Distributed Systems Architecture [2205104]

Offerta didattica a.a. 2025/2026

Docenti: LUCA VOLLERO

Periodo: Secondo Ciclo Semestrale

Obiettivi formativi
The course will provide the student with knowledge and skills related to the hardware and software architectures of computer systems with particular emphasis on systems capable of acquiring, storing and processing, offline and online, data from sensors and other data sources distributed in the physical environment, involving intelligent systems for intermediate data processing and the tuning of the involved systems. The student is further introduced to methods and techniques for configuring and scaling such systems to optimise their performance.

Prerequisiti
-

Contenuti del corso
Distributed systems: Introduction and taxonomy
Systems architecture:
o Centralized models
o Distributed models
o Hybrid models
o Middleware

Processes:
o Operating system basics
o Processes and threads
o Communication between processes and threads
• The Client&Server paradigm
• The Publish-Subscribe paradigm
o Virtual systems

Basics of networks:
o Computer networking
o The RPC model
o The message-passing model
o Flow-based communication
o Multicast

Synchronisation:
o Clock synchronisation
o Logical clocks
o Access to synchronisation in distributed systems
o Polling systems

IoT and distributed systems
o IoT applications
o Web services
o Cloud computing and platform as a service
o Edge computing
o Fog computing

Data integrity and replication:
o Data-centric models
o Client-centric models
o Replication management
o Data integrity protocols
Fault-tolerant systems

Security of distributed systems

Metodi didattici
The course consists of in-class theoretical lectures (48 hours), laboratory exercises (12 hours) and the full implementation of a project aimed at applying the acquired knowledge and skills (12 hours).

Modalità di verifica dell'apprendimento
The exam tests the student's achievement in the knowledge and skills specified by the course's educational objectives. The examination consists of a discussion of a project developed by the student and an oral interview on the theory topics covered in the course syllabus. In the project discussion, the student must demonstrate knowledge and ability to apply the models and methodologies of distributed systems by constructing a punctual requirements analysis and using knowledge about the architectures and technologies covered in the course. In the oral exam, the student will be required to demonstrate his expertise in solving specific problems related to distributed systems' design, description and management.

The final grade is computed as the average of the evaluation of the technical quality of the project (architectural solution and documentation) combined with the proficiency through which the discussion related to its development is conducted, and for the other half by the demonstration of the knowledge of the course topics combined with the clarity of their exposition.
The award of praise is conditioned on an excellent rating on the points listed above and the demonstration of the ability to deal with design and management issues not covered directly in the course

Testi di riferimento
• Andrew S. Tanenbaum, Maarten Van Steen, Distributed Systems: Principles and Paradigms, Pearson
• David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry, IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things, Cisco Press.
• Course notes

Altre informazioni
Knowledge and understanding skills.
The course will transfer the following knowledge and comprehension skills to the student:
- Knowledge and understanding of different distributed architectures in general and IoT architectures in particular, their functional components and characteristics.
- Knowledge of device interconnection hardware and software technologies and understanding of their performance characteristics.
- Knowledge and understanding of architectural and functional solutions for distributed software applications in general and IoT applications in particular.
- Knowledge and understanding of methods of describing and designing distributed systems, in general, IoT, in particular, and ways of configuring and sizing their components.

Ability to apply knowledge and understanding.
Upon completion of the course, the student will be able to:
- Analyze and define the requirements specification of a distributed/IoT system for data acquisition, storage and processing.
- Select architectural and functional solutions for distributed/IoT data acquisition, storage and processing applications.
- Configure and size the infrastructure of a distributed/IoT system for data acquisition, storage, and processing.
- Select the technologies of a distributed system for data acquisition, storage, and processing.

Communication Skills.
The student will develop the ability to formally, rigorously and accurately describe and communicate, verbally and in writing, the functional architecture and interactions among the components of a distributed/IoT system.

Ability to learn.
The student will be able to acquire new knowledge and skills regarding distributed system/IoT technologies and architectural solutions.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.

Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	9	ING-INF/05

Stampa del 06/11/2025

Digital Twins per il Controllo, l'Automazione e la Predective Maintenance [2205102]

Offerta didattica a.a. 2025/2026

Docenti: ROBERTO SETOLA

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course aims to provide theoretical and practical knowledge on the use of modern control techniques based on the concept of state and how this can be inferred through the use of a Digital Twin. Students will learn to use advanced methodologies for modeling and simulating real systems, integrating control, observation systems such as the Kalman filter, and fault detection techniques. The course also includes the use of Digital Twin algorithms within industrial automation frameworks.

Prerequisiti
Basic elements of Control Theory (Foundations of Automatic Control)

Contenuti del corso
State Concept and Modern Control Techniques (25%):
Review of the state concept and related properties of linear systems. Discrete-time systems and sampled-data systems. State-feedback control techniques and optimal control techniques. Introduction to optimal control concepts and their application to Digital Twins for dynamic systems.

Digital Twins (25%):
Introduction to Digital Twin systems. Design techniques for Digital Twin systems based on model-driven approaches: Luenberger Observer, Kalman Filter, and Extended Kalman Filter. Elements for building Digital Twins using data-driven techniques. Use of Digital Twin frameworks for estimating and predicting the state of complex systems and for closing control loops.

Anomaly and Fault Detection Techniques (25%):
Approaches for detecting anomalous conditions and faults. Methodologies for designing algorithms capable of identifying anomalies (Anomaly Detection Systems) and faults (Fault Detection Systems), as well as for their prevention (Predictive Maintenance) and management (Incident Response Systems).

Advanced Algorithms (25%):
Unknown Input Observers for estimating unknown disturbances. Observers for systems subject to non-Gaussian noise using zonotopic approaches. Data-driven approaches (e.g., Least Squares Estimation, Maximum Likelihood Estimation, Variational Autoencoders).

Metodi didattici
Lectures (60%). Exercises on the board, with the computer and/or experimental activities (40%).

Modalità di verifica dell'apprendimento
The final grade is composed of 40% from the project evaluation and 60% from the oral exam evaluation. The oral exam consists of two to three theoretical (e.g., proofs or presentation of control schemes) or practical (e.g., exercises) questions.

Testi di riferimento
Handouts provided by the instructor

Altre informazioni
The course aims to provide the following competencies:

1) Knowledge and Understanding:
Knowledge and methodological tools for designing modern control algorithms based on the use of a system's state.
Understanding of methodological tools for implementing Digital Twin systems to estimate the state of a system.
Comprehension of how estimation algorithms such as the Kalman filter are used within Digital Twin models.

Knowledge of the main techniques for the automatic detection of anomalies and faults (fault detection) and their predictive and corrective management (predictive maintenance and fault management) using Digital Twins.
Ability to integrate supervision, management, and control algorithms based on the Digital Twin concept within industrial automation control schemes.
Ability to use advanced algorithms such as data-driven methods, Zonotopes, and/or Unknown Input Observers.
2) Applied Knowledge and Understanding:
Design of control and monitoring algorithms based on the concept of system state and its reconstruction through the use of Digital Twins, taking into account implementation challenges on computers or microcontrollers.
3) Autonomy of Judgment:
Ability to select the most effective strategy for analyzing and controlling complex systems through the use of Digital Twins.
4) Communication Skills:
Ability to discuss and collaborate with instructors and peers on advanced topics related to modern control, the use of Digital Twins, predictive maintenance, and industrial automation.
Skills in communicating technical solutions and in formulating relevant questions and answers in English.
5) Learning Skills:
Learning approach based on active participation in both theoretical lectures and practical exercises.
Development of problem-solving skills through the use of Digital Twins, with a progressive increase in difficulty throughout the course.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	9	ING-INF/04

Stampa del 06/11/2025

Fundamentals of Cybersecurity [2205105]

Offerta didattica a.a. 2025/2026

Docenti: LUCA FARAMONDI

Periodo: Secondo Ciclo Semestrale

Obiettivi formativi
The course aims to provide the learner with the main concepts of cybersecurity in order to enable him/her to introduce these elements in the design, management, maintenance and decommissioning phase of a cyber-physical system by assessing the architectural details of both infrastructural and applications.
In addition, the course aims to provide basic knowledge about data security standards by providing a set of best practices necessary for information security management.

Prerequisiti
Fundamentals of programming.

Contenuti del corso
Part I - Introduction to Operational Technologies
Hints at automation
Control systems (introduction). Sensors and actuators (references). SCADA systems Industrial controllers
Transmission media

Operational Technology and Information Technology
Architectures and characteristic elements of a plant. Update management. IoT and IIoT devices.
Process security and characteristics of data integrity, availability, and confidentiality of data.

Part II - Network Security
Network architectures
Network devices. Network topologies. Switching techniques. Communication management.

Communication protocols
TCP-IP suite protocols. ModBUS protocol. OPC UA standard. Cryptography techniques. Protocols for email communication, SMTP and phishing.

Vulnerability of networks and protocols
Vulnerability of industrial protocols. Vulnerability of wireless networks. Attack techniques (ARP Spoofing, Man in the Middle, Denial of Service, Distributed Denial of Service).

Tools for Penetration Testing and Vulnerability Assessment
The Kali Linux distribution. Hardware simulation tools in the loop. Mini net.

