Course title	Antenna technology for 5G communications: propagation arrays and integration
Scientific Discipline Sector	ING- INF/02
CFU	2 CFU
SUMMARY /GOAL	The course aims to introduce the fundamental concepts of antenna technologies for new generation telecommunication systems with a particular focus on beam steering and beam forming. The course includes the study of numerical methods and laboratory experiences for testing and characterizing antennas and antenna arrays.

Course title	Green Photonics for a sustainable economy
Scientific Discipline Sector	ING-INF/02
CFU	2 CFU
SUMMARY /GOAL	The course aims at introducing some fundamental photonic technologies for sustainable energy generation, for energy saving, and for environmental monitoring. The topics of the course will be mainly introduced through hands-on computer simulations and they will deal with green photonic devices such as solar cells, sensors, and new photonic technologies for communication.

Course title	Video Compression
Scientific Discipline Sector	ING-INF/03
CFU	2 CFU
SUMMARY /GOAL	The course shall address the various video compression techniques for multimedia transmission in Internet. The course participants will be able by the end of the course to understand the main functionalities of the video compression standards and the related video applications in Internet. Each lesson shall consist in lecture and practical examples.

Course title	Supervision and monitoring of renewable energy systems
Scientific Discipline Sector	ING-IND/31
CFU	2 CFU
SUMMARY /GOAL	The course aims to introduce the fundamental concepts for the monitoring of the electrical and energy performance of plants/systems based on Renewable Energy Sources (RES), notably photovoltaic systems, and for the diagnostics of anomalies or failures.

Course title	Non-integer order systems and controllers
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	The course shows how to apply fractional calculus, as generalization of integer-order calculus, to represent non-integer-order systems and obtain benefits in various modeling and control problems. Basic tools of fractional calculus are introduced, and models are described for different engineering applications, e.g. in automotive systems. Moreover, the course describes approaches to design and realize non-integer-order controllers. Students will learn how such controllers allow higher flexibility, increased robustness, and a better trade-off between stability and dynamic performance with respect to integer-order controllers. As case-studies, the course uses applications in automotive, mechatronic, and robotic systems.

Course title	Reasoning on the Web of Data
Scientific Discipline Sector	ING-INF/05
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to show how to infer new strategic knowledge from the facts modeled in the Web of Data. Such facts represent a huge, always up to date and freely accessible information source, modeled in languages with a formal, although simple, semantics. Nevertheless, most of Semantic Web applications, seem to ignore such semantics and exploit this information source just like it models plain data.

Course title	Deep Neural Networks
Scientific Discipline Sector	ING-INF/05
CFU	2 CFU
SUMMARY /GOAL	The course intends to introduce students and practitioners to the field and applications of Deep Neural Networks. The course participants will be able to design and implement Deep Neural Networks to address various and different tasks autonomously. The lessons alternate theoretical lectures and implementation examples.

Course title	Matlab Recipes for Measurement Data Acquisition and Processing
Scientific Discipline Sector	ING-INF/07
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to present, with a “hands on” approach, a number of useful techniques to acquire and process measurement data, with actual implementation in Matlab. The programme of the course is intended to be adjusted on-the-fly, according to the actual background of the students (in order to avoid too simple or too advanced topics), and to meet actual topics of interest for their Ph.D. work

Course title	Innovative Models Optimization Strategies and Services for Smart Buildings and Smart Mobility systems
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to study the recent advances for Smart Building and Smart Mobility systems, that are fundamental sectors in the Smart City context. In particular, innovative models, techniques and strategies will be analyzed with the aim of understanding how the main issues for modern buildings and mobility systems have been faced. In a smart building, it is important to optimize and control the energy consumption and flow by exploiting the buildings cooperation and the renewable energy and storage systems, and by respecting the user comfort and preferences. In the Smart Mobility context, new generation of vehicles (e.g. electric vehicles), control systems and strategies (e.g. vehicle sharing, route and charge planning) can help to face the main challenges for the mobility and transportation sectors in modern cities.

Course title	Multi-energy and configuration of microgrids: planning management and control
Scientific Discipline Sector	ING- IND/33
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to describe the methodologies and procedures for planning, managing and controlling multi-energy microgrids, in AC or DC configurations, in grid-connected and islanded modes. Control and supervision of a MG is carried out by SCADA system that, through proper Energy Management System (EMS), can optimize operation and reliability.

Course title	Physical layer security
Scientific Discipline Sector	ING-INF/02
CFU	2 CFU
SUMMARY /GOAL	The course will address different security techniques based on the physical layer, which are suitable to improve data security in wireless networks and in IoT (Internet of Things) applications. The course participants will achieve knowledge of Physical Layer Security techniques. The course will consist in theoretical lectures and numerical hands-on examples.

Course title	Environmental data analysis
Scientific Discipline Sector	INF/01
CFU	2 CFU
SUMMARY /GOAL	The course will provide an overview of Machine Learning and Deep Learning strategy in environmental applications. At the end of the course, the participants will be able to design, develop and apply statistical learning methods to the environmental data to produce results. Each lesson will consist of lecture and numerical examples.

Course title	Xtended Realities for Industry 4.0
Scientific Discipline Sector	ING-IND/15
CFU	2 CFU
SUMMARY /GOAL	Quickly introduce the researchers to the Augmented, Virtual, and Mixed technologies providing the key concepts and methods, and by a hands-on practical laboratory. The goal is to explore and envisions new and disruptive research domains and applications.

Course title	Emerging methodologies and technologies for Cyber Security
Scientific Discipline Sector	ING-INF/03
CFU	2 CFU
SUMMARY /GOAL	The course illustrates the emerging methodologies and technologies for the cyber security, with particular focus on (i) Internet, wireless and mobile networks, (ii) Cyber-Physical Systems and Social Internet of Things, (iii) Digital Service Chains, (iv) advanced mechanisms for data protection, user authentication, and access control, (v) Blockchain and examples.

Course title	Fundamentals of Industrial Internet of Things
Scientific Discipline Sector	ING-INF/03
CFU	2 CFU
SUMMARY /GOAL	The course will address the key technologies enabling the so-called Industrial Internet of Things

Course title	Embedded system design for Industry 4.0
Scientific Discipline Sector	ING-INF/01
CFU	2 CFU
SUMMARY /GOAL	The course aims to provide both a theoretical and practical introduction to embedded systems for IoT and Industry 4.0. After a brief introduction to embedded systems and a rundown of the systems currently available on the market, the flow of HW, FW and SW design will be illustrated. The second part is a laboratory and aims to prepare students for the final project. It will be shown how to create a project, how to manage peripherals and how to interface the board with low-cost sensors and actuators.

