Bachelor of Science
in Artificial Intelligence

Presentation of the third year

June 5th, 2024 - 15.00
Room Beta, University of Milano - Statale

Study plan

To be presented in October

- automatically accepted if compliant with the indications
- otherwise subject to approval by the teaching council

Contact me (claudio.cusano@unipv.it) before presenting a non-standard study plan

Study plan

Third year

First semester	Second semester
Statistical modelling (Bicocca)	Practical activities and Final exam
Brain modelling (Statale)	
Track course	Track course
Track course	Track course
Elective	Elective

All activities except the final exam will be located in Milan (Statale and Bicocca)

Brain modeling

Multiscale modelling of biological neural networks for understanding the brain and its functions through a variety of theoretical constructs and computer science analogies

Topics:

- Computational Neuroscience: approaches and applications
- Neuron and synapse modelling at different levels of detail
- Plasticity
- Connectivity
- Network dynamics
- Structure-function in brain circuit models
- Integration and embodiment
- AI inspired by brain science, how AI and neuroscience drive each other forwards

Teachers: Claudia Casellato

Statistical modeling

The course aims at introducing the students to multivariate analysis in statistical modeling. Multivariate data arise when several variables are observed for each unit or individual.

Topics:

- Introduction to regression models
- Linear model via OLS
- Gaussian linear model
- Inference for Gaussian linear models
- Diagnostics and model checking
- Notable examples: ANOVA and ANCOVA
- Generalized linear models: Poisson regression, logistic and probit regression

Teachers: Laura D’Angelo, Valentina Zangirolami

Tracks

Tracks

Four tracks are available:

1. Data analysis, communication and marketing
2. Industrial systems and healthcare
3. Brain, cognition and society
4. Physics for AI: environment, health and quantum information

Each track includes two courses in each semester

Track 1: Data analysis, communication and marketing

Topics

- extraction of information from the web, social media, and documents
- prediction of trends in opinions, interests and behaviors
- interaction with users in a "natural way"
- applications to marketing, finance and social dynamics analysis

First semester	Second semester
Data and Knowledge Bases (Statale)	Web and Social Media Search and Analysis (Bicocca)
Information retrieval and recommender systems (Bicocca)	Artificial Intelligence for Communication and Marketing (Bicocca)

Data and Knowledge Bases

Introduce the main techniques and methodologies for dealing with **structured** data. In particular, how to **model** and **query** data, and how to extract insights (**analytics**) from data.

Topics:

- Introduction to Database architectures and the relational model
- Design and implementation of a Database
- Querying data with the SQL language
- Introduction to Data Warehousing and data analytics
- Design and implementation of a Data Warehouse
- Data analytics on a Data Warehouse
- Frequent Pattern Mining

All lectures are complemented with practical assignments during the course.
Teacher: Marco Calautti

Information retrieval and recommender systems

Aim of the course is to introduce two main categories of systems aimed to support users in accessing information relevant to specific needs: search engines (aka Information Retrieval Systems) and Recommender Systems (aka Information Filtering Systems).

Topics:

- Introduction to Information Retrieval
- Main components of a search engine (indexing, matching,
- Web Search Engines
- Search Engines and Chatbots
- Retrieval Augmented Generation
- Introduction to Information Filtering
- Main components of a recommender system
- Applications

Teacher: Gabriella Pasi

Web and Social Media Search and Analysis

The course aims to address the problems and challenges related to data representation, analysis, and search on social platforms. Such environments are characterized by the fact that they allow the construction of so-called complex networks, with non-trivial characteristics with respect to: 1. the representation of social structures and content disseminated; 2. their analysis from the topological and semantic point of view; 3. the search for the most relevant information with respect to a set of dimensions of relevance peculiar to such platforms.

Topics:

- Graph and complex network theory
- Data representation in social media
- Social network analysis
- Social content analysis
- Social search

Teacher: Marco Viviani

Artificial Intelligence for Communication and Marketing

Aims: At the end of the course students will be able to understand and discuss the principles of Artificial Intelligence applied to the Marketing and Communication. They will be able to analyze a problem, and to design and implement a solution. They will be familiar with the most important techniques and main methodologies in the field of Artificial Intelligence related to the world of Marketing and Communication. In addition, the course is aimed at understanding the fundamental principles of the entire life cycle for the development of data-driven applications necessary to enable a data-driven transformation for all business companies.

