Booklet of Abstracts

DIITET Conference – Strategic Area: “Applied Mathematics”

Conference Programme - overview

9:00 - 9:15 **Saluti di Benvenuto**
Ing Emilio Fortunato Campana, Direttore DIITET

9:15 - 9:30 **Introduzione alla giornata: Matematica Applicata nel DIITET**
Roberto Natalini, Giovanni Rinaldi, Michela Spagnuolo

9:30-10:45 **Scientific Computing**

10:45 - 11:15 Coffee Break

11:15 - 12:15 **Invited Talk by Prof. Alberto Sangiovanni Vincentelli**

12:15-13:15 **Optimization**

13:15 - 14:15 *Lunch Break & Poster session - Buffet in Aula Laguna*

14:15 - 14:30 **Matematica e Imprese**
L’esperienza dello SPORTELLO MATEMATICO

14:30 - 15:45 **Mathematical Modelling**

15:45 - 16:15 Coffee Break

16:15 - 17:30 **Data Science**

Booklet of Abstracts

DIITET Conference – Strategic Area: “Applied Mathematics”

Abstracts

Invited Talk – Hard Sciences: Separating Hype from Fundamentals
Prof. Alberto Sangiovanni Vincentelli

Abstract: Much (too much) has been talked about Digitalization, Big Data, Artificial Intelligence, Deep Learning, Quantum Computing, and other potentially disruptive technologies. Much (too much) has been promised in terms of advances in all kind of applications. Little (too little) has been discussed in terms of limitations and difficulties to overcome. Hard sciences, mainly mathematics and physics, are the main pillars to base our judgement on the variety of proposals that are constantly hyped in the popular and not so popular press. I will review some of the basic principles we need to teach and to do research on for bringing a balanced view to industry, academia and governments.

Booklet of Abstracts

DIITET Conference – Strategic Area: “Applied Mathematics”

Session on Scientific Computing

New CHallenges for (adaptive) PDE solvers: the interplay of ANalysis and GEometry - Micol Pennacchio (IMATI, Pavia and Genova)

Computational techniques for uncertainty quantification of partial differential equations with random parameters - Lorenzo Tamellini (IMATI, Pavia)

Scalable preconditioners for sparse and large linear systems - Pasqua D’Ambra - (IAC, Napoli)

On the role of numerical viscosity in the approximation of systems of conservation laws - Laura Spinolo (IMATI, Pavia)

Innovative methodologies in applied mathematics: the developments of Particle Methods for fluid mechanics at CNR, Andrea Colagrossi (INM, Roma)

***New CHallenges for (adaptive) PDE solvers: the interplay of ANalysis and GEometry,* Micol Pennacchio (IMATI, Pavia e Genova)**

Abstract: We present the ERC research project CHANGE which aims at developing innovative mathematical tools for numerically solving PDEs and for geometric modeling and processing. The final goal of the project is the definition of a common framework where geometrical entities and simulation are coherently integrated and where adaptive methods can be used to guarantee optimal use of computer resources, from the geometric description to the simulation. Two classes of methods for the discretisation of PDEs are mainly considered: isogeometric methods and variational methods on polyhedral partitions. They are both extensions of standard finite elements enjoying exciting features, but both lack of an ad-hoc geometric modelling counterpart.
Our research (and the team involved in the project) combine competencies in geometry processing, numerical analysis, high performance computing, and computational mechanics.