Course title	Electronic Information and Industrial Bioengineering
Scientific Discipline Sector	ING-INF/06
CFU	2 CFU
SUMMARY /GOAL	The course shall address the intelligent diagnostic frameworks and systems based on image and signal processing with particular focus on precision medicine and bioengineering industry scenario and enabling technologies like Virtual and Augmented Reality. The course participants will be able to process and understand medical and industrial images and signals, to design innovative frameworks for robotic navigation, inspections and intervention in assisted surgery and in substanaible and safe industry 4.0.

Course title	Advanced nanomaterials: properties and applications
Scientific Discipline Sector	CHIM/02
CFU	1 CFU
SUMMARY /GOAL	The course aims at providing the basic principles of materials at nanoscale from their fabrication to their individual and collective properties; it aims at offering the fundamental tools to understand the role of nanostructured materials as enabling technology for the Industry 4.0 and sustainability

Course title	Flexible and Stretchable Electronics
Scientific Discipline Sector	ING-INF/01
CFU	2 CFU
SUMMARY /GOAL	Flexible and stretchable electronics is fostering a paradigm shift in many application domains, enabling new mass-market products including wearable devices for e-health and fitness, smart systems for individualised human-machine interaction, and e-textiles. The scope of this course is to provide the participants with a general understanding of the interdisciplinary field of flexible and stretchable electronics. The course illustrates flexible/stretchable electronics through several examples and practical hands-on lab activates. No prerequisites are required.

Course title	Complex Networks: Big Data modelling and learning
Scientific Discipline Sector	FIS/07
CFU	2 CFU
SUMMARY /GOAL	The increasing availability of high dimensional and heterogeneous data samples (big data) makes urgent the development of a scientific background including data science and machine learning techniques, with applications in many fields. This course introduces the fundamental concepts in complex networks and exploits this framework for learning purposes. We will cover the most popular network models: random graphs, small-world networks, scale-free networks; besides, we will explore how supervised and unsupervised learning algorithms including random forests, artificial neural networks, support vector machines and deep learning, can proficiently exploit the knowledge content provided by complex networks. After explaining the basic centrality measures for nodal and edge characterization, we will discuss the matrix representation of a graph and the necessary steps for automated learning: hypothesis space, overfitting, bias and variance, trade-offs between representational power and learnability, evaluation strategies and cross-validation. The course will be accompanied by hands-on problem solving with programming in R and some tutorial sessions.

Course title	Lab-and-field data acquisition and analysis for studying Hydraulic Processes
Scientific Discipline Sector	ICAR/01
CFU	2 CFU
SUMMARY /GOAL	The course provides the basic concepts necessary to carry out measurements, process data and derive hydrodynamic and physical meanings form large data sets. The following topics are studied, combining theory and practical examples: Measurement definition and concept. Measurement instrumentation and sensors. Sources of error. Measurement uncertainty. Measurement in static and dynamic conditions. Instrument calibration. How to get a calibration curve from laboratory data. Sensitivity, accuracy and precision. Measurement range and frequency response. Instrument precision. Measurement error. Theory of errors. How to carry out a measurement. Nyquist theorem. Sampling duration. Signal analysis in time and frequency domain. FFT and IFFT. How to obtain a spectrum of the measured signal with FFT technique. Acquisition signal chain. Control and management of remote measuring stations, with sensors sampling hydrodynamic parameters. Acoustic and laser signal sources. Doppler effect. Measuring flow velocity with LDA and ADV sensors. Practical trials at the Coastal Engineering Laboratory – LIC of the DICATECh and analysis of acquired data.

Course title	Statistical data analysis starting from the highway engineering case
Scientific Discipline Sector	ICAR/04
CFU	2 CFU
SUMMARY /GOAL	Each field of research in engineering may potentially need exploratory and statistical analyses on large dataset of different nature. Highways as a part of the transportation systems generate large volume of data (such as infrastructure, traffic and accident data) which are important for several applications, primarily for safety reasons. The aim of the course is to provide a general theoretical background and operational methodologies (use of open-source software applications) for exploratory and statistical analyses on database, by using case studies and example problems from the highway engineering research.

Course title	Sustainable Mobility and Shared Mobility in a Smart Cities framework: optimization models and applications
Scientific Discipline Sector	ICAR/05
CFU	2 CFU
SUMMARY /GOAL	Shared mobility is one of the possible solutions for reducing the traffic congestion problem following the sustainable mobility perspective. It offers the potential to enhance the efficiency, competitiveness, social equity, and quality of life in large cities. The goal of this course is to provide the Ph.D. students the theoretical background and knowledge necessary to manage optimization models for solving shared mobility problems considering environmental aspects. Moreover, basic knowledge in using IBM ILOG CPLEX and MATLAB software for solving Integer Linear Programming models is carried out. The lectures will be structured into two parts. The first part of the course (10 hours) will be focused on the introduction to shared mobility and recent technologies applied to reach the Mobility-as-a-Service concept. Furthermore, a short introduction about optimization models, e.g., Vehicle Routing Problem, for solving transportation issues. The second part of the course (10 hours) will deal with exercises of Integer Linear Programming models through the usage of IBM ILOG CPLEX and MATLAB software.

Course title	Advances in Geomatic Engineering
Scientific Discipline Sector	ICAR/06
CFU	2 CFU
SUMMARY /GOAL	Recent advances in space (satellite) technology, computing (software and hardware) technology and Geomatic engineering instrumentation technology have had a revolutionary impact on the practice of many engineering fields. The goal of this course is to provide the students the theoretical background and knowledge necessary to manage modern complex geospatial information and technology. The lectures will deal with the following research areas: · Multimedia cartography and information delivery; · Geospatial Information Science and Geographic Databases; · Geospatial Web and Big Data; · Technologies and methods in Remote Sensing (proximal/drone/aerial/satellite platforms); · Survey and 2D/3D geospatial data processing; · Geospatial data modelling and analysis. The advanced topics may serve as an introduction to research skills that may be useful at multidisciplinary level.

Course title	The importance of Suction in Soil Mechanics: its measurement and application
Scientific Discipline Sector	ICAR/07
CFU	1 CFU
SUMMARY /GOAL	During the course the following topics will be discussed: 1. Unsaturated soil and Suction. 2. Standards for the measurements of Soil-Pore Water Pressure. 3. Direct and Indirect measurement of Soil Suction. 4. Soil suction influence on permeability, soil volume and shear strength. 5. Soil suction and Effective Stress.