Topics: Introduction to marketing with a data-driven approach: the basic concepts necessary for carrying out quantitative marketing analysis
Machine Learning & Deep Learning models for customer, product and engagement: the methods of designing, developing and interpreting the results of the main Advanced Analytics and Artificial Intelligence models
Evaluation and monitoring of the main marketing activities: analyzed through the main metrics in order to measure the impact on incremental turnover and return on investment (ROI)

Teacher: Sergio Suriano

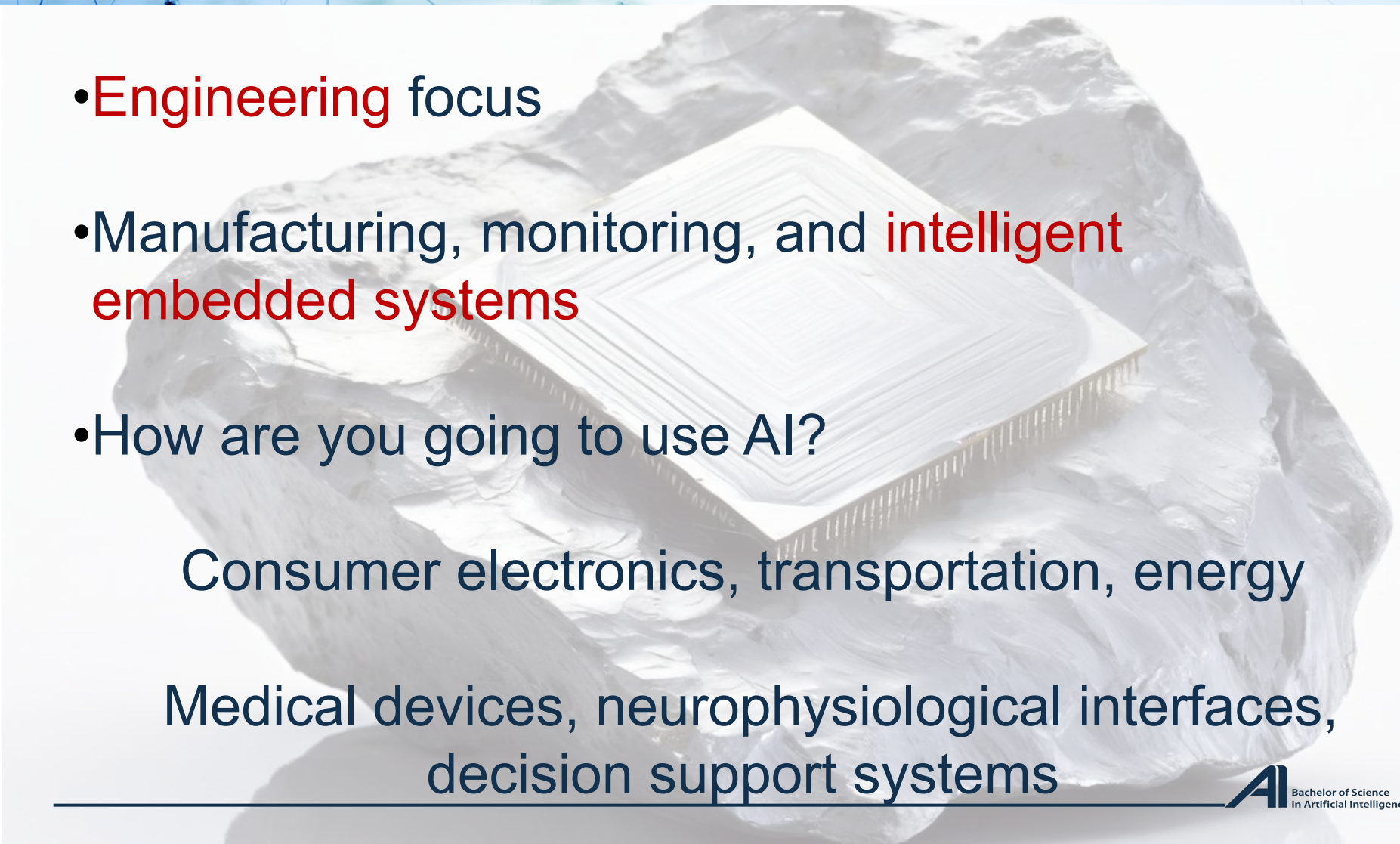
Track 2: Industrial systems and healthcare

Topics

- applications in manufacturing, automation and robotics
- intelligent embedded systems
- signal and image processing
- decision support in industry and healthcare

First semester	Second semester
Medical applications and health-care (Statale)	Signal and image processing (Bicocca)
Human-system interaction (Bicocca)	Process control, industrial automation and robotics (Statale)

Track 2: Industrial systems and healthcare



- Engineering focus
- Manufacturing, monitoring, and intelligent embedded systems
- How are you going to use AI?

