UNIVERSITÀ DEGLI STUDI DI PADOVA

INGEGNERIA DELL'INFORMAZIONE

Course unit English denomination	Entrepreneurship and Startup
SS	I27X (ING-IND/35)
Teacher in charge (if defined)	Muffatto Moreno Ferrati Francesco
Teaching Hours	21
Number of ECTS credits allocated	3
Course period	14-21-28 January, 4-11-18-25 February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (70% minimum of presence) ☐ No
Course unit contents	• characteristics of a technology and innovation-based startup. • characteristics of an effective founding team. • define and evaluate a product and/or service concept. • intellectual property protection and related processes. • evaluate the market aspects of a business idea. • design and evaluate different business models. • understand and develop the financials of a startup. • evaluate cash flow dynamics. • evaluate different options for financing a start-up. • understand what professional investors are interested in and how they assess it.

Learning goals	• Understand the process to develop and Innovation and Entrepreneurship project • identify and articulate the real-world problems your research can address. • select a field and find relevant problems to solve. • translate scientific expertise into practical solutions. • understand how to create an effective team. • engage in team building. • work effectively in a team with individuals from other disciplines, leveraging varied expertise. • understand the fundamentals of entrepreneurship, including business models, value propositions, and market analysis. • understand intellectual property rights, patents, and strategies for bringing research-based innovations to market. • use Generative AI (ChatGPT) more efficiently and effectively. • harnessing the synergy of your creative insights and Generative AI (ChatGPT) to shape and refine every outcome of the project. • understand the basics of a startup financials.
Teaching methods	• Formation of interdisciplinary teams and group working • Development of an Innovation and Entrepreneurship Project designed to provide hands-on experience with practical methodologies. • Integration of Generative AI tools (ChatGPT) to enhance and streamline each stage of the development process.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None

Examination methods (if applicable)	Development of an Innovation and Entrepreneurship project
Suggested readings	Karen Berman and Joe Knight (2008), *Financial Intelligence for Entrepreneurs*, Harvard Business Publishing. Thomas R. Ittelson (2009), *Financial Statements: A Step-by-Step Guide to Understanding and Creating Financial Reports*, Career Press. Ferrati, F. & Muffatto, M. (2021). "Reviewing Equity Investors' Funding Criteria: A Comprehensive Classification and Research Agenda". *Venture Capital*, Vol. 23: No. 2, pp. 1-22. Noam Wasserman (2013) *The Founder's Dilemmas: Anticipating and Avoiding the Pitfalls That Can Sink a Startup*, Princeton University Press.
Additional information	The course is included in the University's cross-disciplinary doctoral programme. https://www.unipd.it/en/phd-interdisciplinary-teachings Kindly note that the maximum capacity for participants is limited to 80. Participants who have met the requirements in terms of attendance and assignment will be awarded the open badge for the course. https://bestr.it/badge/show/2670

Course unit English denomination	Python programming for Data Science and Engineering
SS	IINF/05
Teacher in charge (if defined)	Stefano Tortora
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	03/2026 – 04/2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☐ Yes ☒ No
Course unit contents	Python is an easy-to-learn and powerful high-level language and it is becoming more and more popular for scientific applications such as machine learning, statistics, manipulating and transforming data, but also computer vision and robotics. Topics: ● Introduction to the Python Programming Language o What is different in Python? o The Python Language Syntax and Data Structures ● Modules and Packages o NumPy and SciPy: Numerical and Scientific Python o Pandas: Labeled Column-Oriented Data o Matplotlib: MATLAB-style scientific visualization ● Scikit-learn: Basics of Machine Learning in Python

Learning goals	Acquired knowledge: the first objective of the course is to become familiar with Python syntax, environments and basic libraries. Secondly, the learner will be guided in performing basic inferential data analyses and introduced to the application of common machine learning algorithms. Acquired skills: the students will learn practically how to structure a complex project in Python through the guided execution of 5 assignments. In addition, they will learn how to handle and organize a group project through the subdivisions into small groups (max 3 people) for the handover of the assignments.
Teaching methods	- Lectures - Laboratory exercises - Group projects
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Backgrounds in computing with some object-oriented programming language: C++, Java, MATLAB, etc.
Examination methods (if applicable)	Homework assignments and final presentation
Suggested readings	[1] J. VanderPlas, "A Whirlwind Tour of Python", O'Reilly Media Inc. 2016. [Online: https://www.oreilly.com/programming/free/files/a-whirlwind-tour-of-python.pdf] [2] J. VanderPlas, "Python Data Science Handbook: Essential Tools for Working with Data" O'Reilly Media Inc. 2017. [3] B. Miles, "Begin to Code with Python", Pearson Education, Inc. 2018. [Online: https://aka.ms/BeginCodePython/downloads] [4] Z. Shaw, "Learn Python the Hard Way", Addison-Wesley. 2014. [5] A. Géron, "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems", O'Reilly Media Inc. 2019.

Additional information

Course unit English denomination	Data Visualization
SS	IINF/05
Teacher in charge (if defined)	Matteo Ceccarello
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	January/February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (60% minimum of presence) ☐ No
Course unit contents	• The Grammar of Graphics • Human perception and color theory • The ggplot implementation of the Grammar of Graphics • Case studies: how to visualize data from different perspectives • Avoiding pitfalls in scientific data visualization
Learning goals	PhD students will be able to choose the most appropriate visualization idiom to visualize the data at hand. Furthermore, they will be able to make use of graphical marks and colors to improve the effectiveness of their visualizations.
Teaching methods	Lectures, guided exercises, individual exercises, peer feedback, case studies.

