the results. The theorical and practical knowledge should also provide the students the ability to adapt or even design XAI algorithms for specific and novel cases.

Detailed lecture contents:

1. Introduction on XAI (2h)
    a. What is XAI? Why and When
    b. Definition of "explanation"
    c. Interpretability challenges
    d. Transparent boxes
    e. Taxonomies of XAI methods
2. Explaining the data (2h)
    a. PCA
    b. t-SNE
    c. UMAP
    d. Prototypes
3. Explaining the outcome (2h)
    a. LIME
    b. CAM and Grad-CAM
    c. Shap values
    d. T-CAV
4. Explaining the model (2h)
    a. Integrated gradients (hybrid case explaining the outcome)
    b. Activation maximization
    c. Gradient Ascent
    d. Deconvolution
    e. Evaluation of explanations
5. Practical class: Hands on XAI in Python (4h)
6. Students pitch and discussion (3h)

Teaching method: The course is structured with four theorical lessons supported by slides provided by the lecturer and with one practical lesson at the computer using Python language on free online environments as Google Colab.

Final Exam: Knowledge gained during the course will be assessed with a pitch discussing a research paper about a topic of the student choosing inherent to the course focus. No additional time for the final exam is needed, since it is already scheduled as part of the course.

Prerequisites: Knowledge about basic Machine Learning and Deep Learning techniques and terminology is a necessary prerequisite. Basic experience in Python programming is also a requirement.

Key Bibliography:

Samek, Wojciech, et al., eds. Explainable AI: interpreting, explaining and visualizing deep learning. Vol. 11700. Springer Nature, 2019.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

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

Title: PROBABILISTIC GRAPHICAL MODELS IN INTELLIGENT SYSTEMS

Number of hours: 20

Institution(s): Università del Piemonte Orientale

Location(s): Dipartimento di Scienze e Innovazione Tecnologica, Università del Piemonte Orientale, Alessandria and Online

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Luigi Portinale

Responsible Expert(s)\email: Luigi Portinale, Università Piemonte Orientale
luigi.portinale@uniupo.it

Academic Year: 2022/2023

Semester: 1

Timetable: November 2023

Abstract: The course aims at introducing notions and algorithms for Probabilistic Graphical Models (PGM) in Artificial Intelligence (AI). PGMs are the main AI formalism for dealing with uncertain knowledge and reasoning; they are grounded on both probability calculus and graph theory and represent an effective tool for the construction of intelligent decision support systems. After a short review of probability calculus and of the interpretation of probability, we will discuss different types of PGMs, namely directed models like Bayesian Belief Networks and undirected models like Random Markov Fields. Both representational and algorithmic issues will be discussed, as well as aspects concerning extensions to dynamic models, sensitivity analysis and learning

Learning Outcomes: understanding the basic notions of probabilistic graphical models for reasoning under uncertainty (conditional independence, probability factorization and their relationships); being able to model uncertain knowledge with PGM; understanding inference algorithms for PGM.

Detailed lecture contents:
Probability theory: main concepts and interpretation (frequentist vs subjective)
Directed vs undirected models: Bayesian Networks and Markov Random Fields

Graph theoretic dependency
Modeling Issues
Inference: exact and approximate methods
Learning approaches (parameter and structure learning)

Teaching method: frontal lectures with slides, online webinar

Final Exam: seminar on agreed topic

Prerequisites: basic probability calculus and basic graph theory

Key Bibliography:
D. Koller, N. Fridman: Probabilistic Graphical Models
Principles and Techniques, MIT Press

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: 2022/2023

Semester: 1 semester a.a. 2022/2023

Timetable: The course will be held from between March and May 2023, definitive dates will be delivered to enrolled 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: 2023/2024

Semester: TBD

Timetable: TBD

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

UNIVERSITA' 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: 2022/2023

Semester: 2

Timetable: April - May 2023

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

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

Title: Machine Learning for Edge Computing

Number of hours: 15

Institution(s): Università degli Studi della Campania "Luigi Vanvitelli"
Location(s): Online
Type: Ph.D. course
Attendance Mode: Online
Final Exam: Yes