Consumer electronics, transportation, energy

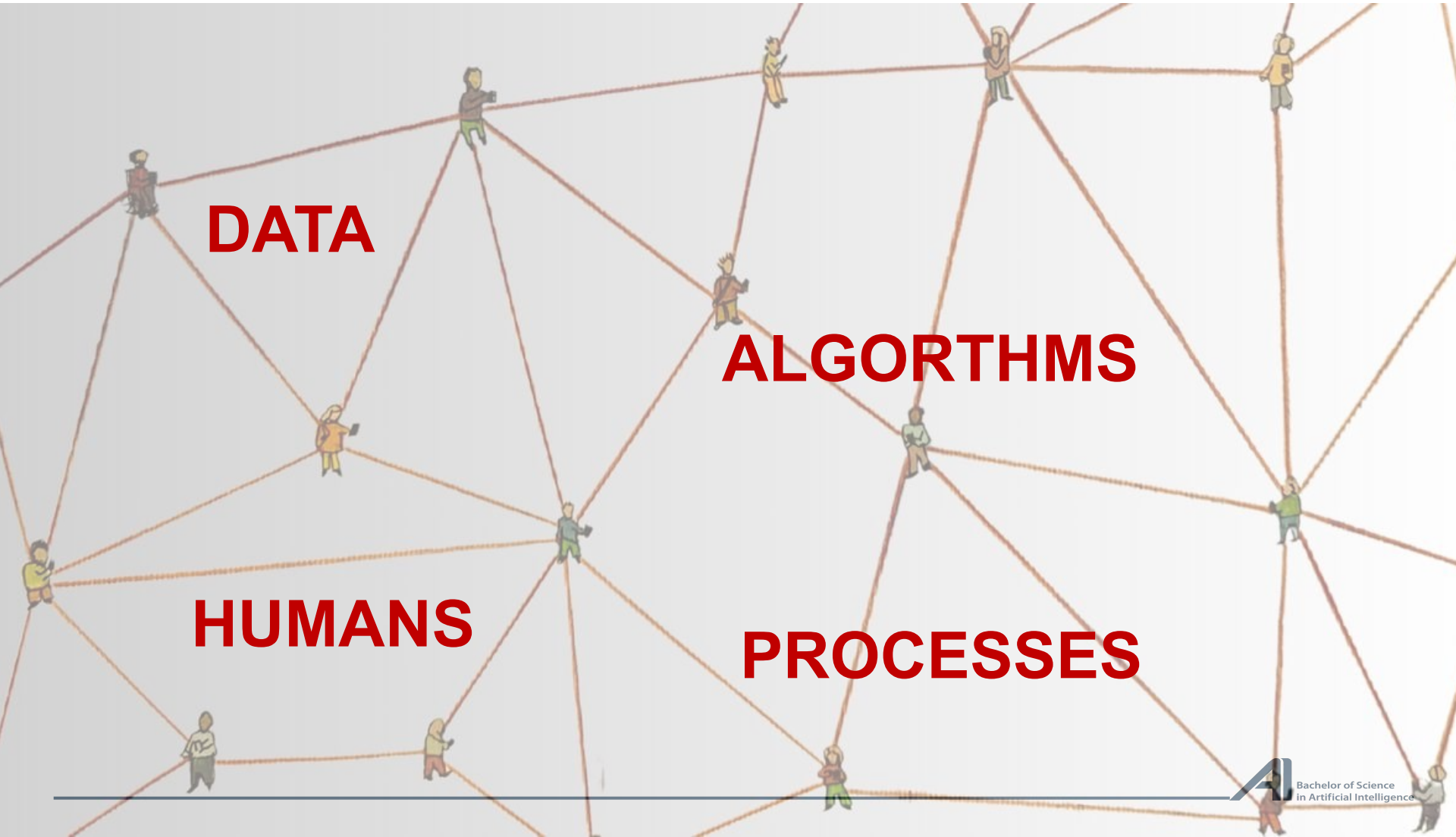
Medical devices, neurophysiological interfaces, decision support systems

