SISSA 40!

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sissa mathLab

innovating with mathematics

Mathematical Modelling
and Numerical Simulation

INTRODUCTION

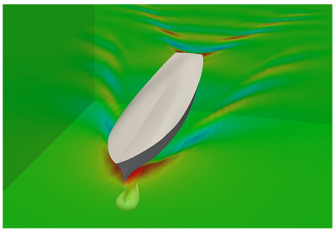
SISSA mathLab established in 2010

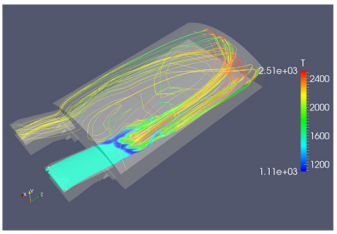
- A laboratory for mathematical modeling and scientific computing devoted to the interactions between mathematics and its applications.
- An interdisciplinary research center powered by the interest in problems coming from the real world, from industrial applications, and from complex systems.
- A team of scientists pursuing frontier research and new trends in computational mechanics and numerical analysis, while expanding the opportunities for a dialogue across academic and disciplinary boundaries.
- Research groups devoted to the development of advanced modeling techniques with focus in Computational Fluid Dynamics (CFD), High Performance Computing (HPC), and Open Source scientific software development, to face and overcome many limitations of the state of the art, and to enable new methodologies for demanding industrial, medical, and applied sciences applications.

INTRODUCTION

Research Topics

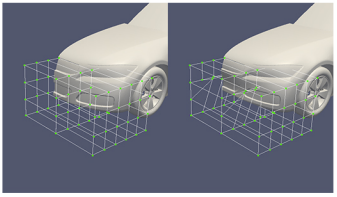
- Computational Mechanics
- Computational Fluid Dynamics (CFD),
- Fluid Structure Interaction (FSI),.
- Structural Mechanics
- Control and optimization,
- Isogeometric Analysis (IGA),
- Uncertainty Quantification (UQ),
- Reduced Order Methods (ROM),
- High Performance Computing (HPC),
- Open Source Software Development.

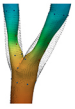


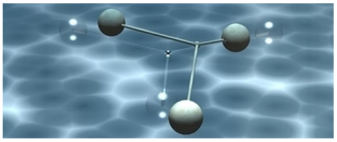


More in detail:

Bifurcations and instabilities in flows and structures at moderate/high Reynolds number; turbulent flows; complex geometrical parametrizations; reduced computational and geometrical framework for nonlinear inverse problems; optimal flow control; shape optimization and uncertainty quantification; advanced developments in reduced order modeling; domain decomposition; multiphysics; fluid-structure interaction; general coupled phenomena involving inviscid, viscous and thermal flows; solids and porous media; non-matching discretizations; finite element method; finite volume method; spectral element method; boundary element method.







FUNDING

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European Research Council

Unione europea
Fondo sociale europeo

MINISTERO DELL' ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

European
Commission
Horizon 2020
European Union funding
for Research & Innovation

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INDUSTRIAL RESEARCH PROJECTS

OpenShip/OpenViewShip:

High-Tech CFD Simulations for Hydrodynamic Performance of the Hull System in OpenSOURCE Environments. Development of a computational ecosystem for the hydrodynamic design of the propeller and hull system. In collaboration with CETENA and eXactLAB.

The project aims to develop a computational ecosystem for industrial environments in which to tackle the hydrodynamic design of the hull-propeller system.

Based on high-performance computing infrastructure integrated with innovative remote viewing technologies, the ecosystem will allow instant viewing of the pre- and post-processing of large amounts of data generated by high-resolution CFD simulations. The ecosystem developed will solve the problems identified in the project OpenSHIP and its adoption by the industry will be promoted.