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic computer programming experience
Examination methods (if applicable)	Project-based exam
Suggested readings	1. Healy K. Data Visualization, a practical introduction. Princeton University Press. https://socviz.co 2. Wickham H., Grolemund G. R for Data Science. O'Reilly. https://r4ds.had.co.nz/ 3. Ware C., Visual thinking for design. Elsevier. 4. Wickham, H. (2010). A layered grammar of graphics. Journal of Computational and Graphical Statistics, 19(1), 3-28.
Additional information	

Course unit English denomination	Geopolitics of ICT in an unpredictably changing world
SS	IINF-01/A, GSPS-04/B
Teacher in charge (if defined)	Alessandro Paccagnella (DEI), David Burigana (SPGI)
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	02/2026 – 04/2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Information and communication technologies are one of the fundamental backbones of the world, based on a formidable scientific and technological development starting from the end of WWII. In this course we follow the ICT technological evolution, in particular its enabling technology – microelectronics - in parallel with the evolution of the international context from the Cold war period to the globalization time, and then in the current de/post-globalized world. From the viewpoint of International Relations, we present the current geopolitical frame that is characterized by a strong comeback of the power politics among countries, where the multilateral approach (i.e., United Nations) appears embroiled in a crisis difficult to overcome. Superpowers (US and China) as well as powers (Russia, India, Brazil, South Africa, United Arab Emirates) are gaining ground; some regional experiences (UE, ASEAN) still resist, while other (western) countries preserve with difficulty their influence and presence in the world (France, UK). Other countries instead are playing a strategic role owing to their techno-scientific capabilities, in particular in the ICT sector: South Korea,

	Taiwan, Singapore, Japan, Israel, to a lesser extent Germany. Others, such as Vietnam, aim to join this group, despite its troubled colonial past. Italy may find its role as a bridge of dialogue among powers. In this complex frame a new gold rush is occurring for the leadership, or at least a significant participation, in the Advanced High Technologies for ICT, which are continuously gaining momentum. In this course we take as a reference the case of semiconductors, which are at the center of a global competition where polarization in alliances is enhancing barriers and mutual distrust. The evolution of Moore's law toward the "more Moore" and "more than Moore" options is spurring massive investments at private and government levels, with the 2022 EU Chips act and the CHIPS for America act being just the most renown actions taking place these days. The recent chip crisis during the pandemic has increased the level of hostility, favoring increasing levels of embargo towards China of the most advanced technologies (such as IC design tools or EUV photolithographic machines) from the Western bloc, that today appears more and more as a military alliance. De-risking, re-shoring, friendly-shoring are widespread keywords leading to reacquiring at least part of the technological sovereignty lost by western countries in the first two decades of the XXI century.
Learning goals	By joining the geopolitical and sci-tech perspectives, the student will be able to identify actors and dynamics that have made ICTs a crucial asset of the foreign policy. Starting from the analysis of the geopolitical and technological situations, the student will assess the relations between experts/advisors and the political decision makers in the international projection of national strategies.
Teaching methods	The course will be based on lectures and discussion. The course will involve also some selected witnesses and actors that will interact with the class, that will be also involved in a simulation of a negotiation in a multinational arena.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes the course is open to all UNIPD PhD students ☐ No
Prerequisites (not mandatory)	The course can be taken by any student interested. Basic knowledge of ICT technologies, as acquired in the previous degrees, would facilitate communication, as well as some fundamental notions about the world

	history of the XX and XXI centuries, that will be nevertheless summarized during the lectures.
Examination methods (if applicable)	simulation of a negotiation in a multinational arena, final presentation.
Suggested readings	Will be given during the lectures
Additional information	

Course unit English denomination	S: Statistics for Engineers
SS	STAT-01/A
Teacher in charge	• Salmaso Luigi • Disegna Marta • Arboretti Rosa
Teaching Hours	42
Number of ECTS credits allocated	7
Course period	• February 2026 • End of June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (90% minimum of presence) ☐ No
Course unit contents	In this course will be developed the following topics: 1) introduction to descriptive statistics; 2) introduction to inferential statistics; 3) introduction to linear and non-linear regression models; 4) introduction to supervised and unsupervised Machine Learning algorithms; 5) Design of Experiments.
Learning goals	The course develops in participants the statistical skills necessary to handle and analyse data of various kinds, including data from the doctoral project they are developing. Students will acquire both theoretical and practical knowledge to independently develop statistical analysis. During the course, students will gain basic skills to correctly use some user-friendly statistical software. Additionally, the course enables students to acquire the skills to effectively and correctly present and interpret statistical analysis.
Teaching methods	Frontal lessons, group works, workshops, case studies.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes

	☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites	-
Examination methods	The final evaluation will be based on the discussion of two projects developed individually or in teams of no more than three people. Students are expected to describe and analyse one or two case studies using the statistical techniques presented during the course.
Suggested readings	Materials (slides, datasets, etc.) of the course will be provided by the course leaders.
Additional information	The course is structured into 2 online (February) and a Summer School of 4 days (June). The Summer School will take place in Villa San Giuseppe, Monguelfo, Bolzano province. During the course an introduction to the use of the following statistical software will be presented: ● R and BlueSky, both open-source software. ● MINITAB, licensed to University of Padova.