Track 2: Industrial systems and healthcare

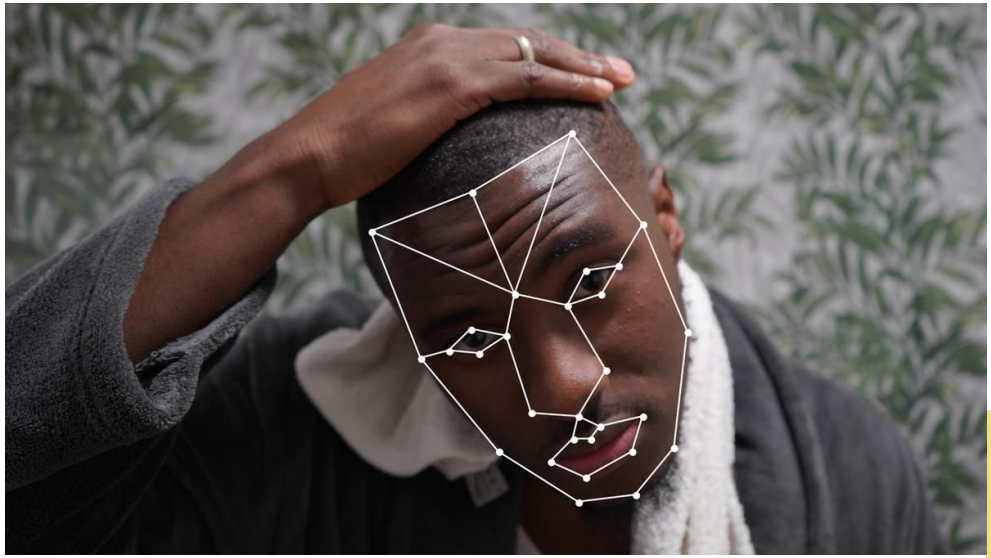
Industrial Automation

Healthcare

Track 2: Industrial systems and healthcare



Track 2: Industrial systems and healthcare



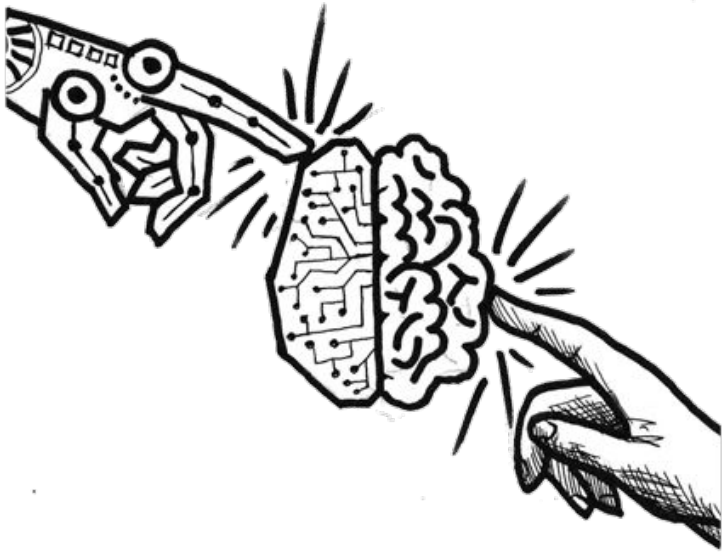
In both industrial automation and healthcare, **input** typically comes from various sensors, including cameras.