OpenViewSHIP

OpenSHIP

REGIONE AUTONOMA FRIULI VENEZIA GIULIA

FSC Fondo per lo Sviluppo e la Coesione

Partners:

CETENA S.p.A.

eXact

mare Technology Cluster FVG

UNIVERSITÀ DEGLI STUDI DI TRIESTE

FRIULI INNOVAZIONE Centro di Ricerca e di Trasferimento Tecnologico

Spring Firm S.r.l.®

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INDUSTRIAL RESEARCH PROJECTS

UBE–Underwater Blue Efficiency

Digital simulation of exhaust emission particles, from the engine, to detachment from the hull, geometries and virtual hydro-aerodynamic appendices, optimal geometries for the exhaust device with the purposes of improving hydrodynamic and environmental emissions efficiency. Innovative configuration of the exhaust manifold, high-fidelity and simplified methods for the prediction of its performance.In collaboration with MonteCarlo Yachts.

The project investigates digital simulation methods for the state of exhaust emission particles, from the engine to detachment from the hull, and then tries different geometries and virtual hydro-aerodynamic appendices and, finally, define the optimal geometries for the exhaust manifold for the purposes of hydrodynamic and environmental emissions efficiency.

The expected results are:

- an innovative configuration of the exhaust manifold.
- high-fidelity and simplified methods for the prediction of its performance.

Underwater Blue Efficiency

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Partners:

MONTECARLO YACHTS

MICAD MARINE INDUSTRY CONSULTING AND DESIGN

OPTIMAD

EIDON Lab

CERGOL ENGINEERING CONSULTANCY MARINE · OFFSHORE · YACHT INDUSTRY

mare Technology Cluster FVG

DLM INSULATIONS • SOUNDPROOFING

UNIVERSITÀ DEGLI STUDI DI UDINE

UPCOMING: UBE2 2019-2021

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INDUSTRIAL RESEARCH PROJECTS

SOPHYA –Seakeeping Of Planing Hull YAchts

A research and development project in Maritime Technologies, co-funded by the European Regional Development Fund. General purpose is the study of the correlation between sea-going performance of planed pleasure craft and sea status, with the aim of improving the energy performance of the boat and of the comfort on board. Predicting the parameters of comfort, safety and energy performance in correlation with the waves. Target is to improve the performance of floating hulls in the sea and experiment with new predictive techniques. In collaboration with MonteCarlo Yachts.

SOPHYA is focused on Maritime Technologies, with the aim to improve the energy performance of the boat and of the comfort on board. New prediction technologies, simulation and modelling will be applied to ameliorate seakindliness, safety and energy performance. The sea-going performance of motor-powered pleasure craft is related to the state of the sea. But the correlation is not always easily predictable with the traditional methods.

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SOPHYA

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POR FESR 2014 2020 Friuli Venezia Giulia

Partners:

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INDUSTRIAL RESEARCH PROJECTS

PRELICA

Advanced Methods for Hydro-Acoustic Design of Naval Propulsion.

In the naval field it is of particular interest to find solutions for the reduction of hydro-acoustic emissions due to the operation of propellers, in order to improve both onboard comfort and environmental impact during navigation. The subject of fluid dynamics has been extensively investigated, but above all in the aeronautical field. The methodologies concerning the reconstruction of the acoustic field generated in the submarine environment are still under development and validation.

The PRELICA project aims at obtaining accurate predictions of the hydro-acoustic emissions of the propulsion that are able to predict irradiated noise at all frequencies, by combining potential methods, RANS and LES, using advanced techniques of numerical modeling and scientific calculus and modern optimization algorithms. In collaboration with CETENA.

prelica

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Partners:

IEFLUIDS

CETENA S.p.A.

engys

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INDUSTRIAL RESEARCH PROJECTS

Danieli

Danieli is one of the largest suppliers of plants and processes for the metal industry. Danieli develops technologies and it can supply equipment and complete plants (turnkey projects). An international multicultural team that covers the full spectrum of technology from iron ore to the different finished products. It introduced to the market the highest number of innovations recent years, investing an average of 140 M Euro/Year in the last eight years. Its extensive, in-house manufacturing capability ensures equipment of the highest quality and reliability, thanks to continuous process control, as well as ensuring multicultural intellectual growth, taking advantage of different cultures and motivations.

Software algorithm models, computerized quality and production control systems, adopting the most advanced information technologies like fuzzy logic, neural systems, modeling, and simulation are developed in-house and this results in a Danieli process know-how transfer to final users.