Course unit English denomination	Heuristics for Mathematical Optimization
SSD	MAT/09 – Operations Research
Teacher in charge (if defined)	Salvagnin Domenico
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	03/2026-04-2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	Italian/English (depending on participants)
Mandatory attendance	☐ Yes ☒ No
Course unit contents	• Mathematical optimization problems (intro). • Heuristics vs exact methods for optimization (intro). • General principle of heuristic design (diversification, intensification, randomization). • Local search-based approaches. • Genetic/population-based approaches. • The subMIP paradigm. • Applications to selected combinatorial optimization problems: TSP, QAP, facility location, scheduling.
Learning goals	Make the students familiar with the most common mathematical heuristic approaches to solve mathematical/combinatorial optimization problems. This includes general strategies like local search, genetic algorithms and heuristics based on mathematical models.

Teaching methods	Lectures, group projects
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	• Moderate programming skills (on a language of choice) • Basics in linear/integer programming.
Examination methods (if applicable)	Final programming project
Suggested readings	[1] Gendreau, Potvin “Handbook of Metaheuristics”, 2010 [2] Marti, Pardalos, Resende “Handbook of Heuristics”, 2018
Additional information	

Course unit English denomination	Quantum communication: methods and implementations
SS	PHYS-03/A
Teacher in charge (if defined)	Dr. Marco Avesani
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	Spring 2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☐ Yes ☒ No
Course unit contents	• Elements of quantum communication and Quantum Key Distribution (QKD) • Entropies in quantum information • Discrete variable QKD • Safety definitions and tests • Finite key analysis for the BB84 protocol and practical implementations (decoy technique) • Numerical methods for estimating the rate of secure key generation • Experimental realizations: polarization coding and time-bin • Free space QKD implementations • QKD Attacks
Learning goals	The course aims to introduce the theoretical methods and experimental techniques

	used in the context of quantum communication. The main topic of the course will be the Quantum Key Distribution (QKD), which offers the possibility to present in a modern way both the theoretical (protocols, security tests) and experimental (sources, detection technologies, implementation schemes and realizations) aspects that characterize quantum communication technologies. At the end of the course the student will know the basics of quantum technologies, both from a theoretical and experimental point of view, and will be able to understand scientific articles in the field of quantum communications and QKD.
Teaching methods	Frontal teaching
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Good knowledge of linear algebra is necessary. Basic knowledge of Quantum Mechanics and Quantum Optics can be useful.
Examination methods (if applicable)	Oral exam on the contents of the course, with the possibility of presenting an in-depth study agreed with the teachers.
Suggested readings	• R. Wolf, "Quantum Key Distribution: An Introduction with Exercises (Lecture Notes in Physics)", 1st Ed., Springer (2021) • S. Pirandola et al., «Advances in quantum cryptography», Adv. Opt. Photonics, vol. 12, n. 4, pagg. 1012–1236, dic. 2020, doi: 10.1364/AOP.361502 • N. Gisin, G. Ribordy, W. Tittel, H. Zbinden, e N. Gisin, «Quantum cryptography», Rev Mod Phys, vol. 74, n. 1, pagg. 145–195, mar. 2002, doi: 10.1103/RevModPhys.74.145 • V. Scarani et al., «The security of practical quantum key distribution», Rev. Mod. Phys., vol. 81, n. 3, pagg. 1301–1350, 2009, doi: 10.1103/RevModPhys.81.1301
Additional information	Additional material (notes, slides, etc.) will be made available by the teachers.

Course unit English denomination	Elements of Synthetic Biology
SS	IBIO-01
Teacher in charge (if defined)	Massimo Bellato
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	June
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	• Introduction to Synthetic Biology: Definitions, aims, DBTL (Design, Build, Test, Learn) cycle, boundaries, and case studies. • Basics of molecular biology and genetics: Essential review of cellular biology and microbiology, genetic parts and modules, living chassis, molecular tools. • Cloning DNA genetic circuits into bacterial cells (wet-lab activity) • Measuring synthetic biology: Instrumentation, data analysis, and modeling • Notable genetic circuits and motifs: genetic feedback loops, toggle switches, oscillators, and perfect adaptation via antithetic integral control. • Additional material depending on the class interests
Learning goals	The course is intended to provide some insights into Synthetic Biology, providing the student knowledge and primary instruments for the design of engineered biological systems. More specifically, the genetic markup of a cell can be modified by inserting rationally designed genetic circuits

	(as happens for electric devices, but with modules composed of DNA instead of resistors and capacitors) to generate novel biological functions with predictable outcomes. Therefore, the course will be focused on stimulating a cross-field mindset, to apply engineering principles and methodologies to the biological world; analogously, "biological parts" as "engineerable toolkits" will be explained. The basic biological knowledge required to understand how to engineer a living cell will be provided at the beginning of the course, including basic mathematical modeling of molecular kinetics and the Central Dogma. The second part will focus on measurement and characterization techniques, for rational experimental design, including data analysis approaches and tools used in this realm. Lastly, advanced topics on engineered biological systems and culture control techniques will be faced including bi-stability, feed forward/feed-back regulations, and perfect adaptation in gene expression and bioreactor setups. Additional specific aspects (e.g., optogenetics and FBA, will also be faced depending on students' specific interests).
Teaching methods	Lectures, Wet lab with practical hands-on, Students presentations
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	ODEs modeling; basics of Matlab programming. Prior knowledge in molecular biology, bioinformatics, and control theory can be useful but not necessary. Students are required to complete the "HIGH-RISK ACTIVITIES (12 hours) – Laboratory activities" security course from https://elearning.unipd.it/formazione/course/index.php?categoryid=40 to access the laboratory space.
Examination methods (if applicable)	Final group project consisting of the design of a genetic circuit in a proper host, on a relevant topic. Alternatively, single student journal club activities. Ph.D. School in Information Engineering - Course Catalogue 2024/2025 [back to Summary] 27 The projects will be presented to the whole class, including a peer-to-peer evaluation activity.
Suggested readings	Teacher slides and linked references. Additional useful books: "Uri Alon, An Introduction to Systems Biology Design Principles of Biological Circuits", "Alberts et al. The Molecular Biology of the Cell (6th edition)" and "Vijai Singh, New Frontiers and Applications of Synthetic Biology"