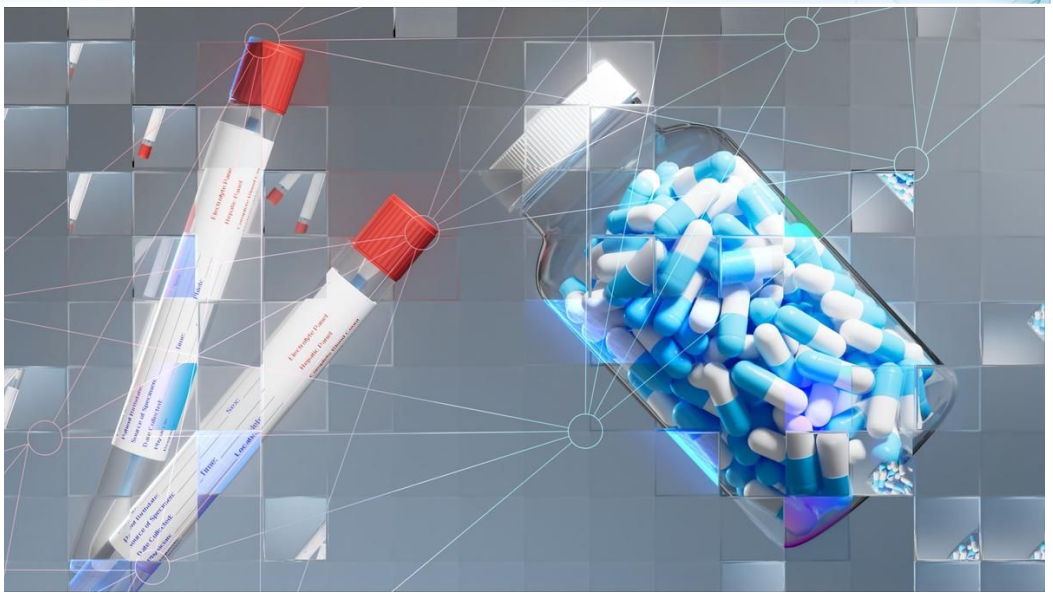
Students learn to process and analyze data from diverse inputs, including **signals and images**

https://betterimagesofai.org/

Track 2: Industrial systems and healthcare

AI challenges in **healthcare**. Decision support, personalized medicine, and electronic phenotyping.





Focus on AI in **neuroscience**. Neuronal excitability, brain activity, movement, voice, and tele-medicine applications.

https://betterimagesofai.org/

Track 2: Industrial systems and healthcare

Given the complexity and variability of real-world applications, there is a growing need for ***non-conventional interaction methods.***

The Human-System Interaction course explores innovative ways for humans to interact with complex systems efficiently and effectively.

Track 2: Industrial systems and healthcare

Civilization advances by extending the number of important operations which we can perform without thinking about them.

An Introduction to Mathematics , Alfred North Whitehead

Medical applications and health-care (mod. 1)

AI applications to medical activities, with a specific focus on neuroscience. The course will introduce the available tools to explore neuronal excitability and brain activity, movement analysis, voice analysis, remote- and tele-medicine.

Topics: neuroscience, neuromodulation, brain activity-machine interface, wearable sensors, voice analysis, remote-communication sensors, medical diagnostic tools.

Teachers: Antonio Pisani, Roberto De Icco

Medical applications and health-care (mod. 2)

Through a series of lectures and case studies students will gain an understanding of challenges in using machine learning in health care and its application in medicine. The course will cover key use cases such as clinical decision support, personalized medicine and electronic phenotyping.

Clinical Data:

- Data generated by health care systems. Type of clinical data, EHR systems, Taxonomies, common biases in clinical data.
- Clinical data sharing. Observational Health Data Sciences and Informatics and Federated learning.
- Precision Medicine. Omics data and unstructured data for precision medicine. How to embed patient generated data in clinical studies.

Statistical Methods (using R):

- How to handle missing data in clinical datasets via Multiple Imputation by Chained Equations
- Representing time in clinical data: Mixed Effect Models, Sequential pattern mining, Latent Class Mixed Models.
- Survival analysis, Kaplan–Meier estimator and Cox Regression

Use Cases:

- Electronic phenotyping
- Clinical studies design
- Clinical Decision Support Systems

Teacher: Arianna Dagliati

Human-system interaction (mod. 1)

Students will learn about the challenges and opportunities of human-AI interaction in various domains such as “AI for code”,and healthcare, and will also gain practical experience in regard to designing and evaluating interactive AI systems that are usable, interpretable, transparent, trustworthiness, and fair.