Network monitoring solutions
Intrusion detection Systems, Intrusion. Prevention Systems. Firewall. DMZ. Snort. Anomaly Based and Signature Based solutions for threat identification.

Part III - Security of IT systems
Authentication systems and access to services
Characteristics of data security. Digital certificates. Digital signature. Mail services. Authentication methods.
IoT Devices Security
Exposed IoT devices, secure network configuration for devices sharing: webcam, network printers, etc.

Part IV - Software security
Vulnerabilities and software threats. Security by Design. Design by Contract and Defensive programming approaches. Code Injection. SQL Injection. Buffer Overflow. Privilege Escalation. Cross-Site Scripting. Web Platforms vulnerabilities.

Part V - Open-Source Analysis
Social Engineering. OSINT investigation tools. Shodan.IO

Metodi didattici
Frontal lessons on the topics of the course (50%)
Classroom and laboratory exercises (30%)
Seminars with experts (20%)

Modalità di verifica dell'apprendimento
Both the written test and the project paper will be awarded a score expressed in thirtieths in relation to the correctness, exhaustiveness and complexity of the work presented. A positive evaluation of both the written test and the project (equal to at least 18/30) is a necessary condition for passing the examination. The final mark will be calculated as a weighted average of the mark for the written paper (40%) and the mark for the group project (60%).

Testi di riferimento
Learning support materials
Lecturer's teaching materials
Scientific articles
Reference texts
James F. Kurose, Keith W. Ross "Internet and Computer Networks" Pearson Education. C. P. Pfleeger, S. L. Pfleeger, J. Margulies: "Security in Computing, 5th Edition", Prentice Hall, 2015 Charles J. Brooks, Christopher Grow, Philip Craig, Donald Short, "Cybersecurity Essentials", Sybex Inc, 2018
Alan Calder, Steve Watkins "IT Governance: An International Guide to Data Security and ISO 27001/ISO 27002", Kogan Page Ltd, 2019

Altre informazioni
- Awareness of the links between physical industrial processes and IT infrastructure
- Knowledge of the main communication protocols in industrial networks and their vulnerabilities
- Ability to design network and software infrastructures for cyber-physical applications minimising cyber risk.
- Ability to organise penetration testing and vulnerability assessment activities on cyber-physical environments
- Ability to design solutions for the identification and mitigation of cyber threats
- Ability to assess threats to IT systems and web services
- Knowledge of the main and best practices governing information security management

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	9	ING-INF/04

Stampa del 06/11/2025

Fundamentals of Artificial Intelligence: development tools and methods [2205103]

Offerta didattica a.a. 2025/2026

Docenti: PAOLO SODA

Periodo: Ciclo Annuale Unico

Obiettivi formativi

The course consists of two modules: Development Tools and Methods.

The learning objectives of the module Development Tools provide the student with knowledge and skills necessary to use high-level programming languages for the development of software applications oriented to data processing. The student will deepen the use of programming methods and tools allowing the efficient development of software through the generation and reuse of high-quality modular components. Programming skills are applied to strategies and algorithms for data analysis in Artificial Intelligence applications.

The learning objectives of the module Methods is to acquire the basic concepts of Machine Learning (ML) and of symbolic AI, i.e., the systems and algorithms that rely on observations of data for the synthesis of new knowledge. For example, learning can take place by capturing features from examples, data structures or sensors, to analyse and to evaluate the relationships between the observed variables.
In particular, the student should:
- Acquire an adequate level of knowledge of the theoretical foundations of the main computational models for learning (e.g. supervised and unsupervised learning, classifiers and regressors, distance-based and model-based learning models, linear and kernel classifiers, evolutionary models, time series mining, etc.);
- Understand methods for the synthesis of new knowledge;
- Understand the fundamentals of methods for defining an experimental procedure and for performance evaluation;
- Understand the potential of AI for the development of decision support systems, data mining and big data analytics;
- Learn the use of appropriate development environments for the application of AI methods.

Prerequisiti

The knowledge and skills required for admission to the degree program are prerequisites.
It is moreover recommended to pass the final examination of the Optimization course.

Contenuti del corso

Module Development Tools
• Basic elements of the Python language (4 hours, held by the owner of the course)
• Built-in types
• Variables
• Objects and methods
• The data structures in Python: lists, tuples, sets, dictionaries
• Control structures
• Functions and parameters passing
• Recursion
• Packages
• Data representation (6 hours, held by the owner of the course)
• The concept of information and references to data representation
• Data structures: models and implementation
• References to the relational model
• The associative and object model
• Serialized representation of data: JSON, YAML and XML
• Object-oriented programming (10 hours, held by the owner of the course and by the co-teacher)
• The concept of class, subclass and interface
• Modularity and decoupling
• Information hiding
• Inheritance and Polymorphism
• Design Patterns
• Object-oriented programming in Python
• Complements of Python programming (4 hours, held by the owner of the course)

• Functional programming in Python
• Lambda expressions
• The map and filter functions
• List comprehension
• Relevant packages (6 hours, held by the co-teacher)
• numpy
• scipy
• pandas
• Software development and organization (10 hours, held by the co-teacher)
• Collaborative software development models
• Software systems modeling tools: UML (Class diagram, Use case diagram, Sequence diagram)
• Code version control tools (git, GitHub)
• Test Driven Development (TDD)
• Container-based software development
• The Infrastructure-as-Code (IaC) paradigm
• Development of a project (20 hours, held by the owner of the course, by the co-teachers)

Module Methods
• Introduction, definition of the concept of learning and pattern recognition, various definitions, methodology and process of analysis, concept of descriptor or feature
• Supervised, unsupervised, semi-supervised learning, reinforcement learning
• Model of the data analysis process, simple example of what it means to classify based on experience, example of fish recognition, overfitting, underfitting
• Validation methods
• Performance evaluation methods, experimental methodologies, cross-validation, confusion matrix, matrix-derived metrics, confusion, the ROC curve
• Bayes' theorem, Bayesian decision theory and the Bayesian classifier
• Non-parametric classifier: Nearest Neighbor (NN) and its extension (kNN), reliability of kNN decisions, computational considerations
• Support Vector Machine (SVM): learning algorithm, kernel types, the problem of XOR decision reliability
• Decision trees (CART, ID3, C4.5); the tree as a tool for regression and feature selection
• Classification methods based on binary decomposition of multiclass problems
• Multi-expert systems: bagging and boosting, adaboost; random forest
• Dimensionality Reduction: Feature Selection and Feature Extraction
• Data Preparation and cleaning: Data cleaning, Missing data, Incorrect and inconsistent data, Scaling and normalization, Data reduction and transformation, Data sampling, Data reduction with type transformation (for Time series)
• Introduction to neural networks and deep learning. Neuron model, transfer functions, the perceptron, LMS, stochastic downward gradient, MLP introduction, the saturation problem, Error-Backpropagation, cross-entropy, Softmax, ReLU, Techniques to fight overfitting (e.g. L1 and L2 regularization, dropout), the problem of the evanescent or explosive gradient
• Unsupervised learning, clustering, and performance estimation: definition of unsupervised learning, nomenclature and main applications, theoretical and algorithmic knowledge of the main clustering algorithms (Hierarchical Agglomerative, K-means, DB-SCAN, Expectation Maximization, Mean Shift and Spectral Clustering), knowledge of the main metrics for internal and external performance estimation (Silhouette index and Adjusted Rand index)
• Regression methods (linear, logistic, kNN, trees, SVR) and performance estimation;
• Introduction to reinforcement learning;
• Introduction to time series analysis: univariate and multivariate time series definitions, preprocessing noise reduction, representation (Discrete Fourirer Transform and Symbolic Aggregate Approximation), forecasting with autoregressive models, classification with Dynamic Time Warping and Time-Delay Neural Networks, hints on time series clustering and taxonomy.
• AutoEncoders: Undercomplete and Overcomplete
• Evolutionary models: Natural evolution and molecular genetics, Artificial evolutionary systems, Swarm Intelligence;
• Laboratory activity: using Python libraries for AI, even in cloud

Metodi didattici
The course consists of frontal theoretical classes (55%), flipped classes (10%), laboratory exercises using open source tools (20%) and the complete development of one or more projects in small groups (15% plus individual work) aimed at applying the acquired knowledge and skills.