***Computational techniques for uncertainty quantification of partial differential equations with random parameters,* Lorenzo Tamellini (IMATI, Pavia)**

Abstract: When building a mathematical model (typically, and ordinary or partial differential equation) to describe the behavior of a physical system, one often has to face the fact that some of the parameters of the model (coefficients, forcing terms, boundary conditions, shape of the physical domain, etc.) are not known exactly but rather affected by a certain amount of uncertainty, and hence naturally described in terms of random variables/random fields. Possible sources of uncertainty are e.g. measurement errors, lack of data, or inherent randomness of the quantity ad hand (wind loads, rainfalls). “Uncertainty quantification” is the branch of numerical analysis / scientific computing that deals with this kind of models. A typical goal in this framework is to compute statistical quantities (mean, variance, probability density function, quantiles) for quantities of interest related to the solution of the equation at hand. One of the main challenges in uncertainty quantification is represented by the fact that in many applications tens/hundreds of random variables may be necessary to obtain an accurate

representation of the solution, which can be moreover evaluated only by running expensive computer simulations. In this talk, we discuss some methodologies able to cope with such complexity, and in particular, the so-called “Multi-Index Stochastic Collocation”.

***Scalable preconditioners for large and sparse linear systems,* Pasqua D’Ambra - (IAC, Napoli)**

Abstract. Large and sparse linear systems are ubiquitous in nowadays applications: from numerical solution of differential models for complex systems to analysis of discrete models in artificial intelligence. The notion of "large" is qualitative and there is a clear tendency to increase it. Currently, it is not unusual the need to solve systems with millions or even billions of unknowns. The method of choice to efficiently solve the above systems on modern high-performance computers are the iterative Krylov methods, whose convergence and scalability properties are strictly related to the choice of a suitable preconditioning technique.
In this talk we will describe some activities aimed at the design, the implementation and the analysis of multigrid preconditioners for fluid dynamic applications arising in the context of interdisciplinary projects in energy and environmental fields in which the research group is involved, also with coordination roles.

***On the role of numerical viscosity in the approximation of systems of conservation laws,* Laura Spinolo (IMATI, Pavia)**

Abstract: Most numerical schemes used to approximate nonlinear systems of conservation laws contain the so-called "numerical viscosity". In some cases, the presence of the numerical viscosity jeopardizes the reliability of the numerical scheme. This talk aims at discussing some examples coming from real world applications where the theoretical analysis of the system played a key role in i) identifying the problems caused by the numerical viscosity and ii) designing reliable solutions.

Innovative methodologies in applied mathematics: the developments of Particle Methods for fluid mechanics at CNR, Andrea Colagrossi, (INN, Roma)

Abstract. The presentation is dedicated to 20-years of developments, studies and applications of particle methods in the fluid mechanics field. Two main models are discussed. The former is the Smoothed Particle Hydrodynamic method, where a fluid is modelled as a macroscopic system of discrete particles, which dynamic equations can be derived rigorously through Lagrangian mechanics. In the last decade the SPH was successfully applied in fluid dynamics problems characterized by large deformation of interfaces such as: simulations of violent free-surface flows, multi-phase flows, flows around deformable bodies, etc. Furthermore, the SPH method has also been used profitably by computer graphics studios for special effects of movie sequences and for the improvement of virtual and augmented reality frameworks. The second particle method developed is the Diffused Vortex Hydrodynamics (DVH) methods, which is used to numerically solve Navier-Stokes equations expressed in vorticity. Also this second model presents some peculiarities and advantages with respect to more classical mesh-based solvers which are briefly exposed.

Booklet of Abstracts

DIITET Conference – Strategic Area: “Applied Mathematics”

Session on Optimization

Optimization-based Decision Support Tools to Promote Sustainable Freight Transport in Urban Contexts - Antonino Sgalambro (IAC, Roma)

The Perspective Reformulation in Mixed-Integer Nonlinear Optimization - Claudio Gentile, (IASI, Roma)

Robust Optimization - Sara Mattia (IASI, Roma)

Optimization under uncertainty - Fabrizio Dabbene (IEIIT, Torino)

***Optimization-based Decision Support Tools to Promote Sustainable Freight Transport in Urban Contexts (ProSFeT Project)*, Antonino Sgalambro (IAC Roma)**

The aim of this talk is to present some results obtained so far by the IAC-CNR research unit in the context of the H2020-MSCA-RISE project entitled ProSFeT- Promoting Sustainable Freight Transport in Urban Contexts: Policy and Decision-Making Approaches. Firstly the aims, structure and organization of the project will be briefly recalled, together with the characteristics of the relevant Working Package, which is devoted to design and promote the use of decision support tools for urban freight transport by public authorities in Europe. Afterwards, some preliminary results obtained by the IAC-CNR research unit in this context will be illustrated, with particular emphasis on the design of an integrated Optimization-based Decision Support System for strategical planning of Waste Management services.