The project concerns the numerical investigation of very complex multiphysics scenarios characterized by fluid-structure interaction, free-surface turbulent flows and thermo-chemical reactions. Numerical simulations will be performed by developing open-source libraries.

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DANIELI

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POR FESR 2014 2020 Friuli Venezia Giulia

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INDUSTRIAL RESEARCH PROJECTS

Bormioli Pharma

Study of CFD Models for the Management and Design of Glass Fuser Basins - HeAD FSE

The project aims at developing a methodology for the simulation of the glass flow within the melting basin. Such simulations would consistently improve the comprehension of the influence that each functional parameters of the furnace have on the quality of the produced glass. Such a comprehension could then be used to optimize the furnace operational conditions, so as to maximize glass quality. The methodology studied will be based on a suitable physical and mathematical model of the phenomenon under study, which will account for all its most relevant aspects.

Bormioli PHARMA

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FSE FRIULI VENEZIA GIULIA POR 2014 2020

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INDUSTRIAL RESEARCH PROJECTS

ELECTROLUX PROFESSIONAL

Artificial Intelligence Solutions for Performance Enhancement of Professional Food Service Appliances

Collaboration with Electrolux Professional R&D, a global leader in the production and distribution of professional food service and laundry solutions. The research will focus on mathematical modeling, numerical methods and scientific computing as data analysis tools for the development of the next generation Company's products.

Electrolux

The Research Hub™
By ELECTROLUX PROFESSIONAL

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INDUSTRIAL RESEARCH PROJECTS

FINCANTIERI - CANTIERI NAVALI ITALIANI

Parametric structural design of cruise ships with the application of reduced order methods for computational efficiency

Collaboration with FINCANTIERI SpA, a global leader in cruise ship design and construction and one of the largest shipbuilders in the world. The research focus on improving the tools calculating the optimal dimensions of the internal parts of cruise ships manufactured by the company.

Also collaborations in the framework of FSE-HeaD project(European Social Fund, Higher Education and development): Advanced shape optimization and parametrization of hulls for cruise ships.

FINCANTIERI

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FSE FRIULI VENEZIA GIULIA POR 2014 2020

Unione europea
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REPUBBLICA ITALIANA

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SCIENTIFIC RESEARCH PROJECTS

INDAM–GNCS

Scientific Computing National Group in the framework of National Institute for Advanced Mathematics, 4 yearly projects (2015-2018) on Reduced order methods and applications with Politecnico di Milano, Politecnico di Torino, Universities of Pavia, Brescia, and Trento.

INdAM

GNCS

Gruppo Nazionale per il Calcolo Scientifico

EU-MORNET

European Network for Model Reduction

cost

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SCIENTIFIC RESEARCH PROJECTS

Applications in aeronautical, mechanical, naval, off-shore, wind, sport, bio-medical engineering such as cardiovascular surgery, combining high performance computing in dedicated super-computing centers and advanced reduced order modeling, to guarantee real time computing and visualization. Open source software libraries for real time highly advanced computational applications.

TRIM–INSEAN

This project is in strict partnership with CNR-INSEAN, the Italian marine experimental basin, located in Rome in the framework of the technical cluster Trasporti 2020.

It deals with the development of advanced numerical methods for the simulation, optimization and control of complex systems related with CFD.

The range of methodologies under development goes from iso-geometrical techniques to reduced order methods, as well as parameter space studies for complex problems.

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TRIM

Marine Technology Research Institute
INSEAN

SCIENTIFIC RESEARCH PROJECTS

ERC AROMA–CFD Consolidator Grant

Advanced Reduced Order Methods with Applications in Computational Fluid Dynamics, advanced methodological developments in numerical analysis, mathematical modeling and extensive exploitation of computational science and engineering (PI Prof. G. Rozza).

The framework developed within AROMA-CFD provides attractive capabilities for several industrial and medical applications (e.g. aeronautical, mechanical, naval, off-shore, wind, sport, biomedical engineering and cardiovascular surgery as well), combining high performance computing and advanced reduced order modelling to guarantee real time computing and visualization. A new open source software library for AROMA-CFD is created: ITHACA, In real Time Highly Advanced Computational Applications, enhancing current RBniCS educational and training capabilities.