Additional information

Course unit English denomination	Deep Learning for Biomedical Images
SSD	IBIO-01/A
Teacher in charge (if defined)	Castellaro Marco
Teaching Hours	18
Number of ECTS credits allocated	4
Course period	04/2026 – 06/2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	Italian
Mandatory attendance	☒ Yes (70% minimum of presence) ☐ No
Course unit contents	The rapid evolution of deep learning in the field of computer vision provided state-of-the-art solutions for classical tasks such as object detection, classification, segmentation, and activity recognition. Besides, medical imaging is the ideal candidate model for the application of complex deep neural network (DNN) or Convolutional neural network (CNN) and more recent introduced Transformers architectures. In this course the teacher will provide students the knowledge and the practical skills to understand the most recent networks and to use them in the field of biomedical imaging. Topics: • Introduction to biomedical images (DICOM/Nifti standards) • Introduction to Pytorch and Monai (Medical Open Network for Artificial Intelligence) • Pre-processing, transform and data augmentation • Case studies: DNN and CNN architectures for image classification, segmentation, and image reconstruction

	• Training procedures, algorithms, and strategies • Transfer learning and fine tuning • Transformers, attention principle and its application to biomedical images analysis tasks. • Foundational models and their applications to biomedical images analysis tasks.
Learning goals	The learning goal of the deep learning for biomedical images course is to equip students with the knowledge and practical skills necessary to comprehend and utilize the latest deep neural network. Through topics such as data pre-processing, deep neural network and convolutional neural networks architectures, training, transfer learning and fine-tuning procedures, the course aims to empower students to address complex challenges in medical image analysis using cutting-edge deep learning methodologies.
Teaching methods	Two/third frontal lessons and one/third laboratory and coding activity
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic programming skills with Python language and basic theoretical knowledge of machine learning.
Examination methods (if applicable)	The examination will be based on a team-work to implement a deep learning based task to be applied to a real dataset of biomedical images.
Suggested readings	
Additional information	

Course unit English denomination	Healthcare data management and analytics
SS	IBIO-01/A
Teacher in charge (if defined)	Enrico Longato
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	March-June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	The analysis and management of healthcare data present a set of often underestimated practical challenges when attempting to go from the raw data to the communication of scientific results of clinical significance. In this course, we will go over some of the main difficulties in healthcare data management and analytics (e.g., heterogeneity of the data, lack of centralised programming resources), and present tried-and-true, first-line solutions specifically scoped for the biomedical context. The course will follow a learn-by-doing approach with lectures accompanied by hands-on programming sessions in python. • A refresher on the bare necessities of python programming: numpy, pandas, object oriented programming refresher, reading and writing from/to files and databases. • Interfacing with R for access to libraries for advanced biostatistics and clinical data management.

	• Typical workflows for healthcare data preprocessing including missing data imputation. • Patient disposition and characteristics: creating a "Table 1." • Implementing basic experimental frameworks for classification and regression on healthcare data. • Probability theory recap and statistical testing. • Understanding and communicating model performance and specifics.
Learning goals	• Developing complete pipelines for the management and analysis of healthcare or clinical data. • Python programming basics, including interfacing with the R programming language, for the solution of clinical or healthcare data analytics problems • Knowledge and ability to apply the fundamentals of probability theory, inferential statistics, and machine learning
Teaching methods	• Frontal lectures • Hands-on labs • Live coding • Case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☐ Yes ☒ No
Prerequisites (not mandatory)	• Basic knowledge of any programming language • Basics of probability theory and/or statistics
Examination methods (if applicable)	Final project consisting of the end-to-end analysis of a healthcare or clinical dataset from raw data ingestion to results presentation.
Suggested readings	T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction. in Springer Series in Statistics. New York, NY: Springer-Verlag New York, 2009. Available online at: https://hastie.su.domains/ElemStatLearn/download.html

Additional information

Course unit English denomination	Bayesian Machine Learning
Teacher in charge (if defined)	Giorgio Maria Di Nunzio
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	February – March 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	The course on Bayesian Machine Learning aims to introduce students to Bayesian reasoning and its application to common machine learning problems such as classification and regression. It covers key concepts including the mathematical framework of supervised and unsupervised learning, Bayesian decision theory with a focus on classification techniques like minimum-error-rate and decision surfaces, and estimation methods such as Maximum Likelihood Estimation, Expectation Maximization, Maximum A Posteriori, and Bayesian approaches. Additionally, the course explores graphical models, including Bayesian networks and two-dimensional visualization, and concludes with methods for evaluating model accuracy. A graphical tool will be developed to analyze the assumptions underlying Bayesian methods in these contexts.
Learning goals	The learning goals of the course on Bayesian Machine Learning are: understand the fundamentals of Bayesian reasoning and how they apply to classical machine learning problems such as classification and regression; analyze the assumptions of Bayesian approaches in machine learning by developing and utilizing a graphical analysis tool; gain familiarity with graphical models, including the construction and interpretation of Bayesian networks and two-dimensional visualizations; critically assess the pros and cons of Bayesian methods compared to other approaches in machine learning; evaluate the performance of machine learning models** using various accuracy measures.