Modalità di verifica dell'apprendimento
Knowledge assessment methods and criteria:

Specific learning outcomes are verified through the development of two projects carried out in small groups and under the supervision of one of the teachers and one oral.
The development of the first project is constantly monitored by the teacher through the collaborative development platform introduced during the course, verifying the contribution of each member of the group, the methods of interaction between members and the quality of the work carried out by the group as a whole. The assessment of

the knowledge and skills acquired by each student is completed during a final exam consisting of the discussion of the project and of the theory topics included in the program.
The second one consists in an experimental work to be presented in the classroom or in an oral interview. The aim of this test is to verify that the student has acquired the ability to use computational models to solve classification, clustering and regression problems, through the use of software tools available for the application of ML methods. Students will be provided with a real dataset specifying the problem to be solved; for example, a dataset with signals acquired from an IoT device can be provided, requiring students to develop an algorithm able to predict the future value of the signal itself.
In the experimental work, the elements taken into consideration are: the logic followed by the student in solving the problem, the correctness of the procedure identified for the solution, the appropriateness of the proposed solution in relation to the skills that the student is expected to have acquired at the end of the course. Each of these elements weighs equally in the evaluation of the laboratory test, and the satisfaction of these aspects, at least 60%, is a necessary condition for achieving a grade of 18. Higher marks will be awarded to students whose papers meet all the above aspects, in increasing proportion.
The oral test consists of an interview, which aims to verify that the student has acquired an adequate level of knowledge of the theoretical foundations of the main computational models for AI. During the oral test, the elements taken into consideration are: the logic followed by the student in formulating the answer to the question, the correctness of the procedure identified for the solution of the question, the adequacy of the proposed solution in relation to the competences that the student is supposed to have acquired at the end of the course, the use of appropriate language. Each of these elements weighs equally in the assessment of the oral test, and the satisfaction of these aspects, at least 60%, is a necessary condition for achieving a mark of 18. Higher marks will be awarded to students whose papers meet all the aspects listed above, in increasing proportion.
An example of a question might be: "present the decision tree model".

Criteria for measuring learning and defining the final grade:

The evaluation is out of thirty with the possible attribution of honors.
The final grade depends on the first project (30%) the second project (20%) and the oral test (50%).
The evaluation of the two projects depends on the evaluation of the technical quality of the developed work (external and internal documentation and software coding) and of the collaborative activity carried out, combined with the mastery with which the discussion relating to its development is conducted.
With respect to the second project, the group that obtains the best results in the experimental work, in any case above a certain minimum threshold determined on the basis of the complexity of the problem, will be entitled to +1/+2 points on the final grade.
For each of the three components, the final grade is between 18 and 23 if the student demonstrates that he has reached a level that is just sufficient, between 24 and 27 if the student demonstrates that he has reached an adequate level, between 28 and 30 if the student demonstrates that he has achieved a high level, i.e. the student must demonstrate that he/she has acquired an excellent knowledge of all the topics covered in the course, being able to link them in a logical and coherent manner. Honors are obtained by demonstrating a high degree of knowledge of the topics and simulation tools, demonstrating a high degree of autonomy and judgement, and showing a high quality of exposition.

Testi di riferimento

- Luciano Ramalho, Fluent Python, O'Reilly
- Ferdinando Santacroce, Git Essentials, Packt (https://www.packtpub.com/product/git-essentials/9781785287909)
- Network documentation of Python packages
- Bishop, Pattern recognition and machine learning. Springer, 2006
- Duda, et al. Pattern classification. John Wiley & Sons, 2012
- Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani – An Introduction to Statistical Learning with Applications in R. Springer Texts in Statistics
- Aurélien Géron – Hands-On Machine Learning with Scikit-Learn and TensorFlow: Techniques and Tools to Build Learning Machines, O'Reilly;
- Charu C. Aggarwal - Data Mining The Textbook. Springer 2015.
- Charu C. Aggarwal, Chandan K. Reddy – Data Clustering: Algorithms and Applications
- Dario Floreano, Claudio Matiussi – Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies
- Notes provided by the teacher

Altre informazioni

Knowledge and understanding.
The course will transfer the following knowledge and understanding to the student:
- Knowledge and understanding of requirements analysis techniques aimed at developing software components that satisfy those requirements.
- Knowledge of one or more programming languages supporting the modular development and reuse of software in a distributed environment.
- Knowledge of methodologies for software documentation and for verification of software quality.
- Knowledge and understanding of collaborative production, distribution and maintenance of software systems, and knowledge and understanding of the tools supporting these activities.
- Knowledge of how to appropriately interpret the main steps of algorithms for AI.

Applying knowledge and understanding.
At the end of the course the student will be able to:
• Draw up the documentation of a software system, analyze its requirements specifications and plan its development.
• Employ a programming language to develop modular and reusable software components.
• Participate to collaborative production, distribution and maintenance of software systems.
• Check the quality of software components and prepare the necessary documentation for their reuse.
• Manage the software component development cycle.
• Acquire the ability to use computational models for the solution of classical classification, clustering and regression problems;
• Be able to tackle a (simple) data analysis problem to synthetize new knowledge by implementing simple decision systems (e.g. to make decisions following the processing of a signal or of tabular data);
• Be able to identify the variables that describe a decision problem with the most information power
• Be able to use available software tools for the application of AI methods.

Making judgements
The knowledge and understanding skills acquired must enable the student to evaluate and select, on the basis of requirements specifications, the most appropriate tools and software components for modular development and reuse of software in a distributed environment.
Moreover, the student should:
- Know how to judge which are the appropriate choices to be made for solving real application cases.
- know how to judge the main characteristics of the presented computational models.
- know how to evaluate the appropriateness of an experimental procedure.

Communication skills
The student will develop the ability to communicate, in a precise and competent manner, the choices made in the development of software applications, with particular reference to preparation of documentation aimed at software reuse and maintenance.
Moreover, students should be able to draw up, present and explain possible design solutions to real application cases. Furthermore, they should be able to explain the contents of the course in adequate technical language.

Learning skills
The student must be able to acquire new languages and tools for the development of modular and reusable software components as well as to identify and use software components already available.
Moreover, students should develop the learning skills needed to undertake subsequent studies in Artificial Intelligence topics with a high degree of autonomy.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	15	ING-INF/05, ING-INF/05

Stampa del 06/11/2025

Fundamentals of Robotics [2205106]

Offerta didattica a.a. 2025/2026

Docenti: LOREDANA ZOLLO

Periodo: Secondo Ciclo Semestrale

Obiettivi formativi
The course aims to provide students with a solid theoretical and practical foundation in the field of robotics, preparing them to face the technological and scientific challenges. The course is structured to offer a broad overview of fundamental robotics concepts such as kinematics, dynamics, and robot control.

Additionally, the course aims to provide students with practical skills in tools based on artificial intelligence and machine learning, enhancing the autonomy and adaptability of robots in dynamic and unstructured environments.

Specifically, the course seeks to provide students with:
(1) solid theoretical knowledge for the analysis, modeling, programming, and configuration of robots;
(2) skills summarized as follows:
(i) practical fundamentals in the analysis, development, and control of robotic systems;
(ii) practical skills in robot modeling, programming, and management tools.

Prerequisiti
None.

Prerequisites:
Fundamentals of Computer Science

Contenuti del corso
• Introduction to Robotics: Fundamental concepts, definitions, main manipulator structures, basic components and examples of applications.
• Robot kinematics - Elements of rigid body kinematics; Position and orientation of rigid bodies; Rotation matrices, Euler angles, angle and axis, unit quaternion; Denavit-Hartenberg; Forward kinematics.
• Differential kinematics and statics – Differential kinematics; Geometric Jacobian and analytical Jacobian; Kinematic singularities; Redundancy; Inverse kinematics and inverse kinematics algorithms; Statics.
• Trajectory planning – Joint space trajectories; Point-to-point trajectories in cartesian space; trajectories generated with artificial intelligence approaches;
• Learning techniques for robot planning and control, such as demonstration learning, optimization and reinforcement learning.
• Applications of Artificial Intelligence to Kinematic and Dynamic Modeling of Robots; Machine Learning Techniques for Computer Vision
• Introduction to programming in Robot Operating System (ROS2) – Messaging systems and package management (e.g., topics, services, and actions); dynamic modeling of robots using URDF; control in ROS2; robot visualization in Rviz; robot simulation in Gazebo.

Metodi didattici
• Lectures on the topics of the course and practical exercises on their application to specific problems (48 hours).
• Seminars on specific applications of robotics (4 hours).
• Classroom tutorials and laboratory sessions to teach the use of software tools for robot modeling and control (ROS2 in Python) (20 hours).
• Group projects where students will apply competencies acquired during the lectures. The groups will be composed of 4 students at the maximum. They will be required to model and develop in a simulation environment a AR system for the execution of a specific task defined at the beginning of the course.

Modalità di verifica dell'apprendimento
Knowledge acquired during the course is evaluated through an oral exam and the presentation of a practical exercise of robot modeling and control by using ROS2.

The assessment of the acquired knowledge will be carried out by the teachers, who will verify the knowledge of the theoretical aspects of the course, and by the course assistants, who will verify students' capabilities to apply the

theoretical knowledge to a practical problem, through the discussion of the practical exercise.

During the oral exam, the teachers will ask three questions, in written or verbal form, aimed at verifying students' knowledge of theoretical issues. All the questions have the same weight in the evaluation (i.e. 11 points for each one).

The presentation of the practical exercise consists of a description of the applied methods and the achieved results by means of slides. All the practical exercises will be presented and discussed at the end of the course and, however, before the first date of the oral exam. During the discussion, specific questions for each student of the same group will be asked in order to assess the individual contribution to the overall work.

The oral test and discussion of the projects aim to evaluate:
1. Knowledge and ability to understand the course topics;
2. Ability to apply the knowledge and skills acquired in the formulation of solutions (even original ones) for robotic devices;
3. Ability to apply the methods and tools presented during the course to solve robot modeling and control problems;
4. Communication skills in the formal description of the course topics and the knowledge and considerations that underlie them to specialist and non-specialist interlocutors in national and international contexts;
5. Independent judgment in choosing solutions to robot design and development problems and ability to manage complex technical or professional activities or projects in their field of study and to assume responsibility for making decisions;
6. Ability to independently engage in lifelong learning.