Course title	Adaptive technologies for the Mitigation of Urban Heat Island and Climate Change Effects
Scientific Discipline Sector	ICAR/10
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to provide students with the knowledge of the effects of climate change and Urban Heat Island (UHI) on built environment. The course will also provide detailed knowledge on the techniques and technologies to adapt the building fabrics to the effects of climate change and UHI and to counterbalance the temperature increase. The first part of the course will explore in detail the major issues of urban climatology, helping in defining the interaction between environmental variables, outdoor surfaces and building fabrics. In the second part of the course detailed students will investigate in detail adaptive technologies to mitigate the temperature effects of climate change-related phenomena. Examples from successful real case studies will be shown. Finally, the third part of the course will provide students with a hands-on experience of modelling techniques and tools to simulate the thermal characteristics of cities and buildings and assess the impact of adaptation technologies. The assessment will be based on the modelling of a selected case study and on the analysis of the effects of different adaptation technologies.

Course title	Multi-criteria approaches applied to multi-risk analysis
Scientific Discipline Sector	ICAR/09-10
CFU	2 CFU
SUMMARY /GOAL	The proposed teaching program aims at preparing technically qualified PhD students to face interdisciplinary multi-risk analysis by investigating Multi-Hazard, Vulnerability and Exposure through multicriteria decision methods (MCDM). The program gives the students an advanced understanding of multi-criteria analysis in order to set up a multi-risk algorithms and optimize mitigation strategies at different scales. The course consists of an introductory part on Slow Onset Disasters (SOD) and Rapid Onset Disasters (ROD). A module which explains the most used multi-criteria methods such as the Analytic Hierarchy Process (AHP), the Analytic Network Process (ANP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Finally, practical exercises will be carried out to obtain algorithms for risk assessment using MCDM.

Course title	The 3d printing technology in the construction processes
Scientific Discipline Sector	ICAR/09-10
CFU	2 CFU
SUMMARY /GOAL	The class will provide an overview of the various 3D printing technologies focused on the possible research application in the field of construction sector. In particular, the technology of Fused Deposition Modeling (FDM) will be explained in detail by providing specific information on the different printable materials with related mechanical characteristic, energy performance and environmental impact. In the first part of the class, a training course will start from the three-dimensional modeling of objects in specific software, processing and optimization of the digital model. The second part of the course will show how to obtain the actual FDM printing through a specific "slicer software" starting from the three-dimensional model. Finally, a practical experience on the use of the 3D printing in a real research project regarding the construction sector will be proposed to the PhD students.

Course title	How to build an ontology that lasts for design matters
Scientific Discipline Sector	ICAR/20
CFU	3CFU
SUMMARY /GOAL	The course aims to provide the knowledge tools and skills for the use of the method of ontological analysis and applied ontology in the topics of analysis (problem setting-problem solving), conception and planning of action in engineering and design (architectural design, industrial design, planning) The tools of ontological analysis and ontology will be added with the reflection on the rules to which the agent refers during the conception of the project (in engineering or architecture or design), for an effective response that goes beyond the expectation of the result. posted by the task itself. This is in order to identify the possibility of managing the project conception in a practical and effective way through formal or automated systems.

Course title	Introduction to Partial Differential Equations with Applications
Scientific Discipline Sector	MAT/05
CFU	2 CFU
SUMMARY /GOAL	During the course the following topics will be discussed: Preliminary Calculus tools • Differential Calculus • Function sequences and function series o Taylor Series o Fourier Series Partial Differential Equations • Transport Equation o Physical model o Solving the initial value problem o Transport equation with damping o Transport equation with concentrated source • Heat Equation o Linear diffusion model o Separation variables o Maximum principle • Laplace Equation o Harmonic functions o Separation variables o Maximum principle • Wave Equation o d'Alembert's formula o Vibrating string o Energy conservation

Course title	Advanced Opto-Acoustics Methods for Experimental Mechanics
Scientific Discipline Sector	ING-IND/14
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to provide knowledge and competencies in applying advanced both optical and/or acoustic techniques for an innovative approach to mechanical characterize materials in the experimental mechanics. The course will be split in two branches referring to the two methodologies in object. Ten hours will be devoted to the optical approach: 6 for theory and 4 for laboratories. They will focus on the main characteristics of the geometrical optics and its properties according to the Fraunhofer's approximation, an overview on lens distortions and calibration methods, and the application for the correlation of the images: 2D, 3D and volumetric. During the laboratory the students will experience a real measurement for evaluating the displacement field of a component by using the Digital Image Correlation equipment. Ten hours will be devoted to the acoustic approach: 6 for theory and 4 for laboratories. They will focus on the origin of acoustic emissions in materials, the main features of stress waves produced by materials, description of the equipment for acoustic emission, and the analysis techniques of acoustic emissions. During the laboratory the students will experience a real evaluation of the wave sound speed for different materials and on the proper location of defects.

Course title	Conservation laws in continuum mechanics and traffic modeling
Scientific Discipline Sector	MAT/05
CFU	2 CFU
SUMMARY /GOAL	Scalar conservation laws. Hyperbolic systems of conservation laws. Euler and Burgers equations. The Method of Characteristics: creation of shock waves. Rankine-Hugoniot conditions. Shock waves. Entropies and entropy fluxes for scalar equations and systems. Entropy weak solutions. Kruzkhov entropies. Change of variables. Liu conditions: entropic shock waves. Kruzkhov Theorem. Uniqueness and stability of entropy weak solutions. Change of coordinates. Oleinik estimate for conservation laws with convex fluxes. Uniqueness via Oleinik type estimates. Minimal entropy conditions. Riemann Problem. Vanishing Viscosity approximants. Viscous shock waves. Fluidodynamic models for vehicular traffic. LWR model: shock and rarefaction waves. Moving bottleneck. Nonlocal models. Aw-Rascle model. Two phase models. Multi-population models. Traffic on networks: shocks generated by the junctions. Nonlinear elasticity. Gas dynamics. The p-system. Shock waves. Riemann invariants.

Course title	Lean_production_digital_factory
Scientific Discipline Sector	ING-IND/17
CFU	2 CFU
SUMMARY /GOAL	The course provides PhD students with the core knowledge they need: i. to understand the concept of Lean Production (principles, models and tools); ii. to design and manage the process of continuous improvement of a smart production system; iii. to enable the Lean Transformation in the digital factory.