The Perspective Reformulation in Mixed-Integer Nonlinear Optimization, Claudio Gentile, (IASI, Roma)

Abstract: Semi-continuous variable is one that can assume values in two disconnected convex sets. The Perspective Reformulation (PR) of a Mixed-Integer Non Linear Program with semi-continuous variables is obtained by replacing each term in the (separable) objective function with its convex envelope. Such a convex envelope is related to a well-known object in Convex Optimization, i.e. the Perspective Function. In some special cases the Perspective Function can be handled by MIP solvers, such as CPLEX or GUROBI, but its special form can be exploited to design more efficient algorithms. We designed different algorithmic schemes for its optimization: the Perspective Cuts (PC) method, the Projected Perspective Reformulation (P2R), the Approximated Projected Perspective Reformulation (AP2R), and further improvements. The Perspective Reformulations arises in many applications and in particular in short-term power energy scheduling, portfolio optimization, network design, facility location, data science, and others. We have also considered extensions for the case of non-separable quadratic functions that arise in portfolio optimization and in nonconvex optimization.

***Robust Optimization* - Sara Mattia (IASI, Roma)**

Abstract: Traditionally, the constraint matrix, the right-hand-sides and the objective coefficients of an optimization problem are supposed to be constant and fully known when the problem is solved. Unfortunately, this is not always the case in the applications. Indeed, it may

happen that those parameters are affected by measurement, implementation or estimation errors, making them uncertain. Moreover, they can change over time. All these cases are classified as Problems with Data Uncertainty and are tackled with different approaches. One of them is Robust Optimization, that has some interesting theoretical and practical properties, as it will be shown in the talk also with the help of some real-world applications

***Optimization under uncertainty,* Fabrizio Dabbene (IEIIT, Torino)**

Abstract: Modern optimization problems are characterized by an imperfect knowledge of the design environment. Hence, coping in an efficient way with uncertainty represents a key issue in this field. In this lecture, we will show how the right combination of uncertainty randomization and convex optimization can lead to design solutions which are reliable without being overly conservative. After a very brief very introduction to the main technical tools of randomized algorithms for optimization, we will provide an overview of different applications areas, ranging from space robotics to smart grid optimization and social network analysis.

Session on Mathematical Modelling

Modelling the Immune Response - Filippo Castiglione (IAC, Roma)

Mathematical Modeling in Systems Biology and Biomedical Application - Pasquale Palumbo (IASI, Rome)

Optimal spatio-temporal control of invasive plants in protected areas – Carmela Marangi (IAC, Bari)

Computational topology methods for reasoning on shape analysis and similarity - Silvia Biasotti (IMATI, Genova)

Persistent homology for data analysis and machine learning: past, present, and future challenges - Daniela Giorgi (ISTI, Pisa)

***Modelling the Immune Response,* Filippo Castiglione (IAC, Roma)**

Abstract: In this talk we will describe the main features of a mathematical/computational model of the immune system also briefly showing the way it has been applied to the study of common pathologies such as infections and cancer. It provides an example of a model fostering interdisciplinary collaboration in the field of mathematical-biology.

***Mathematical Modeling in Systems Biology and Biomedical Application,* Pasquale Palumbo (IASI, Roma)**

Abstract: One of the most challenging fields in Life Science research is to deeply understand how complex cellular functions arise from the interactions of molecules in a biochemical network. Mathematical and computational methods in systems biology are fundamental to study the complex molecular interactions within biological systems and to accelerate discoveries. Within this framework, the knowledge of a mathematical model explaining the functioning of a physical system under investigation would be of paramount importance to apply personalized therapies in biomedical applications. This talk addresses a couple of examples on systems biology and biomedical application in the artificial pancreas.