Maximum duration of the oral exam: 45 minutes.
Maximum duration of the presentation of the project: 30 minutes.

The final evaluation is formulated according to the following rule:
8/9 of the final score will be assigned based on the oral exam;
1/9 of the final score will be assigned based on the presentation of the developed robot in ROS2.

Honors will be given in case of full marks for all the examinations and a final score higher than 30.

Testi di riferimento

• B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Robotics – Modelling, Planning and Control, Springer 2010.
• Rico, Francisco Martín. A concise introduction to robot programming with ROS2. Chapman and Hall/CRC, 2022.
• Aude Billard, Sina Mirrazavi and Nadia Figueroa – Learning for Adaptive and Reactive Robot Control". MIT Press, 2022
• H. Govers. Artificial Intelligence for Robotics – Second Edition: Build intelligent robots using ROS 2, Python, OpenCV, and AI/ML techniques for real-world tasks, Packt.
• Lecture notes provided by the teacher.

Altre informazioni

Knowledge and understanding
• Basic principles of robotic systems, functioning schemes and methods for modelling, programming and configuration;
• Software tools to aid modelling, programming and management of robotic systems in dynamic environments.
Applying knowledge and understanding:
• Capability to apply methods and tools of electronics, computer science, automation and mechanics to the analysis of complex systems such as robots.
• Capability to develop systems that combine the physical world with computational techniques, control methods, telematic and communication technologies by adopting advanced methods and also proposing innovative solutions for simple components or for the integrated system;
• Capability to use software tools for modeling, programming and managing robots for industrial processes and collaborative robotics in scenarios of interaction and cooperation with humans.

Autonomy in judging: Students will be encouraged to develop their analytical and critical skills by proposing exercises and practical activities on the topics explained during lectures.
Learning skills: The course relies on an approach based on the active involvement of the students by promoting re-examination and in-depth analysis of competences acquired in previous studies, and the application of the learnt concepts in other specific areas.
Communication abilities and soft skills: The course wants to promote the development of communication abilities and soft skills to work in team and in multidisciplinary settings. This goal will be pursued by soliciting pro-active involvement of the students during the lectures and group activities requiring practical implementation of the learnt theoretical issues.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	9	ING-IND/34

Stampa del 06/11/2025

General English [22051C1]

Offerta didattica a.a. 2025/2026

Docenti: ROBERTA ARONICA, DOCENTE_FITTIZIO DOCENTE_FITTIZIO

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course is aimed at consolidating the B2 CEFR level and embarking upon level C1 CEFR. The teaching activities are taught by native speakers who collaborate with the University Language Centre.

Prerequisiti
Students with language certifications – issued no longer than three years previously by one of the following Exam Certifiers: Cambridge Assessment English; LinguaSkill; City and Guilds, Pitman; Edexcel / Pearson Ltd; IELTS; TCL Trinity College London; TOEFL ET – of level C1 or higher can obtain exemption by submitting an application to the attention of the University Language Center (cla@unicampus.it).

Contenuti del corso
In the one semester, curricular course of 3 credits, English language logical-grammatical structures and vocabulary are studied in depth in order to consolidate level B2 CEFR and to embark level C1 CEFR.

Metodi didattici
The course is delivered through lectures and classroom exercises.

Modalità di verifica dell'apprendimento
Final exam.
Learning assessment is conducted via a written test consisting of grammar exercises, text comprehension, writing and listening.

Lexical and grammatical knowledge and skills related to comprehension and written production are evaluated through a written test and a listening test with a respective open-ended comprehension questions at course level. Communication skills (speaking) are assessed by the teacher during the course through interactive activities. The test is evaluated on a pass or fail basis. To be awarded a pass grade, the student must obtain a total score equal to or greater than 60%.

Testi di riferimento
The teacher will provide the teaching material during the course.

Altre informazioni
Each student is required to take a placement test to identify their initial level of knowledge of the English language.

Ability to apply knowledge and understanding
At the end of the course, the student should be able to:
– converse, read and write passages in English, answer text comprehension questions;
– produce a written text on a general topic.

Independent judgement making
The student will be encouraged to develop a critical approach in their comprehension capabilities by listening to English audios and in written production through teaching methods gradually introduced during the course. Students will be urged to independently self-correct their own papers while verifying the level of understanding of other texts analyzed during the frontal lessons.

Communication skills
The student must be able to communicate clearly and grammatically correctly.

Ability to learn
The student must demonstrate active participation by interacting in English with the teacher and the class.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	3	L-LIN/12

Stampa del 06/11/2025

Models and Methods for Optimization and Statistics [2205101]

Offerta didattica a.a. 2025/2026

Docenti: MARCO PAPI

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The aim of the course is to introduce students to basic operational and methodological knowledge and skills regarding optimization and statistics. A particular emphasis is placed on models and algorithms for engineering and IT applications in the industrial and management field. Students are also introduced to data analysis, probabilistic reasoning and statistical inference, showing how the use of appropriate statistical methods allows to solve a variety of concrete problems starting from data analysis. The theoretical study of the main algorithms for calculating the optimal solution is completed by the numerical experimentation of these algorithms using modelling languages. The contents regarding optimization and statistics are aimed at providing concepts used in several engineering applications and structured decision-making problems.

Prerequisiti
Basic topics of mathematical analysis, probability and statistics.

Contenuti del corso
1) Operations Research and Optimization (42 hours): Mathematical programming models: decision variables, objective function and constraints. Problems on graphs and flow networks. Trees and graphs, graph search algorithms. Minimum paths, maximum flow, minimum cost flow. Some data structures and solution algorithms. Linear programming. The graphical method. Basic solutions and optimality conditions. The Simplex method. Duality theory, pairs of dual problems. Dual simplex method. Sensitivity and parametric analysis. Mixed integer linear programming and combinatorial optimization. Discrete optimization problems. Relaxation technique and Branch-and-Bound algorithm. Convex and concave optimization problems. Constrained optimization. Algorithms for solving problems with convex constraints. The conditions of Karush-Kuhn-Tucker. Heuristic and local research methods. Real-world industrial and computer science applications.

2) Statistics and Decision Analysis: Frequency distributions and visualizing data. Central tendency and variability. Probability and random variables. Main probability distributions. Estimation of parameters. Simple and multiple regression: the statistical model and the main assumptions. Analytical approaches to regression. Factorial and variance analysis. analysis. Principal component analysis (PCA) and linear discriminant analysis (LDA). Risk and uncertainty. Structured and unstructured decisions. Decisions under conditions of uncertainty. Alternatives, outcomes and states of nuture, decision matrix. Expected value criterion. Introduction to Bayesian decision theory. Likelihood function and Inferential logic. Choice of the initial distribution.

Metodi didattici
- Lessons (52 hours): the course topics and exercises are carried out in order to show the application to specific problems.
- Exercise sessions (20 hours), with a weekly planning.

Modalità di verifica dell'apprendimento
The exam consists of a written test and in the development of a project work. The written test structure includes practical questions of optimization and statistics. The written test aims to assess the effective degree of learning and the autonomous ability of the students to identify the most important aspects of each topic. In the project-work, students have to demonstrate their ability to apply the methodologies studied during the course in order to solve the selected problem. The written test consists of three exercises. Precisely, first and second exercises concern points 1) of the program. The third exercise concerns point 2) of the program. The maximum score achievable in the written test is 32. The exam duration is two hours and a half. The exam involves an evaluation which is expressed as a grade of out of 30. The final mark arises from the combination of the grades assigned to the written test (60%) and to the project-work (40%). The exam is deemed to be passed successfully if the grade is equal to or higher than 18/30. The student who achieves an overall score above 30 obtains honors.

Testi di riferimento
[1] F. S. Hillier, G. J. Lieberman, Ricerca Operativa: Fondamenti, Editore: McGraw-Hill.

[2] Fletcher, R. Practical: Methods of Optimization, Wiley.
[3] W.L. Winston, Operations Research, Applications and Algorithms, third edition.
[4] Dimitri P. Bertsekas, Nonlinear Programming, Athena Scientific.

Altre informazioni

By the end of the course, students should be able to:
a. Identify the methods to be used for the determination of the optimal solution of operations research problems.
b. Analyze the optimal solution determined by the numerical technique, its uniqueness and the sensitivity with respect to the values assigned to the model parameters.
c. Use computer programming languages to solve the models.
d. Formulate a decision-making problem in a real-world context by means of a mathematical programming model, thanks to the identification of the decision variables, the objective to be achieved and the constraints of the problem.
e. Apply the methodological foundations of data analysis.
f. Use the main statistical techniques for data analysis.
The course is inspired to the “student engagement”. Students have to learn and progress in their skills and competencies aimed at knowing how to translate theoretical information and practical skills gained in operations research and statistical analysis in a scientific and technological context. Students must be able to actively deal with typical problems of optmization faced in engineering applications.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Ingegneria dei Sistemi Intelligenti (2025)	comune	9	SECS-S/06

Stampa del 06/11/2025

Deep Learning [2203218]

Offerta didattica a.a. 2025/2026

Docenti: ROSA SICILIA

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course will explore in depth the main Deep Learning approaches based on deep neural networks for the analysis of multidimensional data. Deep learning algorithms are general nonlinear models capable of learning features directly from data, making them an excellent choice for applications in robotics, natural language processing, healthcare, and computer vision. The final project aims to develop the ability to independently address a real-world or laboratory problem by applying a neural network model to either create an application or experimentally evaluate the effectiveness of Deep Learning approaches in various contexts. The course will be divided into two parts: the first consisting of theoretical lectures, and the second comprising laboratory sessions focused on applying the studied models using the Python programming language.