European Research Council

Established by the European Commission

sissa AROMA-CFD reduced order modelling

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SCIENTIFIC RESEARCH PROJECTS

ERC AdG 340685 MicroMotility

The research aim is to gain insight into the mechanics of biological motility (in particular, swimming and crawling of microscopic organisms), to distill the key principles that underlie successful locomotion strategies in Nature, and to exploit them for the conceptual design of bio-mimetic, self-propelled micro-devices (PI Prof. Antonio De Simone).

A combination of theoretical, numerical, and experimental tools are exploited to approach the problem of biological and bio-inspired motility from a multidisciplinary perspective.

European Research Council

Established by the European Commission

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SCIENTIFIC RESEARCH PROJECTS

PRIN–Projects of Relevant National Interest

Mathematical and Numerical Modeling of the cardiovascular system, and their clinical applications

The project deals with the mathematical and numerical modeling of the cardiovascular system and their applications in medicine and bioengineering. The activity focuses on the development of reduced models by using reduced basis methods, POD and shape parametrization techniques for geometric complexity reduction, in order to tackle optimal flow control and shape optimization problems, and related software focusing on a reduced basis software library for the solution of parametrized optimization and control problems in computational fluid dynamics.

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SCIENTIFIC RESEARCH PROJECTS

MIUR–FARE

The FARE-X-AROMA-CFD project deals with advanced numerical analysis for parametric partial differential equations (PDEs) to improve scientific computing performances in more complex computational mechanics problems (PI Prof. G. Rozza).

The aim of the FARE-X-AROMA-CFD project is to guarantee two further goals for ERC funded AROMA CFD project and to consolidate a strong critical mass in the development of numerical methods for computational reduction in fluid-dynamics and application. The first goal aims at the investigation of reduction strategies for the parameter space in order to be able to deal with problems with only a reasonable number of important parameters. The second goal aims at developing reduction strategies for the computational reduction of parametric aero-fluid dynamics compressible flows.

FARE
RICERCA IN ITALIA
FRAMEWORK PER L'ATTRAZIONE E IL RAFFORZAMENTO DELLE ECCELLENZE PER LA RICERCA IN ITALIA

FARE X aroma-cfd

MINISTERO DELL' ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

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SCIENTIFIC RESEARCH PROJECTS

ROM2S Reduced Order Methods

MIT and SISSA: MISTI Italy Seed Funds

The MIT-FVG project is, first of all, a big chance to create an important link between two of the major excellence research institute: SISSA and MIT. In SISSA mathLab, Prof. Gianluigi Rozza's group is the one focusing on ROM methodologies in CFD and structural problems. The opportunity of a cooperation with Prof. Anthony T. Patera's group (http://augustine.mit.edu/) and MIT Department of Mechanical Engineering is crucial from the scientific point of view. This collaboration is fundamental thanks to the bridge between the experience of an avant-garde scientific group, that has laid the foundations of the above - mentioned techniques, and a well coordinated young group with a special focus on industrial applications. In practice, it could be very promising and strategic to combine the structural nonlinear analysis of a plate governed by the Von Kàrmàn equations, carried out in SISSA, with the vibroacoustic problems in the RB context investigated at MIT.

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MIT SISSA FVG
mathLab
Reduced Order Methods

REGIONE AUTONOMA FRIULI VENEZIA GIULIA

MISTI

SCIENTIFIC RESEARCH PROJECTS

EID - ROMSOC

Reduced Order Modelling, Simulation and Optimization of Coupled systems

ROMSOC is a European Industrial Doctorate (EID) project in the programme Innovative Training Networks (ITN) and part of Marie Sklodowska Curie Actions within the Horizon 2020 programme (PI Prof. G. Rozza).

The research is focused on three major topics: coupling methods, model reduction methods, and optimization methods, for industrial applications in well selected areas, such as optical and electronic systems, economic processes, and materials. The ROMSOC EID Network offers a unique research environment that provides an excellent structured training programme in modelling, simulation and optimization of whole products and processes.

EID ROMSOC partners are: ITMATI (Spain), University of Santiago de Compostela (Spain), ArcelorMittal AMII (Spain), and Danieli Research Center (Italy).