Booklet of Abstracts

DIITET Conference – Strategic Area: “Applied Mathematics”

***Optimal spatio-temporal control of invasive plants in protected areas*, Carmela Marangi (IAC Bari)**

Abstract: We developed a modelling approach for the optimal spatio-temporal control of invasive species in natural protected areas of high conservation value. The proposed approach, based on diffusion equations, is spatially explicit, and includes a functional response (Holling type II) which models the control rate as a function of the invasive species density. We apply a budget constraint to the control program and search for the optimal effort ort allocation for the minimization of the invasive species density. Both the initial density map and the and cover map used to estimate the habitat suitability to the species diffusion, have been generated by using very high resolution satellite images and validated by means of ground truth data. The approach has been applied to the Alta Murgia National Park, one of the study site of the on-going H2020 project ECOPOTENTIAL: Improving Future Ecosystem Benefits Through Earth Observations' (http://www.ecopotential-project.eu) which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641762. All the ground data regarding Ailanthus altissima (Mill.) Swingle presence and distribution are from the EU LIFE Alta Murgia Project (LIFE12 BIO/IT/000213) titled Eradication of the invasive exotic plant species Ailanthus altissima from the Alta Murgia National Park funded by the LIFE+ financial instrument of the European Commission. The model has been implemented in R, version 3.5.0, i.e. in Open Source and it is available on GitHub (https://github.com/CnrIacBaGit/COINSvlabrepo). The Docker technology has been used for the model porting on the ECOPOTENTIAL VLab (Virtual Laboratory Platform). The VLab, developed by CNR-IIA represent one of the most relevant contributions of the project to GEOSS.

***Computational topology methods for shape analysis and similarity,* Silvia Biasotti (IMATI, Genova)**

Abstract: Geometry and topology offer a range of concepts to support modelling, analysis and interpretation of complex digital data, such as 3D digital models. The talk overviews the last decade of activities of the Computational Topology group at IMATI in differential topology, and especially Morse theory for modelling and analyzing topological spaces (Reeb graphs, critical points and Jacobi sets). The talk will also introduce the definition of metrics for parameter-based shape similarity and for similarities over time-varying 3D data, and recent work on computational algebra (splines, B-splines, extended Hough transforms) to fit templates over (non-planar) surfaces.

***Persistent Homology for data analysis and machine learning: past, present, and future challenges,* Daniela Giorgi (ISTI, Pisa)**

Abstract: Topological Data Analysis (TDA) is a growing field of research which studies topological approaches to make sense of complex data. One of the main concepts in TDA is Persistent Homology, a mathematical tool that captures topological information about data at multiple scales. Persistent Homology is growing more and more important in the international scientific community: it benefits from the continuous interplay between theoretical contributions and input from real-world applications. In the first part of my talk, I will briefly

recollect the contribution CNR has brought to the research in Persistent Homology in the last years. I will also describe applications in different domains, from 3D data analysis to personal health monitoring. In the second part, I will introduce recent results about a general mathematical model for group equivariance in the machine learning context. The model builds on a synergy between Persistent Homology and the theory of group actions. I will define group-equivariant non-expansive operators (GENEOs), which are maps between function spaces associated with groups of transformations. I will show how the study of the topological and metric properties of the space of GENEOs can set the basis for general strategies to initialise and compose operators for (deep) learning.