Course title	Fundamentals of Lasers
Scientific Discipline Sector	ING-IND/14
CFU	2 CFU
SUMMARY /GOAL	Laser sources are employed in an incredibly large number of applications and fields ranging from material characterization and processing to metrology, from optical communications to satellites, from biomedical devices to spectroscopy. The reasons of this large diffusion rely on the unique features associated with these light sources. The aim of this course is to explore, in brief, what are the principal characteristics of the radiation emitted by lasers and to describe what are the basic mechanisms of radiation-matter interaction leading to Laser emission. The rationale of pumping schemes will also be described and some basic concepts about optical resonators will be provided. Finally, a brief overview about the different kinds of lasers will be given.

Course title	Hydrogen towards a global decarbonisation
Scientific Discipline Sector	ING-IND/08
CFU	2 CFU
SUMMARY /GOAL	Given the rising interest of Academia and Industry in hydrogen as future energy vector towards the global decarbonisation, the course aims to provide students with a review of the state of the art and recent perspectives in the field of hydrogen production, storage and usage. The course starts with an overview of the emissions of the conventional energy production systems and their impact on the environment in terms greenhouse gas and carbon footprint, explaining why today hydrogen becomes so attractive. (2h) Then the main hydrogen production processes (electrolysis, gasification, reforming, etc.) and its different nomenclature (green, blue, brown and grey hydrogen) will be discussed. (4h) Concerning the production of hydrogen, a crucial point is represented by its peculiar chemical-physical properties (such as: flammability limits, molecular diffusivity, lower heating value, Joule-Thomson effect, etc.), which will be analysed by solving specific cases. (4h) Given its particular chemical-physical properties, the main conventional and more advanced storage systems will be presented (LH2, pressurized hydrogen, etc.) dividing them in near, mid and long term applications. The hydrogen use and distribution, and the standard storage systems in the automotive, aeronautic, civil and domestic fields will be presented. (4h) Ammonia (NH3) as useful hydrogen carrier and the recent achievements in the field of combustion of hydrogen in CH4-H2, NH3-H2 mixtures will be presented. Calculations on a real CCTG power plant will proposed to investigate greenhouse gas emissions and operating conditions when hydrogen is introduced. (3h) Close to the well-known technologies currently employed, the emerging technologies such as thermochemical, photoelectrochemical and photobiological production will be presented focusing on their development weakness towards a higher Technology Readiness Level (TRL). (2h) In the end, the main drawbacks about the use of hydrogen will be discussed. (1h)

Course title	Mechano-biological Tools for Orthopedic Biomaterials
Scientific Discipline Sector	ING-IND/15
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to describe the main tools of Mechanobiology for the optimization of the biomaterials geometry that allows maximizing the bone formation in the fracture healing process. After a brief description of the mechanobiological models available in the literature, the attention will be focused on the model of Prendergast and Huiskes that describes the bone and the regenerating tissue as biphasic poroelastic materials and that hypothesizes the biophysical stimulus triggering the differentiation process, to be a function of the octahedral shear strain and of the interstitial fluid flow. Examples of the application of this model in the simulation of the regeneration process in long and short bones will be given. Finally, we will show how this mechanobiological model can be combined with structural optimization routines to determine the optimal geometry of scaffolds for bone tissue engineering and the optimal surface microgeometry of porous prostheses.

Course title	Combustion Processes and Pollutant Emissions
Scientific Discipline Sector	ING-IND/08-09
CFU	2 CFU
SUMMARY /GOAL	This course will enable students with general knowledge in energy generation to move to an integrated understanding of combustion, by illustrating the fundamental principles of combustion chemistry, how they relate to experimental observations and how they can be used in theoretical and numerical modeling. The course will cover aspects ranging from a review of thermodynamics and kinetic theory of gases to the concept and applications of detailed kinetic modeling. A description of the main theories of kinetics, including collision theory, statistical mechanics, transition state and unimolecular reaction rate theories, will be provided. The course will then move the study of reaction mechanisms, from the identification of explosion limits in H2/O2 system to the complex hydrocarbons oxidation. Flammability limits and ignition processes will be discussed, as well. Deflagration and detonation waves, premixed and non-premixed flames, laminar and turbulent flame speeds will be introduced. Some of the most relevant reaction paths involved in hydrocarbons oxidation and leading to gaseous and soot emissions formation will be discussed in more detail.

Course title	High-energy particle physics detectors in space
Scientific Discipline Sector	FIS/01
CFU	2 CFU
SUMMARY /GOAL	The course aims to provide an overview of basic principles of particle physics and of the main detectors used for space applications. Moreover, the explanation of the environmental verification strategy aims to give the students a complete overview of the steps needed to take a detector from construction to a correct on-orbit operation.

Course title	Oscillations and waves
Scientific Discipline Sector	FIS/01
CFU	2 CFU
SUMMARY /GOAL	The goal of the course is to provide students with the basic concepts of mechanical waves and give them the ability to deal with oscillation phenomena and with the generation and propagation of electromagnetic waves over the entire electromagnetic spectrum.

Course title	Optical communications for space
Scientific Discipline Sector	ING-INF/02
CFU	2 CFU
SUMMARY /GOAL	The course aims to provide an overview of some of the recent technologies related to optical/photonic communication for space. Participants will acquire the related knowledge through theoretical lectures and numerical examples.

Course title	Spacecraft Structural Dynamics & Loads
Scientific Discipline Sector	ING-IND/04
CFU	2 CFU
SUMMARY /GOAL	This course intends to explain basic notions as well as some "advanced" concepts with minimum mathematics. The content is the result of the author's experience acquired through his involvement with research and industrial activities mainly at the European Space Agency and Alenia Spazio.

Course title	Fundamentals of surface roughness analysis for tribology
Scientific Discipline Sector	ING-IND/13
CFU	2 CFU
SUMMARY /GOAL	The course will introduce the fundamentals of the theory of probability with application to rough surface analysis. In the second part of the course, a specific focus will be developed on the tribological application of real surfaces roughness analysis.

