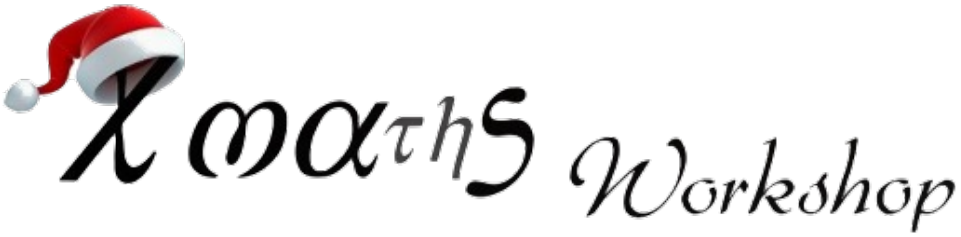

XMaths Workshop 2023

Università degli Studi di Bari Aldo Moro
Dipartimento di Matematica

Book of abstracts

Bari, December 20–21, 2023

- **Sebastiano Argenti**, Università degli Studi della Basilicata

  Title: *The combinatorial theory of polynomial identities*

  Abstract: The theory of polynomial identities is an active area of research that encompasses the study of commutative algebras, finite dimensional algebras and many more. The use of combinatorial techniques in this context can be traced back to Regev who introduced the notion of codimension sequence and showed how understanding its quantitative properties can lead to qualitative results about algebras with polynomial identities (A. Regev, Existence of identities in $A \otimes B$, Israel J. Math 11 (1972), no. 2, 131–152). A major breakthrough was the development of Kemer's theory whose main results are the representability theorem and the positive solution to the Specht problem (A. Kemer, Ideals of identities of associative algebras, American Mathematical Society, jun 1991). In recent times the combinatorial theory culminated in the positive solution of the Amitsur's conjecture which provides one the most useful tools in the theory of polynomial identities: the exponent of the codimension sequence (A. Giambruno, M. Zaicev, Exponential codimension growth of PI algebras: An exact estimate, Adv Math 142 (1999), no. 2, 221–243). In this talk we will give an overview of the aforementioned historical development of the theory and its applications. Then we will discuss the modern approach which focuses on the extension of the classical theory to algebras with additional structures.

- **Sara Bagossi**, Università degli Studi di Torino

  Title: *Highlights from research on learning calculus concepts with augmented reality*

  Abstract: Emerging technologies are shaping the world around us, and their affordances for mathematics education are also discussed and explored. In this talk, I will focus on the affordances of augmented reality and then share some insights related to the learning of calculus concepts such as function, derivative, and modelling of dynamic situations. Augmented reality indeed offers the possibility to create a learning environment in which the interaction between the student's body and virtual mathematical objects may help "feel" the concept of slope. Visualizing and interacting with 3D mathematical surfaces may enable one to explore and master properties of mathematical objects. Again, overlapping real-time mathematical representations of a real phenomenon with the phenomenon itself can support students' conceptualization of dynamic situations. Moreover, in suitable collaborative learning settings, students can come up with meaningful questions leading their learning process. Such findings result from two international projects I am involved in: AR4MATH – Augmented Reality for Learning Math and TransEET – Transforming Education with Emerging Technology.

- **Chiara Cicolani**, Università degli Studi dell'Aquila

  Title: *Exponential synchronization of Kuramoto oscillators with time-delayed interactions*

  Abstract: We study the asymptotic synchronization for the Kuramoto oscillators model with time-delayed interactions. The Kuramoto model appears in many biological/physiological applications. Then, often, time delay effects have to be considered. We provide an explicit lower bound on the coupling strength and an upper bound on the time delay in terms of initial configurations ensuring exponential synchronization. Our approach, which relies on continuity arguments and careful estimates of the trajectories, allows us to significantly relax previous thresholds on the time delay size. Moreover, we introduce a graph topology on the structure of the model in order to consider a non-universal interaction among the states. This talk is based on joint work with Young-Pil Choi and Cristina Pignotti.

- **Marica De Lucia**, Istituto sull'Inquinamento Atmosferico - CNR

  Title: *APEMAIA: prediction of PM10 concentrations satellite-based machine learning models*

  Abstract: Increasingly frequent epidemiological studies show how the negative health effects of health of PM2.5 and PM10 have an impact that goes beyond respiratory and cardiovascular diseases and also affect brain development and metabolic diseases. There is therefore a growing need for accurate and high spatial resolution data to be able to implement preventive and safety actions for the population. Hence the 'APEMAIA' project (in collaboration with NASA JPL) aims to obtain PM10 concentration maps of the study areas using satellite data. The information provided by the measurements of the stations located in the area are mostly insufficient for monitoring the entire area, in contrast with satellite data that have a greater spatial capillarity. The first study area is the metropolitan area of Bari, on which meteorological, vegetation and demographic data were collected. These data are exploited in the application of various Machine Learning techniques, such as example the Random Forest, to predict and obtain the value of particulate matter in air PM10.