European Commission
Horizon 2020
European Union funding
for Research & Innovation

ROMSOC

Partners:

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

ITMATI

DANIELI

ArcelorMittal

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www.romsoc.eu

OPEN-SOURCE SOFTWARE

SISSA mathLab contributes to the development of software in computational science and engineering.

deal.II

A C++ software library supporting the creation of finite element codes and an open community of users and developers.

URL: github.com/dealii

ITHACA

In real Time Highly Advanced Computational Applications Reduced Order Modeling implementation.

mathlab.sissa.it/cse-software

OPEN-SOURCE SOFTWARE

ITHACA–FV

In real Time Highly Advanced Computational Applications for Finite Volumes is C++ library based on the finite volume solver OpenFOAM. It consists of the implementation of several reduced order modeling techniques for parametrized problems.

URL: github.com/mathLab/ITHACA-FV

ITHACA–SEM

In real Time Highly Advanced Computational Applications with Spectral Element Methods is a python implementation of several reduced order modelling techniques. It is designed to work with Nektar++ 4.4.0 simulations.

URL: github.com/mathLab/ITHACA-SEM

mathlab.sissa.it/cse-software

OPEN-SOURCE SOFTWARE

WaveBEM

INonlinear Unsteady Potential Flow Solver for Ship-Wave Interaction Problems is an open source software for ship hydrodynamics simulations currently under development at SISSA mathLab.

URL: github.com/mathLab/WaveBEM

RBniCS

IReduced order modeling implementation in FEniCS of several reduced order algorithms including certified reduced basis methods and Proper Orthogonal Decomposition-Galerkin methods for parameterized problems. It is ideally suited for an introductory course on reduced basis methods and reduced order modeling, thanks to an object-oriented approach and an intuitive and versatile python interface.

URL: github.com/mathLab/RBniCS

mathlab.sissa.it/cse-software

OPEN-SOURCE SOFTWARE

multiphenics

IPython library that aims at providing tools in FEniCS for an easy prototyping of multi-physics problems on conforming meshes. In particular, it facilitates the definition of subdomain/boundary restricted variables and enables the definition of the problem by means of a block structure.

URL: github.com/mathLab/multiphenics

PyGeM

Python package using Free Form Deformation, Radial Basis Functions and Inverse Distance Weighting to parameterize and morph complex geometries. It is ideally suited for actual industrial problems, since it allows to handle: Computer Aided Design files (in .iges, .step, and .stl formats) - Mesh files (in .unv and OpenFOAM formats) - Output files (in .vtk format) - LS-Dyna Keyword files (.k format).

URL: github.com/mathLab/PyGeM

mathlab.sissa.it/cse-software

OPEN-SOURCE SOFTWARE

PyDMD

Python Dynamic Mode Decomposition, a software related to recent mathematical innovation that allows us to solve or approximate dynamical systems in terms of coherent structures that grow, decay, and / or oscillate in time.

URL: github.com/mathLab/PyDMD

BladeX

(Python Blade Deformation) is a Python package for geometrical parametrization and bottom-up construction of propeller blades. It allows to generate and deform a blade based on the radial distribution of its parameters. The package is ideally suited for parametric simulations on large number of blade deformations. It provides an automated procedure for the CAD generation, hence reducing the time and effort required for modelling.

URL: github.com/mathLab/BladeX

mathlab.sissa.it/cse-software

OPEN-SOURCE SOFTWARE

π-BEM

A C++ parallel BEM library, directly interfaced with CAD files, providing Fast Multipole acceleration, high order capabilities, local refinement, and hybrid MPI-multithreaded parallelization.

URL: github.com/mathLab/pi-BEM

π-DoMUS

A C++ parallel multi-physics solver, based on the deal.II library, exploiting open source HPC libraries for the fast prototyping of complex multi-physics problems.

URL: github.com/mathLab/pi-DoMUS

Pydata

Simple file handler written in Python, to allow reading and writing files in several formats such as .iges, .stl, .vtk, .vtp, .lsdyna, and more.

URL: github.com/mathLab/pydata

EZyRB

Python library for the Model Order Reduction based on barycentric triangulation for the selection of the parameter points and on Proper Orthogonal Decomposition for the selection of the modes. It is ideally suited for actual industrial problems, since its structure can interact with several simulation software simply providing the output file of the simulations.