Course title	Compressible Turbulence: Phenomenology and Modeling
Scientific Discipline Sector	ING-IND/06
CFU	2 CFU
SUMMARY /GOAL	The investigation of compressible turbulent flows, besides being a fundamental topic of classical physics, plays a key role in aerodynamics especially in supersonic and hypersonic flow regimes. The aim of this course is to introduce students to the topics of compressible turbulence, closure models for numerical simulations of turbulent flows and High-Performance Computing for scale-resolving simulations. On successful completion of this module, a student should be able to: 1. Demonstrate a critical awareness of the basic features of compressible flows and turbulence 2. Explain the consequences of compressibility effects on subsonic and supersonic turbulent flows 3. Appraise and evaluate different levels of closure for high-fidelity simulations 4. Critically evaluate the challenges in the implementation of scale-resolving techniques on modern architectures

Course title	Theories and methods in structural design: modeling and experimental issues
Scientific Discipline Sector	SSD: ICAR/08
CFU	2 CFU
SUMMARY /GOAL	The shape of masonry constructions and the influence of the curvature in the load bearing capacity of arches, domes and vaults. Seismic actions and masonry constructions. Mechanical behavior of masonry: heterogeneity, different behavior in tension / compression, non-linear mechanical response, anisotropy, failure modes, damage. Modeling strategies: micromechanical models, FEM and DEM implementation of micromechanical models, macro-mechanical models, multiscale models, NT (No-Tension) and RNT (Rigid No Tension) models, macro-elements. Limit Analysis: static and kinematic approaches. From the static approach of Limit Analysis to the relation between shape and structures in masonry arches and vaults (and back to graphic statics).

Course title	Generative Algorithms: digital tools for parametric design and assessment of structures
Scientific Discipline Sector	SSD: ICAR/09
CFU	2 CFU
SUMMARY /GOAL	New technologies are changing the way engineers work within the construction sector. Newly developed software solutions have provided effective methods to explore the design space at the interface between Structural Engineering and Architecture, allowing more efficient design strategies. The course aims to explore the potentials of new digital tools based on generative algorisms. The course is organized into four main parts in which both theoretical and practical aspects will be illustrated: 1) Theoretical aspects of the Generative Scripting. 2) Introduction of the Python interpreter component for Grasshopper (Rhino 3D), which allows to execution of dynamic scripts. 3) Introduction to Structural Optimisation. 4) Workshop: the students will be divided into groups, and they would be defining helpful generative algorithms in their research topic.

Course title	Contextual Design and Heritage: identity and material culture of the territories
Scientific Discipline Sector	SSD: ICAR/13
CFU	2 CFU
SUMMARY /GOAL	The course aims to explore the role of design in the enhancement of material culture as recommended by the 2003 UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, with a particular focus on Southern Contexts. The “intangible cultural heritage means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage”. The Heritage dimension proposed by the UNESCO Convention is a “phenomenal extension” of the field of knowledge, conservation, enhancement and re-activation of material culture in which contextual design is developing a prominent role. Contextual Design is an important field of contemporary research developed in North Europe, in the Design Academy of Eindhoven. The aim is to investigate the meaning of the material and immaterial artifacts of design in relation to the identities of the territories and to the historical and cultural stratification that distinguishes them. Contextual Design and Cultural Heritage thus become a strategic combination to face the modern challenges of enhancing territorial contexts against the current phenomena of globalization and spectacularization of culture.

Course title	Theories and methods of design for the Antique
Scientific Discipline Sector	SSD: ICAR/14
CFU	2 CFU
SUMMARY /GOAL	The first part will be structured into four thematic sections: the first, by investigating the contributions offered by the Masters of Architecture between the XIX° and XX° centuries and deducing their theoretical background, will try to outline the general principles underlying the main points of view that connote contemporary architectural research; the other three will be thematically articulated and focused on the relationships between "Antique and Landscape", "Antique and City", "Renovation and Museography", and will see the compositional analysis of some exemplary contemporary works, in order to recognize methods and techniques of the design for the Antique. The second part will be devoted to the exercises. They will be carried out in the modality of an intensive design workshop, dealing with and developing a project concerning the main topics of the course.

Course title	Theory of Formativeness in Architecture
Scientific Discipline Sector	SSD: ICAR/14
CFU	2 CFU
SUMMARY /GOAL	It seems lost today, in architecture as generally in arts, a unitary point of view on which to found a theory on. That civil conscience that has always been the basis of the art of building seems no longer part of the collective heritage. This condition is recognizable in the contradictory experience of contemporary architecture. For this reason, the class aims to try to outline a "classical" theory of architectural research; a classicism that does not renounce, rather it investigates, the culture of modernity, trying to measures itself against this alleged contradiction. All the architecture that we can include within the “classic” experience (that we can also define “rational experience”) is characterized by a peculiarity: the intelligibility of forms, along with we define a method of formativeness. According to this idea of architecture, there’s no advancement of forms without an advancement of knowledge - without an increasingly higher level of self-awareness. Hence the need for a theory of architectural research. The method of formativeness we want to investigate regards three major chapters of architecture: The relationship among architecture, city and landscape; The “construction issue”; The question of the project with the Ancient.

Course title	Theories and Methods of the Project for the City
Scientific Discipline Sector	SSD: ICAR/14
CFU	2 CFU
SUMMARY /GOAL	The course is divided into two parts, corresponding to the phases of lessons and exercises. The first part of the course will deal with issues related to the city as a historical- aesthetic palimpsest, interpreted as a synthesis of an approach that is both documentary and transformative, based on the relationship between physical form and "cognitive form". The second part will instead focus on issues relating to the processes and methods of urban interpretation and modification throughout history, focusing especially on those that have appeared since the twentieth century, with their multiple problems. In this sense, various themes will be central, such as that of the "diachronic relationship" within the general urban processes, the theme of the narrative function of their inheritance, and finally the theme of the consequent theoretical and methodological choices, developed -in different ways- in the main researches of Italian and international contemporaneity (from the "organic vision" proposed by the first Roman and then Muratorian schools, to the phenomenological-cognitivist one proposed by the various Italian and American schools already in the second half of the 1900s, to the analytical-structuralist research of the successive neo-rationalist tendencies, up to the most recent ones, which experience the "dialectical contradiction" as a tool through which to reformulate the figurative heritage in relation to the unprecedented condition of the contemporary city). This phase will be carried out through an intensive urban design workshop, based on the critical exercise of the main themes developed during the course.

Course title	Theories and Methods of the Project for the Territory
Scientific Discipline Sector	SSD: ICAR/21
CFU	2 CFU
SUMMARY /GOAL	The course is divided into 2 steps, corresponding to the 2 blocks of lessons and exercises. The first step will be structured in 4 thematic sections: the first will deal with general questions on the main approaches to the contemporary territories regarding a discipline that is found between the epistemological model of scientific disciplines and that of Social Sciences; the other 3 lessons will focus on the topics that are at the heart of the contemporary disciplinary debate (as well as in the PhD course in "Project for Heritage: Knowledge and Innovation"), relating to the relationship between" City and Landscape "and" Architecture and Heritage ". The second step will be dedicated to exercises and seminars of teachers external to the course: the first will be conducted in the form of a workshop on sample territories on which to experiment an approach to contemporary issues (relationship between places and communities, territories palimpsest, territories in crisis…), developing a synthetic written-graphic report concerning the main topics of the course. A seminar held by an Italian or foreign external personality, with a relevant point of view on the topics of the course, will allow a wide reflection between PhD students and author on the topics covered.