- **Nicola De Nitti**, École Polytechnique Fédérale de Lausanne

  Title: *Exponential convergence to steady-states for trajectories of a damped dynamical system modelling adhesive strings*

  Abstract: We study the global well-posedness and asymptotic behavior for a semilinear damped wave equation with Neumann boundary conditions, modelling a one-dimensional

linearly elastic body interacting with a rigid substrate through an adhesive material. The key feature of the problem is that the interplay between the nonlinear force and the boundary conditions allows for a continuous set of equilibrium points. We prove an exponential convergence rate for the solution towards a (uniquely determined) equilibrium point. This talk is based on joint work with Giuseppe Maria Coclite, Francesco Maddalena, Gianluca Orlando and Enrique Zuazua.

- **Dario Di Pinto**, Università degli Studi di Bari Aldo Moro

  Title: *Geometric obstructions to the existence of anti-quasi-Sasakian structures*

  Abstract: Almost contact metric manifolds are odd dimensional Riemannian manifolds endowed with a special geometric structure represented by a hyperplane distribution $\mathcal{D}$, an almost Hermitian structure J on it, and an orthogonal vector field ξ. Among such manifolds several remarkable classes can be distinguished, such as contact metric, Sasakian and cokähler manifolds.

  Recently, in a joint work with Giulia Dileo, the new class of anti-quasi-Sasakian manifolds has been introduced. Their characteristic feature is to be non-normal almost contact metric manifolds, locally fibering along the Reeb vector field ξ onto Kähler manifolds endowed with a closed 2-form of type $(2, 0)$. In the present talk, after a brief overview of almost contact metric geometry, I will present some results about the existence of anti-quasi-Sasakian structures, especially on compact manifolds.

- **Alessandro Fania**, Istituto Nazionale di Fisica Nucleare

  Title: *Machine Learning approach to predict ground-level air pollution in Italy*

  Abstract: In recent years, there has been a growing interest in the topic of environmental pollution, particularly its connections to human health. This interest has given rise to a One Health approach, which explores the interplay between human and animal health and the surrounding environment. Satellite data has emerged as a valuable resource for monitoring air pollution, thanks to an increasing number of sensor missions, including Sentinel-5P. These missions can detect concentrations of various pollutants based on the National Ambient Air Quality Standards (NAAQS) list.

  However, it's important to note that satellite-derived concentrations differ from surface concentrations, as they do not account for the vertical density of pollutants. Surface information concentrations are typically collected by stations like ARPA, but their coverage is limited due to their sparse distribution across the entire territory.

  This study aims to develop an Artificial Intelligence model for predicting daily concentrations of air pollutants at the surface level. The model utilizes satellite pollution and

meteorological data, along with surface data describing the territory and ground control unit measurements as ground truth. The analysis covers the entire Italian territory over the period 2019-2022, at the municipal level (8092 municipalities). After evaluating the performance of various models, an Explainable Artificial Intelligence approach is employed to interpret the obtained results.

- **Marco Gallo**, Università Cattolica del Sacro Cuore (Brescia)

  Title: *Quasi-concavity and tailor-made clothes*

  Abstract: Regarding the qualitative properties of a fixed function $u : \Omega \subset \mathbb{R}^N \to \mathbb{R}$, a significant role is played by the *concavity*: in this talk we will discuss this property in the case u is a solution of a partial differential equation of the type

  $$-\Delta u = f(u) \quad \text{in } \Omega.$$

  Since, in the general case, concavity itself is a too strong goal, we will be interested in some *weaker* properties, some of them suitably *sewed on* the function f itself.

- **Antonio Lagioia**, Università degli Studi di Bari Aldo Moro

  Title: *The double dispersion equation: a case of very uneffective damping*

  Abstract: In this talk, I will discuss the effects of applying a damping term to wave equations or other related evolution equations. Dissipation can result in one or both of two different situations: the fundamental solution may exhibit oscillations with reduced amplitude (damped oscillations regime), or the oscillations may be suppressed by friction (overdamping regime).

  I will specifically focus on the Cauchy problem

  $$\begin{cases} u_{tt} + Au + (I + A)^{-1} Au_t = 0, \quad t \geq 0, x \in \mathbb{R}^n \\ u(0, x) = 0,\ u_t(0, x) = u_1(x), \end{cases} \tag{1}$$

  where A is a differential operator in the form $A = (-\Delta)^k$ for a even integer $k \geq 2$. The case $k = 1$ is known as DDE (Double Dispersion Equation) and has been of great interest in recent years. The peculiarity of this model is that the fundamental solution has oscillations at both large and low frequencies, inheriting well-known problems from the standpoint of regularity and long- time decay. I will present the obtained results concerning $L^p - L^q$ long time estimates for the solution to (1) and an application to some associated semi-linear problems.