Prerequisiti
It is recommended to pass the final examination of the Foundations of Artificial Intelligence.

Contenuti del corso
PART 1: Theory Lectures (60%)
Topics covered in the lectures:
- Introduction to the course, overview of Deep Learning, evaluation methods, application domains (robotics, NLP, healthcare, computer vision); (1 h)
- Review of linear algebra, probability, information theory, and numerical computation; (1 h)
- Deep Feedforward Networks: architecture, activation functions, training with backpropagation, loss functions; Regularization techniques for Deep Learning: L1, L2, Dropout, data augmentation, handling data imbalance; Training optimization strategies: mini-batch training, early stopping, learning rate scheduling, surrogate loss functions; (2 h)
- Convolutional Neural Networks (CNNs): convolution, pooling, basic architectures, and Softmax; Advanced CNNs: from AlexNet to EfficientNet; (6 h)
- Autoencoders: architecture, training and regularization, denoising autoencoders (DAE), U-Net for segmentation; (2 h)
- Recurrent and sequential networks: RNN, LSTM, GRU, encoder-decoder architectures; Hybrid solutions for time series and transfer learning; (6 h)
- Transformers: attention mechanisms, encoder-decoder architecture, positional encoding, residual connections; Transformer variants: decoder-only models (GPT), BERT, ViT, applications to time series and NLP; (4 h)
- Introduction to Multimodal Learning: definition of multimodality, data types, main challenges; Architectures and fusion strategies for multimodal learning: early, joint, and late fusion; soft/hard attention, co-attention, cross-attention; Open challenges and future directions in Multimodal Learning: generalization, efficiency, interpretability, emerging trends; (2 h)
- Introduction to Deep Reinforcement Learning: DQN, Double DQN, Dueling DQN; Policy gradient methods, actor-critic algorithms, advanced approaches (PPO, DDPG, TD3, SAC), Multi-Agent Reinforcement Learning. (6 h)

PART 2: Laboratory (40%)
All topics covered during the lectures will be analyzed from a practical development perspective through hands-on lab sessions, with a focus on the use of PyTorch.

Metodi didattici
Lectures (60% of the total class time), during which the course topics are presented and exercises are carried out to demonstrate their application to specific problems. Laboratory sessions (40% of the total class time), aimed at teaching the use of software tools for the development of deep learning networks. Students will work on a group project related to the course topics.

Modalità di verifica dell'apprendimento
The knowledge and skills acquired during the course are assessed through two main components: a group project and an oral examination.
The group project, carried out in the lab, involves developing an application based on deep learning models to solve a real-world problem assigned by the instructor (e.g., classification, segmentation, time series analysis, or

multimodal learning). Evaluation will consider the correctness of the proposed solution, the coherence of the chosen approach, and the efficiency and robustness of the implementation.
The oral exam will assess the student's theoretical knowledge of the main models covered in the course, their ability to logically connect concepts, and the use of appropriate technical language. The group project will also be discussed during the oral exam.
The final grade will be based 75% on the oral exam and 25% on the project. Passing the course requires meeting minimum standards in both components (i.e., achieving a grade of 18/30 in both components). Particularly well-executed projects may earn a bonus of +1 or +2 points.
The highest grade (30/30 cum laude) will be awarded to students who demonstrate complete mastery of the course topics, critical thinking, and clear, structured communication.

Testi di riferimento

Lecture notes, PowerPoint presentations, and exercises are distributed in electronic format at the following address: http://elearning.unicampus.it/.
The course content is covered in the following reference textbook:
Ian Goodfellow, Yoshua Bengio, Aaron Courville – Deep Learning, The MIT Press.

Altre informazioni

Applying knowledge and understanding
The student is expected to:
- Understand and implement the main deep learning models covered in the course;
- Be able to tackle real-world problems using appropriate neural network architectures (e.g., classification, regression, segmentation, sequence analysis, multimodal learning);
- Use software tools (particularly PyTorch) to design, train, and validate deep learning models on complex datasets.

Independent Judgment
The student is expected to:
- Critically evaluate design choices when addressing complex applied problems;
- Assess the strengths and limitations of neural models proposed in the literature or implemented during lab sessions;
- Evaluate the quality of proposed solutions in terms of accuracy, computational efficiency, and robustness;
- Make autonomous decisions regarding data preprocessing, model design, and training strategies across different application scenarios.

Communication Skills
The student is expected to:
- Clearly and effectively draft and present project-based solutions to real-world problems, even in multidisciplinary contexts;
- Appropriately use technical language related to deep learning and neural modeling, both in written and oral form.

Learning Skills
The student is expected to develop the skills needed to independently pursue further study and stay updated in the field of artificial intelligence. Specifically, they should:
- Acquire a solid understanding of the theoretical foundations of deep neural networks;
- Understand the principles behind designing deep learning pipelines for different data types (images, text, signals, sequences);
- Recognize the potential of deep learning techniques to build intelligent systems capable of analyzing, interpreting, and generating data in complex real-world scenarios.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Robotica	6	ING-INF/05
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Intelligenza Artificiale - Cybersecurity	6	ING-INF/05

Stampa del 06/11/2025

Ethical Hacking [2203217]

Offerta didattica a.a. 2025/2026

Docenti: IVANO GABRIELLI

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course aims to provide the learner with advanced cybersecurity concepts about network security to enable the learner to independently manage and conduct vulnerability assessment and penetration testing activities on IT and OT infrastructures.
Furthermore, the course aims to provide the learner with the the key knowledge for analysing software security in order to perform vulnerability checks on software applications.
Finally, the course aims to provide learners with advanced notions of web security with a focus on web services and client and server side vulnerabilities. At the end of the course, learners will be given the opportunity to obtain a cybersecurity certification.

Prerequisiti
Cybersecurity

Contenuti del corso
Part I – Introduction
OS architecture, file system structure, main commands, network configuration, processes, Kernel, Virtual Machine, Linux Distributions, Virtualisation, Initial Setup, Review of main components

Part II – Network Security
Network protection tools, Virtual LAN, vulerability assessment and penetration testing activities
Information Gathering and Footprinting, traceroute, ping, whois, nmap, nslookup, Google Dorks.

Firewall, IDS, IPS and DMZ configuration activities.
Part III – Software Security and Malware Analysis
Architetture X86, Executable and Linkable format (ELF), Secure Programming, Secure Software Development, Defensive Programming, Memory management e debugging, GDB, reverse engineering tools, Ghidra

Part IV – Web Security
File Disclosure: (Impact and Overview, Paths 101, Path traversal attacks, Fixes), Server-Side Request Forgery, command e code injections, Blind SQL injection, Time-based SQL injection, Cross-Site Scripting, Cross-Site request Forgery.

Part V – Hardware Security
Circuiti digitali, Flip-Flops, latch, registry e memorie. Hardware trojan, side channel attacks, power analysis, fault attacks, test infrastructure-based attacks.

Metodi didattici
Lectures on course topics (35%)
Classroom and laboratory exercises (50%)
Seminars with experts (15%)

Modalità di verifica dell'apprendimento
Knowledge assessment methods and criteria:
Written exam and group project

The written test, which lasts 1 hour, includes three questions aimed at verifying the basic skills acquired during the course with particular reference to software, web services and network security management policies.
The group project paper (maximum 4 students) will be arranged with the group members and may cover the following areas
- Hardware Security: Carrying out and testing the security of an electronic circuit
- Malware analysis: execution of a malware in an isolated context and production of a post-incident report

- Software security: solving a challenge involving debugging and reverse engineering activities

Criteria for measuring learning and defining the final grade:
Both the written test and the project paper will be awarded a mark expressed in thirtieths in relation to the correctness, exhaustiveness and complexity of the work submitted. A positive evaluation of both the written test and the project (equal, at least, to 18/30) is a necessary condition for passing the examination. The final mark will be calculated as the weighted average of the written test mark (40%) and the group project mark (60%).