Teaching methods	The course on Bayesian Machine Learning will use a combination of flipped-classroom methods, slides, and Python Jupyter notebooks to support both theoretical understanding and practical skills. Slides will introduce key topics, with in-class time dedicated to collaborative problem-solving, and hands-on learning using Jupyter notebooks with live demonstrations and visualizations of Bayesian concepts.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (in applicable)	Participation and interaction in course activities. Presentation of a case study (scientific article) or collaborative work on a research topic relevant to the course.
Suggested readings	[1] J. Kruschke, Doing Bayesian Data Analysis: A Tutorial Introduction With R and Bugs, Academic Press 2010 [2] Christopher M. Bishop, Pattern Recognition and Machine Learning (Information Science and Statistics), Springer 2007 [3] Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification (2nd Edition), Wiley-Interscience, 2000 [4] Yaser S. Abu-Mostafa, Malik Magdon-Ismail, Hsuan-Tien Lin, Learning from Data, AMLBook, 2012 (supporting material available at http://amlbook.com/support.html) [5] David J. C. MacKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003 (freely available and supporting material at http://www.inference.phy.cam.ac.uk/mackay/ [6] David Barber, Bayesian Reasoning and Machine Learning, Cambridge University Press, 2012 (freely available at http://web4.cs.ucl.ac.uk/staff/D.Barber/pmwiki/pmwiki.php?n= [7] Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012 (supporting material http://www.cs.ubc.ca/murphyk/MLbook/) [8] Richard McElreath, Statistical Rethinking, CRC Presso, 2015 (supporting material https://xcelab.net/rm/statistical-rethinking/)
Additional information	None

Course unit English denomination	Introduction to Modern Cryptography
SS	INGINF05 - MAT/05
Teacher in charge (if defined)	Alessandro LANGUASCO
Teaching Hours	24
Number of ECTS credits allocated	5
Course period	First semester
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75 % minimum of presence) ☐ No
Course unit contents	First definition of a cryptosystem. Some historical examples. Fundamental crypto algorithms. Shannon's perfect cipher. A review about symmetric methods (historical ones, DES, AES). Asymmetric methods based on primality/factoring and discret log problems. Known attacks to some of the most used public key cryptosystems. How to use a public key system to build a digital signature algorithm. Digital Signatures with RSA and discrete log. Authentication protocols (Kerberos, Needham-Schroeder) and public key systems. Key exchange in three steps (Diffie-Hellman key exchange protocol), secret splitting, secret sharing, secret broadcasting, timestamping.
Learning goals	We present some of the main features about what a Modern Cryptosystem is. In particular we will focus on showing the internal characteristics of some of the now used public key cryptosystems. We will overview the methods based on the primality/factorization and on the discrete logarithm problems. The focus will be on the actual implementation and its feasibility in terms of both time and space, while taking care of the needed mathematical concepts (congruences, finite fields) and explaining them along the course as needed.

	As a final topic, we will show how to use a public key system in an authentication/identification protocol. The goal of the course will be to evaluate pros and cons of the cryptographic choices performed in designing such protocols.
Teaching methods	In class; us
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	none
Examination methods (if applicable)	a seminar on a related topic. For example (but on others of common interest we can agree upon): The Secure Hash Algorithm (SHA); other hash algorithms; primality algorithms; factoring algorithms; discrete log algorithms; homomorphic cryptography; elliptic curves cryptography; compression and hash functions; probabilistic cryptography; digital currencies, electronic voting.
Suggested readings	Books: 1) Languasco-Zaccagnini, "Manuale di Crittografia", Hoepli, 2015. 2) Knospe, "A course in Cryptography", AMS, 2019. 3) Schneier, "Applied Cryptography, Protocols, Algorithms, and Source Code in C", Wiley, 1993.
Additional information	none

Course unit English denomination	Applied functional analysis and machine learning
SS	IINF/04
Teacher in charge (if defined)	Gianluigi Pillonetto
Teaching Hours	24
Number of ECTS credits allocated	5
Course period	November-december 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Review of some notions on metric spaces and Lebesgue integration: Metric spaces. Open sets, closed sets, neighborhoods. Convergence, Cauchy sequences, completeness. Completion of metric spaces. Review of the Lebesgue integration theory. Lebesgue spaces. Banach and Hilbert spaces: Finite dimensional normed spaces and subspaces. Compactness and finite dimension. Bounded linear operators. Linear functionals. The finite dimensional case. Normed spaces of operators and the dual space. Weak topologies. Inner product spaces and Hilbert spaces. Orthogonal complements and direct sums. Orthonormal sets and sequences. Representation of functionals on Hilbert spaces. Reproducing kernel Hilbert spaces, inverse problems and regularization theory: Representer theorem. Reproducing Kernel Hilbert Spaces (RKHS): definition and basic properties. Examples of RKHS. Function estimation problems in RKHS. Tikhonov regularization. Support vector regression and classification. Extensions of the theory to deep kernel-based networks: multi-valued RKHSs and the concatenated representer theorem.
Learning goals	The course is intended to give a survey of the basic aspects of functional analysis, machine learning, regularization theory and inverse problems. At the end of the course, the student will have the methodological tools

	to tackle various machine learning problems in both regression and classification (estimation of functions from scattered and noisy data) starting from very general hypothesis spaces.
Teaching methods	Blackboard lectures and various questions posed to students regarding previous lessons
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	The classical theory of functions of real variable: limits and continuity, differentiation and Riemann integration, infinite series and uniform convergence. Some elementary set theory and linear algebra.
Examination methods (if applicable)	Two written exams, one in the middle of the course and the other at the end
Suggested readings	[1] G. Pillonetto, T. Chen, A. Chiuso, G. De Nicolao, L. Ljung. Regularized System Identification –learning dynamic models from data, Springer Nature 2022 [2] W. Rudin. Real and Complex Analysis, McGraw Hill, 2006 [3] C.E. Rasmussen and C.K.I. Williams. Gaussian Processes for Machine Learning. The MIT Press, 2006 [4] H. Brezis, Functional analysis, Sobolev spaces and partial differential equations, Springer 2010 [5] G. Pillonetto, A. Aravkin, D. Gedon, L. Ljung, A.H. Ribeiro and T.B. Schön, Deep networks for system identification: a Survey, eprint 2301.12832 arXiv, 2023 In addition, written notes will be made available to the students.
Additional information	None