- **Mario Lepore**, Università degli Studi di Salerno

  Title: *Enhancing Undergraduate Students Learning Path: A Situational Awareness Approach*

  Abstract: This work explores an adaptive learning system rooted in the principles of Situation Awareness and Goal-Directed Task Analysis, aiming to enhance students' performance by intensifying the awareness about their learning path using crucial parameters for situation identification such as engagement, motivation, and participation. Utilizing a technique based on Fuzzy Cognitive Map (FCM), the system discerns the learner's current situation by monitoring their behavior and interactions within the system. The FCM also actively contributes to drive the feedback generation process, thereby enriching the learner's motivation, engagement, and participation. The system underwent rigorous evaluation using the Situation Awareness Global Assessment Technique, encompassing students from the academic years 2017 to 2022. The experimental results convincingly demonstrate that, thanks to the FCM, the system significantly improves the learner's situation awareness, even in emergency contexts.

- **Tommaso Monni**, Università degli Studi di Bari Aldo Moro

  Title: *Freedman's Theorem for unitarily invariant states on the CCR algebra*

  Abstract: The set of states on CCR(H), the CCR algebra of a separable Hilbert space H, is here looked at as a natural object to obtain a non-commutative version of Freedman's theorem for unitarily invariant stochastic processes. In this regard, we provide a complete description of the compact convex set of states of CCR(H) that are invariant under the action of all automorphisms induced in second quantization by unitaries of H. We prove that this set is a Bauer simplex, whose extreme states are either the canonical trace of the CCR algebra or Gaussian states with variance at least 1.

- **Maria Teresa Ruggiero**, Università degli Studi di Pavia

  Title: *Gonality of curves on algebraic regular surfaces*

  Abstract: This project falls within the field of algebraic geometry and aims to study the gonality of curves on non-singular complex projective surfaces. This topic is particularly relevant in current research, as gonality is generally considered one of the most important invariants of a curve.

  The research objectives of this project are focused on studying conditions that characterize the existence of algebraic curves with fixed gonality and singularities on non-singular projective surfaces. Initially, we analyze the case of nodal curves over K3 surfaces, and

then generalize it to surfaces with a non-trivial canonical bundle and zero irregularity.

In essence, this project seeks to advance the understanding of the gonality of curves on complex projective surfaces by exploring both the conditions for their existence and the study of linear systems on various types of surfaces.

- **Laura Selicato**, Istituto di Ricerca Sulle Acque - CNR

  Title: *Topological Data Analysis for resilience assessment of a Water Distribution Networks*

  Abstract: Water Distribution Networks (WDNs) are critical assets, which are required to provide safe drinking water under a wide range of operational and management conditions, including failures. Therefore, understanding the structural properties of a water distribution system in different disruptive event scenarios is a key aspect of improving the security, reliability, and efficiency of the WDNs. In particular, the identification of critical components whose failure can negatively influence network performances and system resilience has direct relevance for decision-makers involved in planning, management, and improvement activities. Among the many methods and tools available, Topological Data Analysis (TDA) has emerged as a cutting-edge tool in this field. In particular, the persistent homology can be used to derive a new metric for the resilience of water networks, which, together with the other metrics known in the literature, can provide a more complete description of the system.

- **Gaetano Settembre**, Università degli Studi di Bari Aldo Moro

  Title: *Unlocking insights from the sky: Low-Rank Methods in remote sensing and case studies*

  Abstract: Hyperspectral imaging (HSI) is a rapidly growing field of remote sensing that has significantly contributed to a comprehensive characterization of the Earth's surface in recent decades. Thanks to the high spectral resolution, it is possible to identify the materials or components present in each pixel of the hyperspectral image. However, due to their very high correlation between spectral channels and spatial pixels, HSIs have intrinsically sparse and low-rank structures [1]. Methods based on sparse and low-rank representation have demonstrated considerable efficacy in various hyperspectral image processing tasks, including but not limited to denoising, super-resolution, dimension reduction, unmixing, classification, and anomaly detection. Advanced HSI matrix-based processing should consider both spectral and spatial information, and their specific characteristics, such as neighborhood similarity homogeneity, spectral low rank and variability, sparsity. In this talk, an overview of the variants of Nonnegative Matrix Factorization (NMF) to in-

corporate physical-chemical properties of the data during the factorization process in HSI analysis is presented [2]. Additionally, some examples of applications based on low-rank hierarchical clustering to identify burned areas, fire severity and land cover change using PRISMA hyperspectral images will be shown and discussed. The experimental part is a joint work with the MIδAS Research Group and Planetek Italia S.r.l., which co-finances the project H91I22000410007.

References

1. J. Peng et al., "Low-Rank and Sparse Representation for Hyperspectral Image Processing: A review," in IEEE Geoscience and Remote Sensing Magazine, vol. 10, no. 1, pp. 10-43, March 2022.
2. X. -R. Feng et al., "Hyperspectral Unmixing Based on Nonnegative Matrix Factorization: A Comprehensive Review," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 4414-4436, 2022.

- **Caterina Sportelli**, University of Western Australia

Title: *A fractional perspective on the theory of edge dislocations*

Abstract: In this talk we briefly outline a model for the dynamics of edge dislocations in crystals which are based on the fractional Laplace representation of the associated system of equations.

Specifically, we consider a nonlocal version of this kind of dynamical systems in a variational setting and we delve into results related to the existence of different tipes of solutions (e.g. homoclinic and/or heteroclinic trajectories).

These results are part of a joint work with Serena Dipierro and Enrico Valdinoci.