Session on *Data Science*

Industrial statistics: between tradition and innovation - Antonio Pievatolo (IMATI, Milano)

SAR Meteorology: is it a new perspective in the atmospheric remote sensing with space geodesy and high precision NUmerical Weather Prediction (NWP) models? - Giovanni Nico (IAC, Bari)

Advancing the frontiers of earthquake science through statistical seismology - Elisa Varini (IMATI, Milano)

Traffic Data Classification for Police Activity - Stefano Guarino (IAC Roma)

Network-Based Data Analysis - Paola Paci - (IASI, Roma)

***Industrial statistics: between tradition and innovation,* Antonio Pievatolo (IMATI, Milano)**

Abstract: Statistics gained recognition in industry in the years following the second World War, and areas such as quality control, design of experiments and reliability and maintenance are regarded as fields where it plays a prominent role. However it is still possible to find situations in which statistical methods are not used at their best, so, part of the statistician’s job continues to be that of helping non statistical colleagues to use statistics effectively. At the same time, new challenges continue to emerge, brought by the massive amount of data both measured on the system of interest and obtained from contextual sources of information. We will show three industrial applications: one in the optimisation of an electrospinning process, one in the recovery of materials from printed circuit boards and one in the forecasting of failures. In all these applications the role of classical statistical modelling tools is key, but also the integration of these tools within a broader perspective can help leverage their full potential.

SAR meteorology: is it a new perspective in the atmospheric remote sensing with space geodesy and high precision Numerical Weather Prediction (NWP) models?, Giovanni Nico - (IAC, Bari)

Abstract: The basics of Synthetic Aperture Radar (SAR) meteorology are presented. This is new methodology for the estimation of Precipitable Water Vapor (PWV) in atmosphere based on the processing of time series of interferometric SAR (InSAR) images and the assimilation

in high resolution Numerical Weather Prediction (NWP) models. The enhancement of NWP models forecasts is studied in terms of their thermodynamic and hydrological properties. It is shown how the predictability time interval of NWP models mainly depends on both the wind speed and direction in the steering level of troposphere and spatial coverage of spaceborne SAR images. InSAR measurements of PWV are assimilated in the Weather Research and Forecast (WRF) model using a 3Dvar scheme. A statistical analysis is carried out to compare the output of WRF model, before and after the assimilation. Two case studies are described based on the use of Sentinel-1 data. The perspective use of SAR meteorology for the study of extreme weather events is also discussed

Advancing the frontiers of earthquake science through statistical seismology, Elisa Varini (IMATI, Milano)

Abstract: Statistical Seismology is a phrase first coined in 1956 by Keiiti Aki, one of the most eminent seismologists of the twentieth century. This discipline belongs to the area of Environmental Statistics and deals with applying rigorous statistical methods to earthquake science. Progress in seismological knowledge and availability of large data sets have placed demands on statisticians for their contribution to modelling and analyses. Our research focuses on stochastic modelling of long-term seismicity for probabilistic seismic hazard assessments, evaluation and testing of earthquake forecast, Bayesian methodologies to assess uncertainty.

***Traffic Data Classification for Police Activity,* Stefano Guarino (IAC Roma)**

Abstract: Traffic data, automatically collected en masse every day, can be mined to discover information or patterns to support police investigations. In this talk we describe a new model for unsupervised classification of routes and vehicles specifically devised to guarantee robustness to noise and easy interpretability. Our classifier is capable of inferring trending behaviors for road-users, which, leveraging on domain expertise, can be used to detect anomalies possibly connected to criminal activity. We present the results of experiments involving three years worth data, discuss the potentials of our tool, and identify directions for future work.

***Network Based Data Analysis,* Paola Paci, (IASI, Roma)**

Abstract: In the last two decades, the biological sciences have undergone a radical transformation thanks to the development of new technologies that have produced a real explosion in the amount of data available. This huge amount of data represents an important resource for the scientific community, but only the quantity is not enough. It is essentially making use of computational strategies that allow to manage, analyze and integrate these biological "Big Data". A noteworthy example is SWIM (SWitchMiner), open-source software under the GNU GPL license, equipped with a wizard-like graphical interface, which implements a complex network theory approach to analyze large-scale biological data. The exciting results obtained so far by applying SWIM to oncology, suggest SWIM as a fundamental tool towards "precision medicine", able to identify new molecular targets of drugs. This could lead the development of new therapeutic options that can ensure the best possible outcome in terms of treatment of serious diseases with high social impact.