UNIVERSITÀ DEGLI STUDI DI PADOVA

INGEGNERIA DELL'INFORMAZIONE

Course unit English denomination	Physics and Operation of Heterostructure-Based Electronic and Optoelectronic Devices
SS	IINF-01/A
Teacher in charge (if defined)	Carlo De Santi
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	February/March 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (% minimum of presence) ☒ No
Course unit contents	This course provides an introduction to the physics and operating principles of advanced electronic and optoelectronic devices based on compound semiconductors. These devices are particularly important for several applications: high electron mobility transistors (HEMTs) are excellent devices for the realization of high-frequency communication systems, radar, satellite applications and high-efficiency power converters. On the other hand, LEDs and lasers are highly efficient monochromatic light sources, which can be used for lighting applications (with significant energy savings), in the biomedical field, as well as in photochemistry and telecommunications. A special focus will be given to devices based on gallium nitride (GaN) and gallium oxide (Ga_2O_3), which represent the most promising devices for future applications in power electronics. The course will focus on the main aspects related to the physics of heterostructures, quantum processes in heterostructures, recombination processes in semiconductors, carrier transport in heterostructures, structure and operating principles of MESFET, HEMT,

	GIT, trapping and reliability in compound semiconductor devices, operating principles of LEDs and lasers and parasitic effects in LEDs and lasers. An overview of real applications will also be provided, highlighting the possibilities offered by these devices. Finally, an overview of the modern approach to the simulation of the physics of such devices may be provided.
Learning goals	The course aims to provide skills and competences related to the physics and operation of heterostructure devices and their modeling. Specific topics may include, among others: • Future developments of microelectronic technologies • Elements of quantum mechanics • Properties of heterostructures • Compound semiconductors • Defects in semiconductors • Operating principles of heterostructure devices (e.g. LEDs, lasers, heterostructure transistors, …) • Modeling of heterostructure devices • Basic principles of numerical simulation • Optoelectronic devices for silicon-photonics
Teaching methods	Different teaching methodologies will be applied, in order to develop both methodological aspects and experimental skills. Specific methodologies may include: • Lectures • Flipped classroom • Classroom discussion • Homework • Classroom exercises • Literature analysis
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	
Examination methods (if applicable)	Examination methods may include: • Evaluation of homework • Evaluation of presentations prepared by students • Practical exercises and related report
Suggested readings	Teaching material provided by teachers via the course Moodle
Additional information	

Course unit English denomination	Embedded Design with FPGA
SS	IINF-01/A
Teacher in charge (if defined)	• Andrea Stanco (teacher in charge), Department of Information Engineering, andrea.stanco@unipd.it • Daniele Vogrig, Department of Information Engineering, daniele.vogrig@unipd.it • Andrea Triossi, Department of Physics and Astronomy, andrea.triossi@unipd.it
Teaching Hours	24
Number of ECTS credits allocated	5
Course period	12/2025 – 03/2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (at least 4 lab-lessons out of 7) ☐ No
Course unit contents	• Recap on the basics of Digital Design. Digital Design Flow (HDL language and HLS). Introduction to VHDL program language. • Introduction to FPGA and Zynq SoC. • Introduction to Vivado System Design environment. Time domains, time violations, metastability, system constraints, time-to-digital converter (TDC) • Introduction to SDK environment • Information exchange between processor and programmable logic. Hardware and Software interrupts.

	• Communication between SoC and the outside world. • PYNQ (Python on Zinq) project as example of how to make easier the design embedded systems • Several case studies including a time-to-digital converter (TDC)
Learning goals	The course aims at teaching how to practically use System-on-a-Chip (FPGA+CPU) technology as a potential application to academic research topics.
Teaching methods	The course fully supports a hands-on and practical approach to deliver a more effective comprehension of the challenges and issues related to the SoC/FPGA design. The course includes 5 lectures and 7 lab-lessons that will be held in a dedicated laboratory using the boards Pynq-Z1 and Pynq-Z2
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of digital electronics. Knowledge of program language (e.g. C/C++). No VHDL knowledge or experience on FPGAs is required.
Examination methods (if applicable)	Final project (abstract+presentation) about the application of FPGA/SoC to an academic research topic.
Suggested readings	1. Hubert Kaeslin "Top-Down Digital VLSI Design: From Architectures to Gate-Level Circuits and FPGAs", Morgan Kaufmann, 2014 2. Xilinx, Vivado Design Suite User Guide, UG893 (v2019.1), https://www.xilinx.com/support/documentation/sw_manuals/xilinx2019_1/ug893-vivado-ide.pdf 3. Xilinx, Xilinx Software Development Kit (SDK) User Guide, https://www.xilinx.com/support/documentation/sw_manuals/xilinx2015_1/SDK_Doc/index.html

Additional information	The course is divided in 5 standard lessons and 7 “hands-on” laboratory lessons.