Lecturer(s): Antonio Esposito, Beniamino Di Martino

Responsible Expert(s)\email: Antonio Esposito, Beniamino Di Martino, Università degli Studi della Campania "Luigi Vanvitelli", Dipartimento di Ingegneria, antonio.esposito@unicampania.it, beniamino.dimartino@unicampania.it

Academic Year: 2023/2024
Semester: 1

Timetable:
06/10/2023 Lecture 1: 10:00-12:00 Lecture 2: 12:00-14:00

13/10/2023 Lecture 3: 10:00-12:00 Lecture 4: 12:00-14:00

20/10/2023 Lecture 5: 10:00-12:00 Lecture 6: 12:00-14:00

27/10/2023 Lecture 7: 10:00-11:00 Lecture 8: 11:00-13:00

Abstract:
Machine learning is one of the fundamental applications of Artificial Intelligence, providing artificial systems the potentiality to automatically learn and improve from experience without being explicitly programmed.
The learning process starts with the observations of data, used to identify patterns in data and to make future decisions based on the examples provided. Through machine learning approaches, the computing systems are allowed to learn automatically without the human intervention.

A Machine Learning system automatically learns facts during a training phase, on the basis of provided examples, and then it is able to generalize and abstract the acquired knowledge to manage new data and situations, within the same application domain.

Many Machine Learning algorithms are currently run locally, in specialized devices that collect data and learn from them, in order to provide immediate action and eventually correct any "incorrect" behaviour. Edge Computing plays a fundamental role in providing the computational resources to support such algorithms, and specific Federated Learning approaches have been defined for this reason.
The objective of this course is to introduce artificial intelligence techniques, involving in particular Machine Learning, providing both a theoretical base and a practical insight on the matter. Furthermore, it will present the Edge Computing paradigm and will focus on Federated Learning approaches and algorithms.

Learning Outcomes:
The students will acquire knowledge regarding the main Machine Learning techniques, and will be able to analyse datasets to implement Classification, Regression and Clustering algorithms, by using Python based libraries. Students will also acquire familiarity with Edge Computing and Federated Learning techniques, with examples in the E-Health domain.

Detailed lecture contents:
Lecture 1: Introduction to Machine Learning (2 hours)

- Problems addressed: Classification, Regression, Clustering, Dimensionality Reduction
- Supervised and Unsupervised approaches
- Evaluation metrics

Lecture 2: Classification Techniques (2 hours)

- Support Vector Machine
- Decision Trees and Random Forest
- K-NN

Lecture 3: Regression Techniques and Dimensionality Reduction (2 hours)

- Linear and nonlinear Regression Techniques
- Dimensionality Reduction
  - Principal Component Analysis
  - Linear Discriminant Analysis

Lecture 4: Clustering (2 hours)

- K-Means
- Silhouette score and Elbow graphs
- Hierarchical Clustering

Lecture 5: Neural Networks (2 hours)

- Rosenblatt Perceptron
- Feedforward Networks

- Activation functions

Lecture 6: Edge Computing (2 hours)

- Introduction to Edge Computing
- Architectural Overview
- Patterns for Edge Computing

Lecture 7: Edge Computing Application (1 hour)

- Application Examples of Edge Computing
- Focus on E-Health application and devices

Lecture 8: Federated Learning (2 hours)

- Federated Learning Algorithms
- Application to Practical Problems

Teaching method: Online lessons through slides and Exercitations in Python

Final Exam: Application of Machine Learning techniques to assigned datasets with discussion

Prerequisites: Basic Knowledge of the Python programming language

Key Bibliography:

Géron, A. (2019). *Hands-on machine learning with Scikit-Learn, Keras, and TensorFlow: Concepts, tools, and techniques to build intelligent systems*. " O'Reilly Media, Inc.".

Buyya, Rajkumar, and Satish Narayana Srirama, eds. *Fog and edge computing: principles and paradigms*. John Wiley & Sons, 2019

Title: Approximate Bayesian computation

Number of hours: 15

Institution(s): Università di Firenze

Location(s): Firenze, Viale Morgagni 59, Dipartimento di Statistica, Informatica, Applicazioni

Type: Ph.D. course

Attendance Mode: Blended

Final Exam: Yes

Lecturer(s): Fabio Corradi, Cecilia Viscardi

Responsible Expert(s)\email: Fabio Corradi, fabio.corradi@unifi.it; Cecilia Viscardi, cecilia.viscardi@unifi.it.