Testi di riferimento
Lecturer's teaching materials
Scientific articles

Altre informazioni
- Awareness of the potential effects of exploiting hardware and software vulnerabilities on IT and OT systems.
- Knowledge of hardware and software solutions useful for vulnerability assessment and penetration testing on IT and OT networks and how to produce and test software systems
- Ability to produce secure software and identify potential vulnerabilities with particular attention to issues related to the use of third-party systems, libraries, and memory use.
- Ability to organise penetration testing and vulnerability assessment activities on hardware and software systems
- Ability to design secure web services with focus on client and server side vulnerabilities.
- Ability to assess the security of hardware and software systems
- Knowledge of the main methodologies for hardware and software vulnerability analysis

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Robotica	6	ING-INF/04
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Intelligenza Artificiale - Cybersecurity	6	ING-INF/04

Stampa del 06/11/2025

Generative AI [2203219]

Offerta didattica a.a. 2025/2026

Docenti: VALERIO GUARRASI

Periodo: Primo Ciclo Semestrale

Obiettivi formativi

The primary goal of the Generative AI course is to provide students with comprehensive knowledge and practical skills to understand, implement, and innovate using generative artificial intelligence techniques. Students will explore advanced models and methodologies essential for generating synthetic data across various modalities, including text, images, and multimodal data.
Specifically, students will:
• Gain an in-depth understanding of theoretical and practical foundations of generative AI, including autoencoders, transformers, GANs, diffusion models, and large language models (LLMs).
• Acquire proficiency in developing generative models using frameworks like PyTorch and Hugging Face, enabling the creation and deployment of state-of-the-art AI systems.
• Learn to design, train, fine-tune, and evaluate generative AI models for tasks involving image reconstruction, image generation, text generation, and multimodal data synthesis.
• Understand and apply advanced attention mechanisms, including soft attention, attentional interfaces, and transformer architectures, for enhancing generative processes.
• Develop skills to perform effective prompt engineering and fine-tuning strategies to optimize generative models for specific tasks.
• Analyze ethical considerations, implications, and best practices in deploying generative AI, emphasizing transparency, accountability, and responsible AI use.
• Engage with state-of-the-art research, critically evaluating and presenting recent advancements in generative AI.
• Gain practical experience through hands-on projects that involve building, optimizing, and deploying generative AI models to address real-world problems.

Prerequisiti

It is recommended to pass the final examination in the “Fondamenti di Intelligenza Artificiale: strumenti di sviluppo e metodi” course before proceeding.

Contenuti del corso

Introduction and Historical Context
• History of AI
• Overview of Generative AI
Deep Learning Foundations
• Neural network architectures
• Training and optimization
Natural Language Processing (NLP)
• Language modeling
• Word embeddings and contextual representations
Generative AI with PyTorch
• Fundamentals of PyTorch
• Building and training neural networks
Attention Mechanisms
• Soft Attention
• Attentional Interfaces
• Attention as Memory
Transformers
• Transformer architecture fundamentals
• Transformers for NLP
• Implementing Transformers from scratch
• Hugging Face framework
Large Language Models (LLMs)
• Building and fine-tuning LLMs
• Prompt engineering and practical applications
Computer Vision Models
• Convolutional Neural Networks (CNNs)

• Vision Transformers (ViTs)
• Practical implementation of CNN and ViT models
Autoencoders and Variational Autoencoders
• Theoretical concepts
• Applications in image reconstruction and generation
Generative Adversarial Networks (GANs)
• Introduction and theoretical background
• Practical implementations: GAN, DCGAN, Pix2Pix
Diffusion Models
• Fundamentals and applications
• Fine-tuning diffusion models
• Advanced prompt engineering

Metodi didattici
The course is structured to include frontal theoretical lectures (55%), flipped classes (10%), laboratory exercises with open-source tools (35%). This format is designed to facilitate the application of acquired knowledge and skills.

Modalità di verifica dell'apprendimento
Assessment involves an oral exam and the presentation of a project focused on a state-of-the-art generative model. Students will demonstrate:
• Comprehensive understanding of generative AI methodologies and theories.
• Practical capability in implementing and optimizing generative models.
• Ability to critically analyze recent research advancements and apply ethical considerations.
Evaluation criteria include:
• Logical and coherent problem-solving approach.
• Technical correctness and innovation in the proposed solutions.
• Adequacy and depth of understanding relative to expected competencies.
• Clear communication using appropriate technical language.
Each component (project presentation and oral exam) equally contributes to the final evaluation.

Testi di riferimento
• Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
• Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play by David Foster & Karl Friston
• LLM Engineer's Handbook: Master the Art of Engineering Large Language Models by Paul Iusztin & Maxime Labonne (2024)
• Notes provided by the lecturer.

Altre informazioni
Applying Knowledge and Understanding Students should be able to:
• Correctly interpret and implement generative AI algorithms and their core principles.
• Design and execute end-to-end generative AI workflows, including data preprocessing, model selection, training, evaluation, and deployment.
• Solve practical problems involving image, text, and multimodal data generation using contemporary generative models.
• Utilize software frameworks and tools effectively for building and managing generative AI systems.
Making Judgments Students should be capable of:
• Evaluating the appropriateness of generative AI techniques for various applications.
• Assessing the strengths, limitations, and suitability of different generative architectures and models.
• Making informed decisions regarding ethical implications and responsible use of generative AI technologies.
Communication Skills Students should be able to:
• Clearly present, document, and explain generative AI solutions, using precise technical language.
• Effectively communicate insights from generative models through visualizations and interpretive analyses.
Learning Skills Students should develop the learning skills necessary to independently explore advanced topics and continue professional development in generative AI.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Robotica	6	ING-INF/05

Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Intelligenza Artificiale - Cybersecurity	6	ING-INF/05

Stampa del 06/11/2025

The Human Factor in the Digital Transformation [2203215]

Offerta didattica a.a. 2025/2026

Docenti: MARTA BERTOLASO

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
This course traces the history of how we have attempted to represent human characteristics in machines. It explores how this project, rooted in a Cartesian model of mind-body separation, has led to a gradual erosion of the boundaries it sought to define. The course sets out to analyze the inevitable “alienation” that results from replicating a disembodied mind and to address the contemporary challenge of re-integrating these technologies with our social and ethical values, guided by new philosophies of mind (and body). It is specifically designed for students with engineering backgrounds to provide critical tools to understand the philosophical underpinnings of their work.

Prerequisiti
none

Contenuti del corso
The course is developed as a single narrative in three modules:

Module 1: The Replication Project

The initial module examines the attempt to replicate a specific model of human-the rational mind-in a formal system. We will explore the dawn of cybernetics and the symbolic paradigm as a direct technological application of the legacy of Cartesian dualism, then compare these models with their most powerful philosophical critiques.

Module 2: The Return of the Body and the Erosion of Boundaries.

The second module aims to describe why the disembodied model alone is not enough. We will analyze Connectionism (the metaphor of the brain) as the first attempt at re-integration and the radical alternative of Enactivism, where intelligence is an embodied action that challenges the very idea of representation, demonstrating how the boundaries between mind, body and world are very fragile.

Module 3: The Challenge of Re-integration: ethical-normative issues and their genesis.

The final module addresses the contemporary challenge: understanding the profound psychological impact of interacting with models. The course culminates in an analysis of current critiques and ethical frameworks (EU guidelines), and then applies this knowledge in a practical workshop on responsible AI design.

Metodi didattici
The course combines lectures with guided discussions. Narrative structure is a key teaching element. In particular, the core modules will serve as a “bridge” to connect abstract philosophical debates about AI to the concrete psychological impact of human-computer interaction. The final activity will be a group workshop (“Engineering a Human-Centric AI”) that will require students to apply the entire learning to a practical design problem.

Modalità di verifica dell'apprendimento
The evaluation will be based on the average of the marks of a final workshop and some supplementary questions during the oral exam. During the workshop and the oral exam, the clarity of presentation and the ability to navigate the narrative of the course will be assessed, critically connecting the concepts of the three modules.

Testi di riferimento
Bertolaso M, Marcos A (2023) Umanesimo tecnologico, Carocci.
Bertolaso, M. (2021). Etica digitale. LUISS University Press 2021.
Accoto, C., & Pentland, A. (2017). Il mondo dato: Cinque brevi lezioni di filosofia digitale (Prima edizione). Egea
Bertolaso, M., Capone, L., & Rodríguez Lluesma, C. (A c. Di). (2022). Digital humanism: A human-centric approach to digital technologies. Springer International Publishing AG.
Floridi, L., & Cowls, J. (2019). A Unified Framework of Five Principles for AI in Society. Harvard Data Science

Review, 1(1). https://doi.org/10.1162/99608f92.8cd550d1
Somenzi V., Cordeschi R. (2022). La filosofia degli automi: Origini dell'intelligenza artificiale. Mimesis
A Unified Framework of Five Principles for AI in Society · Issue 1.1, Summer 2019

Altre informazioni

Upon completion of the course, the student will be able to:
Trace the historical-philosophical arc from the replication of the mind to the re-integration of the human.
Critically evaluate the legacy of Cartesian dualism in the design of modern AI.
Explain and compare the main paradigms of philosophy of mind and AI (symbolic, connectionist, enactive).
Analyze how the boundaries between mind/body and human/machine have become fragile and permeable.
Relate philosophical theories to the psychological impact of technology.
Formulate design requirements for AI systems that meet contemporary ethical and social challenges.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	comune	3	M-FIL/02

Stampa del 06/11/2025

The human factor in the digital transition [2203107]

Offerta didattica a.a. 2025/2026

Docenti:

Periodo: Primo Ciclo Semestrale

Syllabus non pubblicato dal Docente.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	comune	3	M-FIL/02

Stampa del 06/11/2025

Innovation and Digital Transformation [2203214]

Offerta didattica a.a. 2025/2026

Docenti: ROBERTO GUIDA

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course aims to provide an understanding of the opportunities related to digital innovation in business models, and to explore in depth the topics related to new enabling technologies that support the digitalization of products and business processes.
Specifically, the learning will focus on trending topics such as IoT and Industry 4.0, Big Data Analysis, Circular Economy, and Open Innovation. This will also involve the development of digital skills, managerial abilities, and leadership techniques necessary for professionals operating within the digital ecosystem or in companies undergoing an irreversible process of digital transformation.