Course title	The post-growth paradigm in planning research
Scientific Discipline Sector	SSD: ICAR/21
CFU	2 CFU
SUMMARY /GOAL	The educational objective of the course The post-growth paradigm in planning research is to offer PhD students the tools to understand the complexity of the contemporary world and acquire the ability to develop an autonomous and conscious thought with respect to the problematic issues and challenges that it arises. The course therefore aims to deepen the main phenomenologies of the post-growth paradigm in the city and in the territory, and at the same time discuss the lines of research that the disciplines of the territory, and in particular urban planning, have started in recent decades. There will be frontal lectures and exercises, closely integrated, that articulate the course in two parts. The first part of the course will be dedicated to thematic lectures, in which the themes of the post-growth paradigm, its causes and material manifestations will be deepened; moreover, the paths of the contemporary urban research will be outlined, in the directions of a renewed relationship with the existing, of the valorization of the territorial heritage, of the integration and contamination with the disciplines that deal with the themes of sustainability and climate change. The second part will be dedicated to exercises to be developed with reference to specific case studies representative of current research. These will take place in the form of interlocutions that, through comparison, will help doctoral students to acquire an autonomous ability to apply the knowledge acquired through analytical and critical tools useful to interpret the different theoretical positions and evaluate the operational consequences. The attribution of training credits will take place through an interview, aimed at verifying the acquisition of knowledge and skills by the doctoral student. In the evaluation will also take into account the participation in training activities carried out.

Course title	Problems and methods of contemporary restoration
Scientific Discipline Sector	SSD: ICAR/19
CFU	2 CFU
SUMMARY /GOAL	The educational objective of the course of Problems and methods of contemporary restoration is to illustrate the general lines of the main ways of understanding restoration and to provide PhD students with the historical-critical tools to develop an autonomous and conscious thought regarding the themes and nodes problematic of the discipline, with particular regard to the conceptual elaborations and experiences that open from the second post-war period to contemporary debate. There will be lectures and exercises, mutually complementary. Through the lectures the methods will be deepened, the knowledge of the theoretical and cultural foundations of restoration will be increased and strengthened and the ability to understand the conceptual nodes of the discipline will be developed in order to direct PhD students to achieve a capacity for critical re-elaboration of the acquired knowledge. Through the exercises the ability to apply knowledge and understanding will be developed and verified. The course is divided into two parts. The first part of the course will be divided into two thematic sections: the first will present the philosophical and cultural foundations of the discipline; in the second, some key issues of the contemporary debate will be addressed, such as the relationship between “restoration and creativity” in the “old and new” dialectic. The second part will be dedicated to exercises. These will take place in the form of discussions which, through comparison, will help PhD students acquire an autonomous ability to apply the knowledge acquired through analytical and critical tools useful for interpreting the different theoretical positions and evaluating their operational implications. The attribution of training credits will take place through a final test, aimed at verifying the acquisition of knowledge and skills by the PhD student. The assessment will also take into account participation in the training activities carried out.

Course title	Multi-agent and multi-object estimation
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	The course will provide an overview of advanced research in estimation, specifically concerning the two topics of multi-agent and multi-object estimation. Multi-agent estimation deals with a network of agents with sensing, processing and communication capabilities that aim to cooperatively monitor a given system of interest. Multi-object estimation aims to detect an unknown number of objects present in a given area and estimate their states. Special attention will be devoted to the Kullback-Leibler paradigm for fusion of possibly correlated information from multiple agents and on the random-finite-set paradigm for the statistical representation of multiple objects. Applications to distributed cooperative surveillance, monitoring and navigation tasks will be discussed.

Course title	Control for Optimization
Scientific Discipline Sector	ING-INF/04
CFU	1 CFU
SUMMARY /GOAL	The course aims at bridging the gap between optimization and control theory. A control-based approach to analyze the convergence of selected optimization algorithms will be presented. Topics from system theory, passivity, operator theory and consensus will be combined in an elegant and synergic way to build an analysis tool that may pave the way to further innovation in the design of optimization algorithms in large-scale systems. Lessons will mainly consist in frontal lectures with examples.

Course title	Optimization via extremum seeking
Scientific Discipline Sector	ING-INF/04
CFU	1 CFU
SUMMARY /GOAL	This course aims at providing PhD students with the fundamentals of an optimisation technique called Extremum Seeking (ES). In the framework of "optimisation without knowledge of the gradient" and under mild assumptions on some of the cost function properties, the ES algorithms steer the optimisation variable close to the optimiser while guaranteeing semi-global and practical stability properties. Classic approaches are reviewed, and recent research results are presented. Each lesson consists of lectures, numerical examples, simulation and analysis of case studies.

Course title	Intelligent Control Systems
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	This course aims at providing PhD students with modelling and methodological tools for formulating and solving control problem using intelligent architectures such as neural networks and fuzzy systems. During the course several problems will be formalized, particularly referred to relevant issues within management and industrial engineering. Problem definition and resolution will be also implemented in simulation and engineering software (Matlab & Simulink). The final goal is to provide PhD students with the necessary background for starting research in the field of intelligent control relying on neural networks and fuzzy prototypes to be applied to autonomous systems. Each lesson consists in lectures, numerical examples, simulation and analysis of case studies.

Course title	Game Theory for Controlling Autonomous Systems
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	This course is designed to provide PhD students with the necessary modeling and methodological tools for analyzing and designing algorithms to solve game equilibrium problems. The course will include lectures, numerical examples, simulations, and analysis of case studies.

Course title	Control of marine vehicles
Scientific Discipline Sector	ING-INF/04
CFU	3 CFU
SUMMARY /GOAL	This course will cover the fundamental principles of the nonlinear control of marine vehicles. The intended audience is PhD students who minimally already possess prior experience with the automatic control of linear time invariant systems at the undergraduate student level and who have a working familiarity with Matlab and Simulink. The dynamics of marine vehicles are generally nonlinear, time varying and highly uncertain. We will study techniques from nonlinear stability and nonlinear control theory that permit one to address the issues that make the control of marine systems so challenging. The overarching goal is to provide a foundation, or at least a good idea of where to start, when trying to solve research-oriented control problems in this field. Some simulation examples will be provided.

