General information	
Academic subject	Machine Learning for Physics
Degree course	Physics
Academic Year	II
European Credit Transfer and Accumulation System (ECTS)	6
Language	ENGLISH
Academic calendar (starting and ending date)	I semester
Attendance	Recommended

Professor/ Lecturer	
Name and Surname	Alfonso Monaco
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Department and address	Dipartimento Interateneo di Fisica
Virtual headquarters (Microsoft Teams code)	
Tutoring (time and day)	Monday and Friday 10-12 am (on request)

Syllabus	
Learning Objectives	Fundamentals of Machine Learning and data processing
Course prerequisites	The course requires: • a deep knowledge of statistics, linear algebra and probability; • basic programming knowledge.
Contents	• Introduction to Machine Learning: supervised and unsupervised approach; • Introduction to the R framework; • Feature engineering: dimensionality reduction techniques, Principal Component Analysis (PCA), filtering methods, wrapper methods, embedded methods; • Unsupervised ML algorithms: clustering algorithms; • Supervised ML algorithms: classification, regression, overfitting, underfitting, bias, variance. • Performance metrics: Accuracy, Sensitivity, Specificity, Roc curve. • K-Nearest Neighbor (KNN) algorithm; • Bayessian algorithm; • Decision trees: CART, ID3, C4.5; • Ensemble techniques: Bagging and Boosting; • Adaboost algorithm; • Random Forest algorithm; • The Boruta wrapper method; • Artificial neural networks; • Support Vector Machine (SVM); • eXplainable Artificial Intelligence (XAI) techniques; • Hints on deep learning: Convolutional Neural Network (CNN).
Books and bibliography	Christopher M. Bishop: Pattern Recognition and Machine Learning
Additional materials	

Work schedule			
Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
Hours			
120	39	16	65
ECTS			

Teaching strategy	

Expected learning outcomes	
Knowledge and understanding on:	• Basic concepts on Machine Learning • Big data programming skills • Fundamentals of R • Visualization and presentation of data analysis results • Ability to work in a team.
Applying knowledge and understanding on:	• Modelling databases of real systems • Ability to understand the underlying dynamics of complex systems

Soft skills	• **Making informed judgments and choices**
	  ○ Apply the notions learned in multi-disciplinary contexts
	  ○ Apply mathematical concepts to real systems
	• **Communicating knowledge and understanding**
	  ○ Use of rigorous and precise language,
	  ○ Use of logical arguments
	• **Capacities to continue learning**
	  ○ Mathematical theory of Machine Learning
	  ○ Problem-solving strategies
	  ○ Modelling real systems

Assessment and feedback	
Methods of assessment	Oral presentation of a case-study

Evaluation criteria	• **Knowledge and understanding**
	Consistency of answers according to formulated questions
	• **Applying knowledge and understanding**
	  ○ Setting up and carrying out numerical examples
	• **Autonomy of judgment**
	  ○ Consistency with the subject of the program
	  ○ Software debug
	• **Communicating knowledge and understanding**
	  ○ Clarity and precision of presentation
	• **Communication skills**
	  ○ Ability to identify interconnection between the subjects of study
	• **Capacities to continue learning**
	  ○ Cross-discipline applications

Criteria for assessment and attribution of the final mark	Capability to select and apply descriptive and predictive data analytics methods. Skill to discover trends in analytical data stores using the data mining techniques of clustering, association, and decision trees. Adequate comprehension and global knowledge of concepts and arguments at the basis of the machine learning methods described throughout the course.
Additional information	