Topics: Introduction to Human-AI Interaction: definitions, concepts, and frameworks; Human cognition and AI: strengths and weaknesses of human and machine intelligence, cognitive biases, mental models, and expectations; Human-in-the-loop AI and AI-in-the-group: methods and techniques for designing interactive AI systems that leverage human feedback, guidance, and collaboration; Interpretability and explainability of AI: methods and techniques for generating and presenting interpretable and explainable AI outputs, such as visualizations, natural language explanations, and counterfactuals; Transparency and trust in AI: methods and techniques for enhancing transparency and trust in AI systems, such as provenance, uncertainty, accountability, and control; Fairness and ethics in AI: methods and techniques for ensuring fairness and ethics in AI systems, such as detecting and mitigating bias, discrimination, and harm; Human-AI interaction in specific domains: examples and case studies of human-AI interaction in domains such as “AI for code”, healthcare

Teacher: Federico Cabitza

Human-system interaction (mod. 2)

The aim of the module is to provide students with theoretical knowledge and practical experience for the cognitive ergonomic design of interactive systems and interfaces, according to the principles of User-Centered Design. Design methodologies and evaluation methods for interactive systems will be presented and implemented in real-world scenarios.

Topics: Cognitive aspects of interaction design (i.e., memory, attention, perception, emotion, Embodied Cognition); Interface Design and Analysis; Usability evaluation; User Experience

Teacher: Silvia Serino

Signal and image processing

Processing and analysis of analog/digital signals and digital images.

Topics:

- Module 1: Fourier analysis of continuous-time and discrete-time signals, stability of linear systems, digital filters;
- Module 2: Image acquisition, low level image processing, image feature analysis.

Teacher: Anna Vizziello, Raimondo Schettini, Marco Buzzelli

Dynamical systems for industrial automation

The class aims to provide the fundamental of control theory and process control.

Topics:

- **System analysis:** definitions, taxonomy, equilibrium, stability.
- **Continuous-time LTI:** , observability, controllability, transfer function, block algebra, stability, step response, frequency response.
- **Control problem:** principal schema, linear control, bode diagram, PID controller, sensitivity analysis.
- **Discrete-time LTI:** transfer function, discretization, stability criteria.

Teacher: Federico di Palma

Track 3: Brain, cognition and society

Topics

- modeling of the nervous system
- neural networks and biologically inspired models
- interfaces between brain activity and medical devices
- neuroscience and behavioral sciences

First semester	Second semester
Brain-inspired neural networks and neural architectures (Statale)	AI and society (Statale)
Human-system interaction (Bicocca)	Logics for practical reasoning and AI (Statale)

Brain-inspired neural networks and neural architectures

Introduction to neural networks which rules are inspired by brain physiology. Structural architectures and topologies to model the brain and its functional activity at multiple scales of complexity. Particular interest will be given to the large-scale characterization of the brain towards Digital Brain Twins.

Topics:

- Brain-inspired ANNs and brain analogies: from the simple perceptron to the Elman network
- Theory for physiologically based mean field models
- Brain structure-function relation
- Functional Brain Networks and large-scale connectivity
- Brain modeling to predict brain activity and functional hierarchy
- Digital Brain Twins
- Application of ANNs to NeuroImaging

Teacher: Fulvia Palesi

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Topics: Introduction to Human-AI Interaction: definitions, concepts, and frameworks; Human cognition and AI: strengths and weaknesses of human and machine intelligence, cognitive biases, mental models, and expectations; Human-in-the-loop AI and AI-in-the-group: methods and techniques for designing interactive AI systems that leverage human feedback, guidance, and collaboration; Interpretability and explainability of AI: methods and techniques for generating and presenting interpretable and explainable AI outputs, such as visualizations, natural language explanations, and counterfactuals; Transparency and trust in AI: methods and techniques for enhancing transparency and trust in AI systems, such as provenance, uncertainty, accountability, and control; Fairness and ethics in AI: methods and techniques for ensuring fairness and ethics in AI systems, such as detecting and mitigating bias, discrimination, and harm; Human-AI interaction in specific domains: examples and case studies of human-AI interaction in domains such as “AI for code”, healthcare

Teacher: Federico Cabitza

Human-system interaction (mod. 2)

Description: The aim of the module is to provide students with theoretical knowledge and practical experience for the cognitive ergonomic design of interactive systems and interfaces, according to the principles of User-Centered Design. Design methodologies and evaluation methods for interactive systems will be presented and implemented in real-world scenarios.