Course title	Data-driven fault diagnosis and fault prognosis
Scientific Discipline Sector	ING-INF/04
CFU	1 CFU
SUMMARY /GOAL	This module aims at providing PhD students with the main concepts of data-driven fault diagnosis and fault prognosis which are at the base of modern condition-based and predictive maintenance. During the module, the students will learn how to apply a data-driven workflow to solve real case studies and to adapt it to the specific cases of fault diagnosis and fault prognosis. The workflow will include data processing, feature extraction and model training, with some insights on deployment complexity; problem resolution will also be implemented by using a common engineering software (MATLAB). The final goal is to provide PhD students with the necessary background to process sensors data and use them to monitor the condition of a physical system, classify possible undesired behaviours and eventually estimate the remaining useful life of specific components. Each lesson consists in lectures, numerical examples and analysis of case studies.

Course title	Introduction to Optimal Linear Quadratic Control
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	The course is an introduction to Optimal Linear Quadratic Control referred also as LQ or H2 Optimal Control. The course will provide the mathematical tools to solve the problem in full generality for continuous time systems via the Algebraic Riccati Equation and the Hamiltonian dynamics associated to this optimization problem.

Course title	From Least Squares to Subspace Identification
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	This course aims at providing PhD students an introductory overview of some classical and modern tools from the fields of system identification and data analysis. Starting from the well-known theory of ordinary least squares, interpreted as a subspace projection problem, the course will discuss general data fitting methodologies and applications to linear system identification, such as the estimation of dynamical models via prediction error methods. Then, interpreting linear system identification as a subspace projection problem, the so-called subspace identification methodologies will be introduced, starting from the seminal Ho-Kalman method and towards the MOESP algorithm. The final goal is to provide PhD students with the necessary background for starting research in the field of data analysis and modern system identification. Each lesson consists in lectures, numerical examples, simulation (MATLAB).

Course title	Human autonomous sytems interaction
Scientific Discipline Sector	ING-INF/04
CFU	1 CFU
SUMMARY /GOAL	This course aims at providing PhD students with the main concepts of the well-known technology for improving human-autonomy interaction with a special focus on autonomous systems. It is especially focused on technology and case studies relevant to complex, applied environments in which people interact with autonomous systems regularly, particularly in the context of ambient assisted living. The study focus on approaches that include task inputs from humans: how to model humans and their tasks and at what level of details. Moreover, the human in-the loop approach will be introduced as a new scenario to facilitate the goal achievement, to reduce the anomalies and the unexpected responses from the system or inappropriate responses by the human in order to enhance human safety. Human-system interaction must provide people with an understanding of an autonomous system's decisions and actions, the ability to interact at appropriate levels of abstraction, and the ability to override the system's actions. New human-system engineering techniques are needed to ensure autonomous systems will be smoothly and readily adopted into society. Autonomous systems that work together in the environment should integrate the connections and interactions between them, over networks, with the physical environment, and with humans must be assured, resilient, productive, and fair in the autonomous future. Systems engineering is critical for ensuring the operational success for which the autonomous systems were intended. Autonomous systems should be analysed including concept, context, requirements, design, integration, operationalization, validation, testing and evaluation. During the course, the students will learn how the human-autonomous system interaction is achieved and how it is articulated. The workflow will include data processing, feature extraction and model training for human-robot interaction tasks, with some insights on deployment complexity; problem resolution will also be proposed by using a common engineering software (MATLAB), and the ROS (Robot Operating System). Each lesson consists in lectures, numerical examples and analysis of case studies.

Course title	Semidefinite programming in Systems and Control
Scientific Discipline Sector	ING-INF/04
CFU	2 CFU
SUMMARY /GOAL	This course aims at introducing the use of semidefinite programming tools to address analysis and design problems in the general area of systems and control. Several applications will be considered throughout the course ranging from linear and nonlinear control systems, observer design, and robust control. A special attention will be devoted to the numerical solution to the problems introduced during the course. The main goal of this module is to provide PhD students with a solid understanding of how semidefinite programming can be efficiently employed to deal with challenging engineering problems in a systematic way.

Course title	Management and Business Research
Scientific Discipline Sector	ING-IND-35
CFU	2 CFU
SUMMARY /GOAL	This course aims to introduce PhD students to a scientific approach to the study of management and business issues. The focus is on equipping students with the fundamental knowledge and skills for undertaking research in management and business and to critically evaluate research conducted by others. The course is divided into four interrelated segments: problem formulation/conceptualisation, implementation, analysis, publication, and communication of research findings. Ethic issues will be further discussed.

Course title	From qualitative to quantitative methods in business research
Scientific Discipline Sector	ING-IND-35
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to provide PhD students with a set of building blocks for conducting, at the academic level, both quantitative and qualitative research in the areas of management, economics, and policy. As quantitative research, the course addresses three main issues of qualitative research. First, the course provides theoretical insights into different quantitative research methodologies and designs. Second, the course introduces PhD students to various methodologies for gathering data, observations, and evidence and for organizing them in ways that can be used for quantitative analysis. Third, the course introduces PhD students to various quantitative methodologies – from regression analysis to text mining –to support PhD students in the development of practical skills as well as critical thinking for interpretation purposes. As to the qualitative research, PhD students will be introduced to the basic ideas behind the qualitative research in social science. Students will learn about data collection, description, analysis and interpretation in qualitative research. Qualitative research often involves an iterative process. The course will focus on the ingredients required for this process: data collection and analysis.

Course title	Human-based Smart Manufacturing Systems
Scientific Discipline Sector	ING-IND/17
CFU	2 CFU
SUMMARY /GOAL	The fifth industrial revolution, known as Industry 5.0 (I5.0), encompass a vision for a human-centered, innovative, resilient, and competitive industry. I4.0 moved the focus from a traditional product-driven (mass) industrial production towards a “demand-driven” market that requires the fully integrated systems able to adapt, in real-time, the production system to the demand change. The I5.0 approach re-introduces the human-centered dimension as the key resource of a smart production systems adopting I4.0 technologies. In the transition from traditional to new production systems, two critical elements arise: the companies' "readiness degree", that is, the assessment of the potential benefits from the adoption of I4.0 technologies and the “human component”. With the adoption of new technologies, the role of human workers will gradually change, and operators will be required to perform more cognitive tasks than in the past. Their dexterity and cognitive capabilities reveal appropriate economic and reliable solutions to meet the required flexibility level. With the aim of successfully implementing ICT technologies allowing ‘thing’, ‘services’ and ‘human’ to be continuously remotely connected by i-cloud centralized systems, a reliable evaluation of both the potential increasing of the competitiveness degree and a reliable description of the behavior and of the knowledge and skills of the human component in the new work environment are required.