Course unit English denomination	Power Electronic Converters for Micro Grid Applications
SS	09/IINF-01
Teacher in charge (if defined)	Simone Buso, Paolo Mattavelli, Giorgio Spiazzi
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	Spring 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Power electronic converter applications for micro dc, ac and hybrid grids. Stability analysis in high converter density power distribution grids. High efficiency topologies for dc-dc bidirectional bridging functions. Digital control techniques for high performance switching converters.
Learning goals	Familiarize with micro grid converter applications. Learning to apply stability analysis techniques for grid connecting and grid connected converters. Understanding design criteria and performance goals for high efficiency bidirectional converters. Learning how to use of digital control techniques to achieve stability and performance goals in high performance converter applications.
Teaching methods	Lectures, working groups, design homework assignments

Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Power electronics course from the Master Degree in Electronic Engineering.
Examination methods (if applicable)	Final presentation of design assignment outcomes
Suggested readings	Lesson notes and topic related papers (indicated by the instructor after each lesson).
Additional information	The course is divided into two modules: 5 lectures and 7 laboratories.

Course unit English denomination	A Deep Dive into 5G Network Specifications and its Applications
SS	ING-INF/03
Teacher in charge (if defined)	Marco Giordani
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	April 2026 – May 2026 (tentative)
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes ☒ No (even though in-presence attendance is highly recommended)

Course unit contents	This course will provide a comprehensive overview of the 3GPP NR standardization activities for 5G cellular networks.
	● Introduction on 5G cellular networks
	● 3GPP NR: the new standard for 5G cellular networks
	  o The Third Generation Partnership Project (3GPP)
	  o How to read standardization documents and specifications
	  o The 5G NR Radio Access Network (RAN) architecture
	● 5G NR spectrum
	  o 5G NR frequencies
	  o The millimeter wave spectrum and channel model

	o The Multiple Input Multiple Output (MIMO) technology ● The 3GPP NR PHY layer o 5G NR frame structure o 5G NR numerology and resource grid o 5G duplexing schemes o 5G PHY signals and channels ● The 3GPP NR MAC layer o 5G MAC signals and channels o Beam/mobility management in 5G NR o Scheduling and resource allocation in 5G NR ● Guidelines for proper design and dimensioning of 5G applications
Learning goals	By the end of the course, students will be provided with: ● An overview of the main features of 5G networks, with a focus on the standard specifications and innovations developed for 3GPP NR. ● An understanding of the main innovations introduced by 3GPP NR specifications for the PHY layer, focusing on the renovated NR frame structure, the NR spectrum, the MIMO technology, the duplexing schemes, and the NR PHY signals and channels. ● An understanding of the main innovations introduced by 3GPP NR specifications for the MAC layer, from scheduling to resource allocation, with a focus on beam and mobility management. ● An understanding of the complex and interesting trade-offs to be considered when designing PHY/MAC protocol solutions for 5G cellular networks by examining a wide set of parameters based on 3GPP NR considerations and agreements.
Teaching methods	The course consists of classroom lectures and student group activities. Several textbooks are suggested. Notes, slides, articles and additional study material will also be provided during the course. The material will be made available on the course STEM webpage.

Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Preliminary knowledge of the ISO/OSI protocol stack
Examination methods (if applicable)	Final project
Suggested readings	1. 3GPP, "NR and NG-RAN Overall Description - Release 15," TS 38.300, 2018. 2. P. Marsch, Ö Bulakci, O. Queseth, M. Boldi (Ed.), "5G System Design: Architectural and Functional Considerations and Long Term Research," Wiley, 2018. 3. D. Chandramouli, R. Liebhart, J. Pirskanen (Ed.), "5G for the Connected World," Wiley, 2019. 4. M. Polese, M. Giordani, and M. Zorzi, "3GPP NR: the cellular standard for 5G networks," 5G-Italy White Book: a Multiperspective View of 5G, 2018. 5. E. Dahlman, S. Parkvall, J. Skold, "5G NR: The next generation wireless access technology," Academic Press, 2020.
Additional information	N/A

Course unit English denomination	Underwater Network Simulation and Experimentation
SS	IINF/03
Teacher in charge (if defined)	Filippo Campagnaro
Teaching Hours	18
Number of ECTS credits allocated	4
Course period	January-February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The course will last one week and will focus on the challenges imposed by the underwater communication channel, where WiFi, 2/3/4/5G and other radio frequency transmissions are strongly attenuated and cannot be used. An underwater network simulation and experimentation tool, called DESERT Underwater, will be used to test and evaluate the performance of underwater networks. Every day will be split into two parts, a theoretical part where the students will attend frontal lessons to learn the concepts and procedures to perform network simulations and develop software modules, and an experimental part where the student will be required to implement the code, run simulation experiments and analyze the results. Required equipment (for all): laptop with GNU/Linux OS (recommended Ubuntu LTS), a Linux virtual machine. Topics: ● Basics of communication networks and differences between the ISO OSI

	• stack and underwater protocol stack. • Differences between network emulation and simulation with an eventbased scheduler • The DESERT Underwater simulation and experimentation framework. • Underwater acoustic networks: Acoustic physical layers, Multipath, • Acoustic Noise, Propagation delay and impact to MAC layers. • Underwater optical and EM communication, and multimodal networks: • Underwater EM channel, Underwater optical channel, Underwater • multimodal networks • From simulation to sea experiment: use of real modems with DESERT • Exercises: at the end of each day, a guided assignment is provided
Learning goals	Understand when simulation and experimental results are statistically relevant, understand the challenges of communicating underwater, learn how to use advanced features of the Linux operating system for telecommunications tasks, learn how to interpreter the underwater channel conditions and see how theory can be used to predict the underwater network performance.
Teaching methods	Frontal interactive lessons, seminars, hands on exercises and assignments
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic of Linux and C++, basic of computer networks, basic of probability theory.