Topics: Cognitive aspects of interaction design (i.e., memory, attention, perception, emotion, Embodied Cognition); Interface Design and Analysis; Usability evaluation; User Experience

Teacher: Silvia Serino

AI and society

The course explores the societal implications of AI through the conceptual and methodological lenses of philosophy. A socio-technical perspective will be adopted, focusing on the social embeddedness of AI systems and more generally on the way a critical reflection on AI should consider both technical and non-technical aspects.

Topics:

- Conceptions and misconceptions of AI
- AI and risk
- AI and uncertainty
- AI systems as experimental technologies
- Anthropomorphism, manipulation and deception in AI

Teacher: Giacomo Zanotti

Logics for practical reasoning and AI

This course covers a number of logical approaches to uncertain inference that lend themselves to implementation. The course prioritises breadth of approaches over in-depth treatments in order to equip students with a large tool-box of methodology for future uses.

Topics: Propositional logics for uncertainty, revision, para-consistency and updating; computational complexity; Bayesian networks; first-order logic.

Teacher: Ekaterina Kubyshkina

Track 4: Physics for AI: environment, health and quantum information

Topics

- sensors and image acquisition systems
- analysis of data in physical systems
- applications in astrophysics and nuclear physics
- quantum information and quantum computing

First semester	Second semester
Experimental Physics 2 (Bicocca)	Materials and platforms for AI (Statale)
Mathematics for imaging and signal processing (Statale)	Imaging and spectroscopy for environment and health (Bicocca)

Experimental Physics 2

The lecture analyze the physics of the **electromagnetic force**, one of the four fundamental forces, covering some of its most important experimental applications, i.e. waves and circuits.

Topics: Electro and magnetic fields, Maxwell's equations, electric circuits, electromagnetic waves.

Teacher: Marco Cavedon

Materials and platforms for AI

AI runs on silicon. We will make a deep dive into the fundamental concepts of condensed matters physics, to gain an understanding of how silicon runs AI, and how AI can lead to better silicon.

Topics: Condensed Matter Physics, Semiconductors, p-n Junctions, Transistors, Physics Informed Neural Networks

Teacher: Giovanni Pellegrini

Imaging and spectroscopy for environment and health

Physical principles of medical imaging, automated analysis of medical images

Topics: NMR/MRI, CT, other techniques. Extraction of diagnostic and prognostic information from medical images: conventional strategies, radiomics, deep learning

Teachers: Alessandro Lascialfari, Luca Presotto

Mathematics for imaging and signal processing

The course aims at providing the fundamental mathematical tools for the processing of signals and images.

Topics: Topics: Lebesgue spaces, elements of Complex and Functional Analysis, Fourier transform and series, wavelets, sampling, Partial Differential Equations, imaging techniques and inverse problems.

Teachers: Matteo Cozzi, Andrea Aspri

Elective courses

Elective course

Two courses (12 ECTS) taken

- from the non-chosen tracks (recommended)
- from the courses offered the University of Pavia
- from the courses offered by Milano - Statale and Milano - Bicocca (with some technical complication)

Elective can be freely allocated on the two semesters

The study plan may include up 24 ECTS of additional activities

Practical activities

Practical activities

For the practical activities, several choices are possible (total of 9 ECTS)

- three laboratories (3 × 3 ECTS) selected in a pool of ten options
- one stage (9 ECTS)
- one short stage (6 ECTS) + one lab (3 ECTS)

Lab activities take places in our universities

The stage is carried out in a company selected by the student

Lab activities

- **Laboratory of Machine Learning**
  Topics: Design and implementation of deep learning applications for natural language processing, computer vision and pattern recognition
  Teachers: Claudio Cusano, Antonino Nocera
- **Laboratory of Computational Intelligence**
  Topics: Configuration and use of computational intelligence techniques (neural networks, fuzzy systems, evolutionary computing) for basic operations (e.g., classification, regression, prediction, control, optimization)
  Teacher: Davide Coluzzi

Lab activities

- **Laboratory of Medical Devices and Systems**

  The course aims to provide technical skills to develop and deploy Artificial intelligence-based medical devices in different areas, such as bioinformatics or biomedical images and signal analysis. The regulatory requirements needed to put these systems on the market will be investigated, such as the MDR and IVDR regulations for medical devices and the AI act. MLops principles for deploying and maintaining machine learning models in production will also be examined. After the theoretical part, students will simulate the development of a software and they will define the steps needed to obtain the certification of their software as a medical device.
  Teacher: Giovanna Nicora