Prerequisiti
None

Contenuti del corso
GENERAL PART
• Introduction to innovation and its various forms;
• Introduction to emerging technologies such as artificial intelligence, blockchain, the Internet of Things (IoT), and augmented reality;
• Impact of these technologies on business processes and society;
• Examples of practical applications of emerging technologies;
• Technology cycles and adoption curves;
• Innovation strategies and management of Research & Development (R&D) processes;
• Innovation funding and performance measurement in R&D;
• Evaluation of innovation projects;
SPECIAL PART
•Innovation and optimization models in the energy sector;
•The importance of forecasting systems for energy generation and consumption;
•Examples of optimization in the electricity sector;
•The role of Digital Decision Platforms.

Metodi didattici
The course is structured into lectures (30%) and practical sessions (18%). The lectures are aimed at presenting the course topics. During the practical sessions, exercises are carried out interactively with students, demonstrating the application of various tools and methods to specific problems and case studies. These activities are conducted both using the whiteboard and through the use of computing environments and productivity and analysis software.

Modalità di verifica dell'apprendimento
The assessment of acquired knowledge and skills is generally carried out through a practical test. The aim is to evaluate both the understanding of the theoretical concepts presented during the course and their application to case studies, through the development of a group project work. The final evaluation is expressed with a grade on a scale of thirty.

Testi di riferimento
Lecture notes and handouts distributed during the course.

Altre informazioni
- Knowledge and Understanding

Through the proposed content, students will be guided in understanding technological evolution and, in particular, how different digital tools influence the transformation of social and business practices.
- Applying Knowledge and Understanding

The course offers a path that integrates a solid theoretical foundation with examples drawn from practical cases. The objective is to help students understand the fundamental elements of technological innovation, focusing on both

theoretical aspects and the ongoing changes that technology brings to companies and society.

- Judgment Autonomy

The integration of theoretical approaches and empirical experiences proposed during the course will allow students to develop critical thinking, which is essential for consciously analyzing the various professional contexts where technological innovation plays a central role. The acquired skills can thus be applied flexibly and purposefully, according to the specific needs of each field.

- Communication Skills

Through the use of teaching materials and by attending lectures, students will be able to discuss the topics covered in the course using appropriate and technical language.

- Learning Skills

Throughout the course, the instructor will not only provide educational input but will also be available to suggest further readings – through articles and reference texts – to facilitate understanding and learning of the subject.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	comune	6	ING-IND/35

Stampa del 06/11/2025

Intelligent Architectures: Microservices Programming for AI [2203221]

Offerta didattica a.a. 2025/2026

Docenti: PAOLO SODA

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course aims to provide students with an in-depth understanding of microservices architectures, with a particular focus on their integration with Artificial Intelligence (AI) solutions. The objective is to train professionals capable of designing, developing, and scaling advanced distributed systems, ensuring modularity, efficiency, and resilience.

Specifically, the student will:
- Understand the fundamental principles of microservices and their comparison with monolithic architectures, becoming familiar with concepts such as autonomy, modularity, and scalability.
- Acquire a solid grasp of design and implementation techniques for distributed systems based on microservices.
- Learn how to integrate AI models into microservices by decomposing Machine and Deep Learning pipelines into modular and scalable components.
- Understand the methods for achieving scalability and resilience in distributed architectures.
- Gain practical experience with appropriate development environments.

Prerequisiti
It is recommended to have passed the course Foundations of Artificial Intelligence: Tools and Methods.

Contenuti del corso
Fundamentals of Microservices
• Definition and principles of microservices (Monolithic systems vs microservices, Key characteristics: autonomy, modularity, scalability)
• Microservices system design: Domain-Driven Design (DDD), Event-Driven Architecture (EDA), API Gateway and service communication (REST, gRPC, GraphQL)
• Data management in microservices (Distributed databases and consistency strategies, Event Sourcing and CQRS – Command Query Responsibility Segregation)
AI Architectures Based on Microservices
• Decomposing the AI pipeline into microservices
• DSPy: Introduction to the framework, practical usage for building AI pipelines and distributed microservices
• MLOps practices; Lifecycle orchestration and management (automated model lifecycle, continuous performance monitoring, and data drift handling)
• Model deployment
Scalability and Resilience
• Scalability: Vertical vs horizontal scaling, load balancing, auto-scaling
• Fault tolerance and monitoring: resilience strategies, monitoring tools (e.g., Prometheus)
• Introduction to edge computing
Case Studies
• Machine Learning pipelines (Microservices for data collection, cleaning, training, inference, and result visualization)
• Recommendation systems based on microservices and AI (Dedicated microservices for data retrieval, feature extraction, recommendation computation, and personalization)
• Computer vision applications (Microservices for image upload, segmentation, feature extraction, and object recognition)
• NLP and RAG (Microservices for tokenization, semantic analysis, inference using a language model – e.g., GPT –, and response generation)

Metodi didattici
The teaching is based on lectures and computer-based exercises, using open-source or proprietary packages. The split between lectures and computer-based exercises is 50%-50%, respectively, unless specific needs arise during the course.

Modalità di verifica dell'apprendimento
The knowledge and skills acquired in the course are assessed through two evaluations.

The first is a practical project, to be carried out in small groups and presented either in class or during the oral exam. The objective of this assessment is to verify that the student has developed the ability to design and implement microservices architectures for AI applications.
Students will be provided with a real-world problem statement to solve. For example, they may be asked to design and develop a distributed system based on microservices that leverages AI to deliver personalized recommendations to e-commerce users, thereby optimizing user experience and increasing conversion rates.
The project will be evaluated based on the following equally weighted criteria:
• The reasoning followed by the student in approaching the problem,
• The correctness of the procedure identified for solving it,
• The adequacy of the proposed solution in relation to the expected competencies acquired by the end of the course.
A minimum of 60% fulfillment of these aspects is required to achieve a passing grade of 18/30. Higher marks will be awarded to students whose work meets all the above criteria to a proportionally higher degree.
The second evaluation is an oral examination, aimed at assessing the student's understanding of the theoretical foundations of the course. During the oral exam, the following elements are considered, with equal weight:
• The logical reasoning used in formulating answers,
• The correctness of the proposed solution,
• The relevance of the answer in relation to the expected course competencies,
• The use of appropriate technical language.
As with the project, a minimum of 60% compliance with these criteria is required to obtain a grade of 18/30. Higher scores will be assigned based on how thoroughly all aspects are addressed.
An example of an oral question might be: "What are the main advantages of a microservices architecture compared to a monolithic architecture when developing AI-based applications?"

Testi di riferimento

• Roberto Franchini, Kubernetes e microservizi.
• Sam Newman, Building Microservices: Designing Fine-Grained Systems, O'Reilly
• Sam Newman, Monolith to Microservices: Evolutionary Patterns to Transform Your Monolith, O'Reilly
• Kristian Bainey, AI-Driven Project Management: Harnessing the Power of Artificial Intelligence and ChatGPT to Achieve Peak Productivity and Success, Wiley
• Gaurav Raje, Security and Microservice Architecture on AWS: Architecting and Implementing a Secured, Scalable Solution, O'Reilly
• Robert C. Martin, Clean Architecture: A Craftsman's Guide to Software Structure and Design, Prentice Hall

Altre informazioni

Applying knowledge and understanding
The student will be expected to:
• Be able to design and implement distributed systems based on microservices, adopting methodologies such as Domain-Driven Design (DDD), Event-Driven Architecture (EDA), and advanced communication techniques (REST, gRPC, GraphQL).
• Acquire the ability to apply MLOps practices, with particular focus on orchestration, continuous monitoring, and lifecycle management of AI models.
• Ensure the scalability and resilience of distributed architectures by implementing strategies such as auto-scaling, load balancing, and fault tolerance.
• Analyze real-world case studies, understanding the use of microservices in applications such as Machine Learning, recommendation systems, computer vision, and Natural Language Processing (NLP).
• Use development environments and tools for the implementation and testing of microservices.

Independent Judgment
The student will be expected to:
• Be able to assess and choose the most appropriate solutions for solving real-world application problems;
• Critically evaluate the main characteristics of the techniques presented;
• Assess the adequacy and soundness of an experimental procedure.

Communication Skills
The student should be able to draft, present, and explain potential design solutions for real-world application scenarios, and effectively communicate the course content using appropriate technical language.

Learning Skills
The student is expected to develop the learning abilities necessary to undertake further studies with a high degree of autonomy.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	comune	6	ING-INF/05

Stampa del 06/11/2025

Mobile Robotics [2203220]

Offerta didattica a.a. 2025/2026

Docenti: CLEMENTE LAURETTI

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course aims to provide students with advanced knowledge in the design, development, and management of mobile robotic systems operating in dynamic and unstructured environments. It focuses on addressing the unique technological challenges associated with wheeled mobile vehicles, underwater robotics, drones, quadruped robotics. The course emphasizes the use of intelligent algorithms to enhance the autonomy and adaptation capabilities of robots in dynamic and unstructured scenarios. Students will develop a solid theoretical foundation in advanced perception and navigation techniques and learn to apply state-of-the-art approaches to create robust solutions for complex real-world problems.