Academic Year: 2022/2023

Semester: 2

Timetable: June/July 2023

Abstract: The course introduces Approximate Bayesian Computation (ABC) - a class of likelihood-free methods for Bayesian inference.
Topics presented during this course: ABC as an explanation of how Bayes rule works; Generative models; ABC with no approximation; Sources of approximation in ABC; Rejection ABC and its convergence to exact Bayesian computation; Limits in the use of Rejection ABC by examples; Examples from network analysis and Population genetics; Trade-off between level of approximation and computational efficiency; Importance Sampling ABC; Markov Chain Monte Carlo ABC. Sequential methods: Population MC and Sequential MC.
At the end of the course, we provide an introduction to some more advanced topics, possibly related to students' research interests, to be further developed in a presentation given by the students during the last lecture.

Learning Outcomes: The course will provide knowledge of the main advantages/disadvantages of ABC methods, as well as the knowledge of the state-of-the-art ABC sampling schemes.

Detailed lecture contents:

- **Lecture 1:** The very beginning of ABC; the basic ABC algorithm; generative models; some motivating examples; ABC formalization.
- **Lecture 2**: The role of the tolerance threshold in ABC; the role of summary statistics in ABC; the choice of summary statistics based on subset selection, projection methods and auxiliary likelihood methods.
- **Lecture 3**: Rejection ABC: limits and possible solutions; Importance Sampling ABC.
- **Lecture 4**: Markov Chains Monte Carlo ABC; Sequential Monte Carlo ABC.
- **Lecture 5**: More advanced topics, possibly related to students' research interests.

Teaching method: Lectures based on slides and examples using R.

Final Exam: Oral presentation.

Prerequisites: Basic knowledge of Bayesian Inference, Monte Carlo and Markov Chains Monte Carlo methods**.**

Key Bibliography: Sisson, S.A., Fan, Y., & Beaumont, M.A. (2018). Handbook of Approximate Bayesian Computation.

Title: Bayesian methods for high-dimensional data

Number of hours: 10

Institution(s): Universita di Firenze

Location(s): Florence, viale Morgagni 59 50134, Department of Statistics, Computer Science, Applications

Type: Ph.D. course

Attendance Mode: Blended

Final Exam: Yes

Lecturer(s): Francesco Stingo

Responsible Expert(s)\email: Francesco Stingo, francesco.stingo@unifi.it

Academic Year: 2021/2022

Semester: 2

Timetable: May 2022

Abstract: Bayesian approaches for model selection and inference in the context of: Linear regression, GLM, Semi-parametric regression and other topics (e.g., mixtures, graphical models). With applications in bio-medicine, with a particular focus on genomics.

Learning Outcomes: Not mentioned

Detailed lecture contents: Not mentioned

Teaching method: Not mentioned

Final Exam: Not mentioned

Prerequisites: Not mentioned

Key Bibliography: Not mentioned

UNIVERSITA' CAMPUS BIO-MEDICO DI ROMA

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: Phygital

Final Exam: Yes

Lecturer(s): Andrea Duggento, Nicola Toschi

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

Academic Year: 2021/2022, 2022/2023

Semester: 2

Timetable: from 13/03/2023 to 17/03/2023. 9:00-11:00 Every day.

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. The course will be include a hands-on self-contained project where the student will be asked to translate a biologically plausible mechanism into an artificial spiking neural network.

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 translate biologically plausible mechanisms into a neuronal simulation with learning capabilities.

Detailed lecture contents:
Lecture 1: Membrane potential, synapses, and chemical neuromodulation
Lecture 2: Spiking neural network in silico: 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
Lecture 6: Hands-on practical demonstrations

Teaching method:
Lectures based on whiteboard for analytical and qualitative concepts, slides for illustrating applications. Git-hub repository and Jupiter notebook as complementary materials.

Final Exam:
The student will either

- prepare a seminar on a topic to be agreed upon
- or complete a self-contained project

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.