URL: github.com/mathLab/EZyRB

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COLLABORATIONS

MAIN INDUSTRIAL AND INSTITUTIONAL PARTNERS:

- CETENA S.p.A.
- Regione Autonoma Friuli Venezia Giulia
- Fondo per lo Sviluppo e la Coesione (FSC)
- Ministero dell'Istruzione dell'Università e della Ricerca (MIUR)
- eXact Lab
- MARITIME TECHNOLOGY CLUSTER FVG s.c.a.r.l. (mare FVG)
- Friuli Innovazione Centro Di Ricerca E Di Trasferimento Tecnologico
- Spring Firm S.r.l.
- Monte Carlo Yachts S.p.A.
- MICAD: Marine Industry Consulting and Design
- OPTIMAD Engineering S.r.l.
- Eidon Laboratori Di Ricerca S.c.a.r.l.
- CERGOL Engineering Consultancy S.r.l.
- DLM Isolazioni e Insonorizzazioni S.r.l.
- IEFLUIDS S.r.l.
- ENGYS S.r.l.
- Danieli S.p.A.
- FINCANTIERI S.p.A.
- Bormioli Pharma S.p.A.
- Electrolux Professional S.p.A.
- Istituto Nazionale per Studi ed Esperienze di Architettura Navale Vasca Navale (I.N.S.E.A.N)
- GNCS: Gruppo Nazionale per il Calcolo Scientifico
- INDAM: Istituto Nazionale di Alta Matematica
- Instituto Tecnológico de Matemática Industrial (ITMATI)
- ArcelorMittal S.A.
- SMACT Competence Center - Impresa 4.0

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COLLABORATIONS

MAIN NATIONAL AND INTERNATIONAL SCIENTIFIC COLLABORATIONS

- Politecnico di Milano,
- Politecnico di Torino,
- École polytechnique fédérale de Lausanne (EPFL),
- Eidgenössische Technische Hochschule Zürich (ETHZ),
- Massachusetts Institute of Technology (MIT),
- Université Pierre-et-Marie-Curie (Paris VI),
- Virginia Tech,
- University of Houston,
- University of Toronto,
- Universidade de Santiago de Compostela (USC)
- Universidad de Sevilla,
- Università degli Studi di Trento,
- Università degli studi di Pavia,
- SAMBA Lab
- AREA Science Park
- Università degli studi di Trieste,
- Università degli Studi di Udine,
- Sapienza Università di Roma,
- Universität Ulm,
- Universität Stuttgart,
- Universität Münster,
- Universität Hamburg (UHH),
- Max Planck Institute Magdeburg,
- Rheinisch - Westfälische Technische Hochschule Aachen (RWTH),
- Technischen Universität Berlin (TU Berlin)
- Technische Universiteit Eindhoven (TU Eindhoven),
- École Polythechnique de Paris,
- Universitat Polythecnica de Catalunia (UPC),
- Penn State University,
- Duke University,
- Florida State University,
- École des ponts ParisTech (ENPC),
- Imperial College London,
- Ghent University,
- Université de Bordeaux,
- Sandia National Laboratories,
- Ospedale Luigi Sacco, Milano,
- Sunnybrook Health Sciences Centre, Toronto.

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EDUCATIONAL INITIATIVES INVOLVING MATHLAB

MHPC

The Master in High Performance Computing is an innovative master degree program that combines lectures with hands-on sessions and applied projects to train HPC specialists for both academia and industry, in collaboration with ICTP.

AMMA

The PhD program in Mathematical Analysis, Modeling, and Applications enables PhDs to work as high level researchers in mathematical and numerical analysis, as well as continuum mechanics.

MATH

MathLab collaborates with the University of Trieste in offering high level training courses for the Master's degree in Mathematics.

DSSC

MathLab contributed to the creation of the new Master's degree in Data Science and Scientific Computing, in collaboration with the University of Trieste, and the University of Udine.

MCS

MathLab covers some of the classes of the Master in Science Communication "Franco Prattico", a training course to offer the best professional opportunities in an ever-changing context.