Prerequisiti
Fundamentals of Robotics

Contenuti del corso
MODULE 1: INTRODUCTION TO MOBILE ROBOTICS (14 hours)
Classification of mobile robots (e.g. wheeled mobile robots, underwater vehicles, drones, quadrupeds, mobile manipulators); Mechanics of mobile robots (locomotion components, stability analysis, traction system etc.); Kinematics and Dynamics of mobile robots

MODULE 2: LOCALIZATION AND MAPPING (10 hours)
Taxonomy of localization problems; Localization based on proprioceptive sensors and exteroceptive sensors; Localization based on multimodal sensor fusion; Methods for Simultaneous Localization and Mapping

MODULE 3: MOTION PLANNING (8 hours)
Space-time separation law; collision-free path planning methods (cell decomposition methods, roadmap-based methods, artificial potential field methods); Optimal path search methods; Power-aware path planning and task scheduling

MODULE 4: CONTROL STRATEGIES FOR AUTONOMOUS NAVIGATION and tele-operatED MANIPULATION (10 hours)
Control Paradigms (deliberative, reactive, hybrid); Trajectory Tracking Control; Regulation Control (Cartesian and posture regulation); Artificial Potential Field Control; Tele-operated Control Architecture and Advanced control techniques for Mobile manipulators

MODULE 5: CASE STUDIES (6 hours)
Application of subsea, aerial, and terrestrial robotics for inspection and maintenance of remote facilities (such as offshore and onshore platforms); application of mobile manipulators, hyper-redundant robots and/or quadrupeds in hostile environments (such as radioactive or confined spaces).

Metodi didattici
• Lectures on the topics of the course (36 hours).
• Seminars on specific applications of robotics in remote and hostile environments (2 hours).
• Classroom tutorials and laboratory sessions to simulate specific use cases using ROS2 in C++ and/or Python (10 hours).

Modalità di verifica dell'apprendimento
The knowledge assessment consists of an oral exam and a practical exercise in ROS2. The oral exam is designed to evaluate students' comprehension of theoretical concepts. It includes three questions of equal weight, focusing on key topics from the course. The practical exercise in ROS2 assesses the student's ability to apply the theoretical concepts to practical scenarios of real-world applications.
The final evaluation is formulated according to the following rule:

• 2/3 of the final score will be assigned based on the oral exam;

• 1/3 of the final score will be assigned based on the practical exercise in ROS2.

Testi di riferimento

• Class notes and materials provided by the professor through the institutional e-learning platform: http://elearning.unicampus.it.
• Robotics: Modelling, Planning and Control, B.Siciliano

Altre informazioni

KNOWLEDGE AND UNDERSTANDING
• Fundamental principles of robotic systems in dynamic and unstructured environments
• Key methodologies for robot modeling, perception, and control tailored to unknown scenarios.
• Intelligent approaches for enhancing the autonomy and adaptability of robotic systems in unstructured environments.

APPLYING KNOWLEDGE AND UNDERSTANDING
• Ability to apply methods and tools from robotics, mechatronics, computer science and automation to design and manage autonomous mobile systems.
• Ability to design and develop robotic systems that integrate intelligent algorithms and advanced control strategies, to perform complex tasks in dynamic environments.
• Capability to use software tools to model, program, and manage robots operating in unstructured environments.

AUTONOMY IN JUDGING
Students will be encouraged to develop their critical thinking and analytical skills by analyzing case studies and exploring solutions for real-world robotic challenges.

LEARNING SKILLS
The course adopts an active learning approach, promoting re-examination and in-depth exploration of competences acquired in prior studies. Students will learn to apply these concepts to design robotic solutions for new and challenging applications.

COMMUNICATION ABILITIES AND SOFT SKILLS
The course aims to enhance communication skills and teamwork in multidisciplinary contexts. This will be achieved through the discussion of case studies and the presentation of innovative robotic solutions, fostering pro-active engagement and collaborative problem-solving

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Robotica	6	ING-IND/34
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Intelligenza Artificiale - Cybersecurity	6	ING-IND/34

Stampa del 06/11/2025

Final Examination [22032PF]

Offerta didattica a.a. 2025/2026

Docenti:

Periodo: Secondo Ciclo Semestrale

Syllabus non pubblicato dal Docente.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	comune	24	PROFIN_S

Stampa del 06/11/2025

Smart Systems [2203216]

Offerta didattica a.a. 2025/2026

Docenti: GABRIELE OLIVA

Periodo: Primo Ciclo Semestrale

Obiettivi formativi
The course provides students with advanced skills to design, develop, and manage complex automated systems, focusing on smart distributed infrastructures. Both the theoretical aspects of cyber-physical systems and practical aspects, such as advanced industrial control systems, IIoT device integration, and event-driven and distributed systems, are covered.

Prerequisiti
None

Contenuti del corso
Part 1: SCADA Systems, Industrial Automation, and PLC Programming (16 hours)
• SCADA systems and industrial automation: Introduction to the supervision and control of distributed industrial systems. Analysis of SCADA systems and automated management techniques.
• Petri Nets: Use of Petri graphs for modeling and managing industrial processes and automated networks.
• PLC Programming: Programming languages for industrial control, with a focus on Ladder (LD) and Sequential Function Chart (SFC) languages.
• Job shop scheduling: introduction to the job scheduling problem on shared machines, applications in the context of industrial automation, mathematical models and formulations, exact and heuristic solution techniques.
Part 2: Industrial Networks and Protocols, Advanced Integration and Automation (16 hours)
• Industrial protocols: Introduction and in-depth study of widely used industrial protocols like Modbus TCP/IP, Profibus, Ethernet/IP, and MQTT for communication between industrial and control devices.
• SCADA System Integration: Practical implementation of a SCADA network for control and supervision of a real plant. Programming PLCs such as Schneider Electric M340 and Siemens S7-1200.
• IIoT (Industrial Internet of Things) systems: Integration of IIoT devices for remote monitoring, control, and advanced automation of plants.
• Mobile and Voice control: Integration of voice control systems with mobile services (e.g., Google) for automation and execution of industrial control routines.
Part 3: Distributed Systems, Graph Theory, and Optimization Algorithms (16 hours)
• Distributed and event-driven systems: Introduction to graph theory and distributed algorithms. In-depth study of depth-first and breadth-first search techniques, consensus, token-passing algorithms, and gossip protocols.
• Distributed optimization: Techniques for optimizing performance in distributed systems, with a focus on applying optimization algorithms to improve operational efficiency in industrial networks and cyber-physical systems.

Metodi didattici
• Lectures (60%): Theoretical presentations and discussions on real case studies.
• Practical lessons (40%): Practical exercises with simulation software, PLC programming, and configuration of SCADA networks and distributed algorithms.

Modalità di verifica dell'apprendimento
The final evaluation of the course will be conducted exclusively through an oral exam. During the oral exam, students must demonstrate an understanding of the key concepts covered throughout the course, including industrial automation models, SCADA systems, PLC and IIoT technologies, and control techniques used in cyber-physical systems.
The oral exam will assess the following skills:
• Knowledge of automated system management models.
• Ability to understand and apply control algorithms for SCADA and PLC systems.
• Ability to critically analyze technological solutions and justify design choices.
• Ability to communicate theoretical and practical concepts clearly and precisely.
The final grade will be expressed in a scale from 0 to 30 and will be based on the quality of the responses, the depth of understanding, and the ability to argue the technological choices, with the possibility of awarding honors at the examiner's discretion.
The oral exam is the only form of evaluation for the course. To pass, the student must achieve a score of 18/30 or

higher.

Testi di riferimento
Course materials provided by the lecturer and available on the e-learning platform
Scientific papers

Altre informazioni
1. Knowledge and Understanding
The evaluation in this section focuses on understanding the main models dedicated to managing networked automated systems and the components of a cyber-physical system. During the course, students must demonstrate an understanding of how SCADA and PLC systems work, as well as the control algorithms applied to such systems.
2. Application of Knowledge and Understanding
Students will need to demonstrate the ability to apply automation techniques to design simple cyber-physical systems. Evaluation will be based on the practical application of theoretical concepts in the realization of an automation system, such as an industrial plant or a distribution system.
3. Judgment Autonomy
Students must demonstrate the ability to critically analyze the proposed technological solutions, evaluating the advantages and disadvantages of different technologies available for a given problem.
4. Communication Skills
The ability to effectively communicate the knowledge acquired during the course will be assessed during the oral exam. Students will need to demonstrate their ability to explain key concepts and communicate both theoretical and practical aspects of the course material clearly and professionally.

L'attività didattica è offerta in:

Facoltà Dipartimentale di Ingegneria

Tipo corso	Corso di studio (Ordinamento)	Percorso	Crediti	S.S.D.
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Robotica	6	ING-INF/04
Corso di Laurea Magistrale	Master Degree in Intelligent Systems Engineering (2020)	Intelligenza Artificiale - Cybersecurity	6	ING-INF/04

Stampa del 06/11/2025