- **Laboratory of Neural Signals and Brain-Inspired systems**

  Topic: cellular and circuit signals and recordings, and ensemble signals and brain-inspired systems.
  Cellular and circuit signals: Recording techniques for cells and circuits, Data analysis methods, Applications to AI, Ensemble brain signals.
  Brain-inspired systems: bringing together artificial intelligence and neuroscience, intro to Neuro-AI and related methods, examples of brain-inspired technologies.
  Teachers: Doris Pischedda, Pawan Faris

Lab activities

- **Laboratory of Cognitive and Behavioural Measures**

  Experimental psychology makes large use of behavioral measures to study psychological functions and, more in general, to build theories of cognition. During this course, students will familiarize with the main experimental paradigms and designs of cognitive psychology and how they are implemented. Students will deepen the theoretical knowledge of paradigms and designs proper of cognitive psychology; at the same time, they will acquire basic knowledge on how to implement them as computerized experiments.
  Finally, students will also work on behavioral data analysis (reaction times, accuracy, eye-movement data) with the aim to reach a good understanding of the behavioral measures and how to treat them.
  Teacher: Valerio Capraro

Lab activities

- **Machine Learning for Physics and Astronomy**
  Topics: Machine learning and data mining are quickly becoming essential techniques in the field of (astro)physics. Such powerful tools provide precious insights into the laws governing natural processes and shed light on the information contained in experimental datasets. This lab provides a quick introduction to such topics, equipping students with some essential background to apply their data-science knowledge to core physical problems.
  Teacher: Davide Gerosa
- **Laboratory of Complex Systems**
  Topics: Simulation of complex phenomena, focusing on emergent phenomena. Topics to be studied include: Random walks and diffusion, Equilibrium phase transitions, Percolation, Non-equilibrium dynamics in disordered systems, Avalanche phenomena and self-organized criticality, Neural networks.
  Teacher: Stefano Zapperi

Lab activities

- **Laboratory of Quantum Information**
  Topics: The course provides an accessible and comprehensive introduction to the principles behind quantum computing, with an exploration of some of the key quantum algorithms and their implementations using quantum circuits.
  Teacher: Alessandro Tosini
- **Laboratory of Physics Sensors and Related Data Analysis**
  Topics: the laboratory deals with the exploitation of sensors able to measure different physical parameters. The student will learn how to operate different type of sensors and to acquire data from them. Students will then apply standard analysis techniques and machine learning based techniques to analyze the data. A comparison between the two methodologies will be performed in order to understand when a ML performs better than a standard technique.
  Teacher: Gabriele Croci, Maurizio Martinelli

Lab activities

- **Project work (new)**
  Activity under the supervision of a teacher chosen by the student.
  The subject of the activity and their modalities are agreed with the supervisor.
  The project work will probably identify the topic of the thesis.

Italian language for foreign students

Foreign students MUST replace one of the labs with the course of “Italian Language for Foreign Students” (3 ECTS)

Are exempted those who

1) completed the high school, or a university degree, in Italy in the Italian language

2) completed an Italian school outside Italy

3) that already have a certification of knowledge of the Italian language at the level A2 or higher

The course is accessible online on the Rosetta Stone platform

https://en.unimib.it/education/languages-unimib/rosetta-stone-language-courses

Stage

9 ECTS (225 hours) of practical activities in collaboration with a company
A short stage (6 ECTS = 150 hours) is also available

The requirements for the activation are

- Acquisition of at least 90 ECTS worth of exams
- Selection of a company
- Definition of a project for the stage
- Selection of a tutor within the company
- Selection of an academic tutor (i.e. one of the teachers)

More information at the address

https://web.unipv.it/formazione/tirocini-curriculari-e-internato-di-tesi/

Final exam

Final exam

The final exam consists in the redaction of a written report and in its public discussion in one of the prescribed dates

The report will describe

- a project or study extending one of the three lab activities
- or the results of the project work
- or the activities carried out during the stage

In the preparation of the report students are assisted by a tutoring teacher of their choice

Final mark

After the final presentation an evaluation committee will assign a mark to the candidate computed as:

- the average of the marks obtained in the exams, scaled in the range 0-110
- up to seven points assigned to the report and its presentation
- two points assigned to students who complete the bachelor in time

The maximum mark is 110/110 cum laude