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: please indicate 2021/2022, 2022/2023 or both: 2022/2023.

Semester: 2

Timetable: final calendar will be communicated, indicatively 4 hours per week in the second semester of a.a. 2022/2023 (from March to June 2023).

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.

Title: Modelling and managing medical processes

Number of hours: 15

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, 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
Paolo Terenziani, University of Eastern Piedmont, paolo.terenziani@uniupo.it

Academic Year: 2022/2023

Semester: 2

Timetable:
May,3, h14-17
May 10, h14-17
May 17, h14-17
May 24, h14-17
May 29, h14-17

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.

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)

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

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

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: 2021/2022 and 2022/2023

Semester: 1

Timetable: three weeks, 2-4 hours per week. Period: September – October 2022

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

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

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 2022/2023.

Semester: Semester 1

Timetable: Classes will be held in February 2023 on the following dates:
Tuesday 14 - 15:00 to 17:00
Friday 17 - 15:00 to 17:00
Tuesday 21 - 15:00 to 17:00
Friday 24 - 15:00 to 17:00
Tuesday 28 - 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 presentation

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.

UNIVERSITÀ CAMPUS BIO-MEDICO DI ROMA

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

Title: AI complexity: open challenges on digital society

Number of hours: 10

Institution(s): University Campus Bio-Medico of Rome

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

Type: Ph.D. course

Attendance Mode: Phygital

Final Exam: Yes

Lecturer(s): Prof. Marta Bertolaso
Laura Corti
Luca Capone

Responsible Expert(s)\email: Prof. Marta Bertolaso, m.bertolaso@unicampus.it

Academic Year: 2022/2023

Semester: 2

Timetable: lease insert the most accurate calendar (days and hours of the lecture), because students need this information to set up the learning program.

Thursday 2/03/2023	12:00-14:00
Thursday 9/03/2023	12:00-14:00
Thursday 16/03/2023	12:00-14:00
Thursday 23/03/2023	12:00-14:00
Thursday 30/03/2023	12:00-14:00 (final exam)

Abstract:

The course aims at providing students with theoretical and epistemological knowledge and understanding of the fundamentals of Artificial Intelligence. Specifically, the course wants to develop a critical analysis of the open questions involved in AI and deepen the philosophical implications of the use of AI in building a 'good society'.

Learning Outcomes:

- Knowledge and understanding of the theoretical and epistemic foundations of AI;
- Ability to identify and analyze critical issues in Artificial Intelligence;

- Ability to identify and discuss appropriate case studies;
- Awareness of the theoretical, epistemological, social, and ethical issues of new technologies.

Detailed lecture contents:

- A socio-technical definition of AI
- From the human-human relationship to the human-machine relationship to the machine-machine relationship: epistemological and ethical approaches
- Critical Reflection on Digital Society: open challenges
- The position of European papers on AI
- Ethical and social responsibility for a 'good AI society'.

Teaching method:

Within the course, lectures are combined with class discussion.

Final Exam:

It is required to present an original research on one of the topics presented during the course or on related topics**.**

Prerequisites:

It is recommended to have successfully attended at least one Humanities, Philosophy or Ethics course.

Key Bibliography:

1. 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
2. Bertolaso, M., Lo Storto, G. (Eds.) (2020) Etica Digitale, Verità, responsabilità e fiducia nell'era delle macchine intelligenti, Luiss Editore
3. 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.
4. Bertolaso M., Capone L., Rodriguez-Lluesma C. (Eds.) (in stampa), Digital Humanism. A human-centric approach to digital technologies, PalgraveJasanoff, S. (2016). The ethics of invention: technology and the human future. WW Norton & Company.
5. Marcos, A. (2010) Filosofia dell'agire scientifico. Le nuove dimensioni, Academia Universa Press, Milano.
6. Russell, S. J., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.
7. The European Commission's High-Level Expert Group on Artificial Intelligence (2018), A Definition of AI: Main Capabilities and Scientific Disciplines.
8. The European Commission's High-Level Expert Group on Artificial Intelligence (2019), Draft Ethics Guidelines for Trustworthy AI. Working Document for Stakeholders' Consultation.