Course title	Technological changes and transition perspective
Scientific Discipline Sector	ING-IND-35
CFU	2 CFU
SUMMARY /GOAL	"The technological change is continuously increasing its pace. New technologies and business models are impacting the economic and social systems in a deep and unexpected way as well as social systems are adapting and reacting to these changes.The aim of the course is firstly to adopt the epistemological point of view for the technological determinism to examine how technology, economy, and society interact each other when a change in technology occurs. Some cases will be presented and discussed (asbestos cement, iron, and automotive technologies).Then, the transition perspective is presented to explain how such changes can determine long-term and wide impact. The type and nature of the transition are discussed. The structural and ideological nature of a transition will be described to support a full understanding of the phenomena. Some tools to operationalize ideologies are introduced. The green and digital transition will be examined adopting this perspective. A specific analysis for the transitions towards the smart city and the new space economy will be discussed with students.

Course title	SMART SUSTAINABLE MANUFACTURING
Scientific Discipline Sector	ING-IND/16
CFU	2 CFU
SUMMARY /GOAL	The major issue of sustainable manufacturing activities is the management of useful information: the way we choose data to measure may strongly change the perception of its nature and influence. Thus sustainability, which is an emerging paradigm in manufacturing, is now leading most of the scientific efforts in defining the assessment of sustainability and the collection of significant measures of transition toward actions that satisfies the economic, environmental, social and technological targets. Smartness paradigm in manufacturing, on the other hand, is deeply tied to the information management and use, provided the Digital Twins as well as Cyber Physical Systems are mostly based on data get from sensing systems and on their elaboration to predict the evolution of systems simulated. The class will bring the students to understand the main driving issues in assessing and managing sustainable manufacturing in the light of a smart transition. At the same time will put major issues to come to stimulate students in their scientific career to deepen open issues still remaining on the subject from a technological perspective. Contents 1CFU. Manufacturing processes and the main factors of production: material and energy. Manufacturing and sustainability. Production systems and their sustainable management. Smart manufacturing paradigms: I4.0 and 5.0. 1CFU Criteria for modeling manufacturing processes and their critical variables. Cyber Physical System and Cyber Physical Social System. Measurement of the ecological footprint of a process: carbon and water footprint. Sustainability Assessment of manufacturing processes based on 1 and 2nd law of thermodynamics.

Course title	STATISTICAL MECHANICS WITH APPLICATIONS
Scientific Discipline Sector	MAT/07
CFU	2 CFU
SUMMARY /GOAL	INTRODUCTION TO STATISTICAL MECHANICS Free energy and entropy; observables; ensembles; probability distribution; partition function; relation with thermodynamics. MODELS AND APPLICATIONS Phase transitions; critical points; order parameter; Landau theory; Ising model; mean field and Curie-Weiss model; effect of disorder; optimization; Hopfield networks.

Course title	Elements of digital transition in civil engineering
Scientific Discipline Sector	ICAR/02
CFU	2 CFU
SUMMARY /GOAL	The course aims to provide elements of digital transition tools and the concept of Digital Twin and Digital Water Services. The students will be introduced to advancements in data acquisition, storage and representation integrated with the latest methodologies developed from technical-scientific research based on complex network theory, machine learning and multi-objective optimization. The final objective is to provide PhD students with key concepts of digital transition in water system management vehiculated by effective and transferable products that implements efficient processes to face various technical issues. Advanced applications to Water Distribution Networks (WDNs) will be used as benchmarks, involving students in applying Digital Water Services to support solving WDN life-cycle management issues.

Course title	Advanced Topics in Port and CoastalEngineering
Scientific Discipline Sector	ICAR/02
CFU	2 CFU
SUMMARY /GOAL	The aim of the course is to provide PhD students with in-depth knowledge of the hydrodynamics of wave motion, focusing on the role of sea waves in coastal dynamics processes, with reference to the interaction between wave motion and coastal defence and port structures. During the course, the interaction between the fundamental physical phenomena and their description through analytical models, long-term statistical analysis for the evaluation of extreme events and the numerical approaches used in the field of coastal engineering to evaluate the environmental loads on structures induced by waves, currents and wind. The course will also deal with the resilience of coastal structures to climate change (e.g., sea level rise and increase in extreme sea storms), with reference to current design criteria and future research developments. Specific contents: Wave mechanics and wave transformation processes from deep water to shallow water; Design principles of coastal and port structures (statistical analysis of extreme events - calculation of loads for the design of structures - wave/structure interaction); Advanced mathematical models and numerical approaches in coastal engineering; Effects of climate change on the design and management of coastal and port structures.

Course title	Digital fabrication, method and theory: a practical approach
Scientific Discipline Sector	ICAR/14
CFU	2 CFU
SUMMARY /GOAL	A course on computational techniques related to parametric design and digital manufacturing, to explore the possibilities and the different developments of computational design applied to design, through the use of subdivision modeling software, and to algorithmic techniques. The various computational techniques, the different approaches and generative processes will be compared. The aspect of parametric design closely connected to digital manufacturing techniques will be explored both through sophisticated CN and "low cost" machines and how the conception and creation of design objects are being modified, bringing full control over the design back into the hands of the designer. First module. History of computational thinking and digital contamination in architectural design. An overview of the first software, not expressly designed for architecture, which have supported architects over time, always intervening with greater presence, both in the creative part and on the control of the design and the final product; up to the present day, where software specifically designed for architecture is developed. The works and major architects who were the first to deal with the digital world will be presented. Second module. Presentation of a typical modeling workflow with software based on subdivision technology, especially with open source software such as Blender or the Foundry's Modo. These software allow a modeling of complex surfaces with a low number of polygons. It plays an important role in the field of design being very powerful in the creative phase and connecting well with other programs more oriented towards numerical control and production. We will start from the description of the main commands and we will create practical examples of typical modeling in the field of design and architecture, up to the export of the models created in a CAD software. Third module. Presentation of a typical modeling workflow with a parametric software and generative algorithms. We will start from the description of the main commands underlying the logic of design with algorithms, with the grasshopper software. Case studies and applications in the fields of architecture and design will be illustrated. Fourth module. Description of the principles of digital manufacturing and presentation of case studies, and of the software used in this area with the description of the main commands. The two worlds of additive and subtractive technologies will be illustrated. Particular attention will be given to 3D printing technology, from the most sophisticated techniques to PLA printing with examples and case studies, from the preparation of the model in STL format to the finished product. The processes for making objects with the use of 5-axis numerical control machines will be illustrated, in the field of marble design.