Examination methods (if applicable)	Homework assignments.
Suggested readings	[1] Filippo Campagnaro, Roberto Francescon, Federico Guerra, Federico Favaro, Paolo Casari, Roee Diamant, Michele Zorzi, "The DESERT Underwater Framework v2: Improved Capabilities and Extension Tools, IEEE Ucomms 2016 [2] Paolo Casari, Cristiano Tapparello, Federico Guerra, Federico Favaro, Ivano Calabrese, Giovanni Toso, Saiful Azad, Riccardo Masiero, Michele Zorzi, Open-source Suites for the Underwater Networking Community: WOSS and DESERT Underwater, IEEE Network SI "Open source for networking," 2014 [3] DESERT Underwater - DEsign, Simulate, Emulate and Realize Test-beds for Underwater network protocols https://desert-underwater.dei.unipd.it/ [4] Milica Stojanovic, On the relationship between capacity and distance in an underwater acoustic communication channel, ACM SIGMOBILE Mobile Computing and Communications Review, Volume 11, Issue 4, October 2007, pp 34–43 [5] Alberto Signori, Filippo Campagnaro, Michele Zorzi, Modeling the Performance of Optical Modems in the DESERT Underwater Network Simulator, IEEE Ucomms 2018 [6] Filippo Campagnaro, Roberto Francescon, Paolo Casari, Roee Diamant and Michele Zorzi Multimodal Underwater Networks: Recent Advances and a Look Ahead, WUWNet 2017
Additional information	This will be an intensive course and will last one week

Course unit English denomination	Generative Artificial Intelligence: foundations and recent trends
SS	IINF/03
Teacher in charge (if defined)	Prof. Simone Milani
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	Nov. 2025-Dec. 2025
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (70% minimum of presence) ☐ No
Course unit contents	Introduction to Generative AI and strategies o Fundamentals, basics, fields of applications, open issues and problems. o Example of generative AI applications. Bringing randomness into neural networks: the Variational Autoencoder. o Basic principles: regularizing an AE, statistical characterization, operation implementation. Becoming adversarial: from adversarial neural networks to generative adversarial networks (GANs). o Network training as a non-cooperative game. o Convergence to equilibrium. Stability points. o Vanishing gradients, convergence problems, mode collapse. o Evaluating and optimizing GANs o Other kinds of GANs. Detecting a GAN.

- GAN-revealing footprints: physical, noise, motion-related, signal-related, statistical. Improving quality by composite loss function.

Overfitting a network.

- Building a neural implicit representation (NIR).
- Creating an overfitted networks: convergence issues, initialization, quantization and compression of network weights.
- Entropy layers versus classical quantization+coding.

Going iterative: diffusion models.

- Basic definition of diffusion process: forward diffusion and reverse diffusion.
- Diffusion process as Markov chains.
- Forward diffusion via stochastic differential equations. Generative reverse stochastic diffusion.
- Sampling issues.

Tips and tricks for diffusion models.

- Accelerated Sampling, Conditional Generation, and Beyond.
- A simple implementation of a diffusion model.
- Accelerated diffusion models. Variational diffusion models. Critical sampling. Progressive distillation. Conditional diffusion models. Latent diffusion models.

Application of diffusion models.

- Image Synthesis, Text-to-Image, Controllable Generation, Image Editing, Image-to-Image, Super-resolution, Segmentation, Video Synthesis, Medical Imaging, 3D Generation.

Combining transformers into diffusion models: diffusion transformers.

- Basics principles of transformers.
- Attention layers. Positional encoding. Application of transformers to DM.
- The GLIDE architecture.
- Application to LLMs.

Learning goals	The course will introduce fundamental strategies in Generative AI overviewing different architectures from GANs to the most recent diffusion models. Students will have the opportunity to understand the building blocks of these solutions and verify their performances, as well as their advantages and disadvantages. In the end, we will discuss a possible application of these solutions in their field of research.
Teaching methods	Frontal lectures, moodle quizzes, demos and video tutorials
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Previous basic knowledge on Probability, Machine Learning and Deep Learning
Examination methods (in applicable)	Oral presentation
Suggested readings	[1] Ian Goodfellow and Yoshua Bengio and Aaron Courville, "Deep learning", MIT Press 2016, https://www.deeplearningbook.org/ [2] Jonathan Ho and Ajay Jain and Pieter Abbeel, Denoising Diffusion Probabilistic Models, 2020, https://arxiv.org/pdf/2006.11239.pdf [3] Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification (2nd Edition), Wiley-Interscience, 2000 [4] Nichol, Alex & Dhariwal, Prafulla. (2021). Improved Denoising Diffusion Probabilistic Models. https://arxiv.org/pdf/2102.09672.pdf [5] David J. C. MacKay, Information Theory, Inference and Learning Algorithms, Cambridge University Press, 2003 (freely available and supporting material at http://www.inference.phy.cam.ac.uk/mackay/ [6] Ian Goodfellow, NIPS 2016 Tutorial: Generative Adversarial Networks, 2016, https://arxiv.org/pdf/1701.00160.pdf [7] Zhiqin Chen and Hao Zhang. 2019. Learning Implicit Fields for Generative Shape Modeling. *arXiv:1812.02822 [cs]* (September 2019). [8] Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Łukasz Kaiser, Illia Polosukhin, Attention is all you need, Proc of Advances in Neural Information Processing Systems (NIPS 2017), https://arxiv.org/pdf/1706.03762.pdf

Additional information