International Workshop on Mathematics and Physical Sciences

BOOK OF ABSTRACTS

University of Évora

15 – 16 June 2023

Évora – Portugal

Technical specifications

Title
Book of Abstracts: International Workshop on Mathematics and Physical Sciences

Editor
Universidade de Évora
Largo dos Colegiais 2
7004-516 Évora

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ISBN
978-972-778-320-5

Format
Digital

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Portugal

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Preface

This book-proceeding comprises the results of various comprehensive Mathematical and Physical Sciences-based studies accepted for presentation and discussion during the 1st Mathematical and Physical Sciences International Workshop in Évora, in 2023 (MatPhys23). The MatPhys23, organized under the auspices of University of Évora throughout the CIMA - Research Center in Mathematics and Applications, the ICT - Institute of Earth Sciences and the NOVA-LINCS - NOVA Laboratory for Informatics and Computer Science (Évora branch). This Workshop brought together many well-known mathematicians, physicists and engineers from University of Beira Interior (UBI, Portugal), University of Cabo Verde (UCV, Cabo Verde), Montclair State University (MSU, NJ, USA) and University of Évora (UÉ, Portugal). This book-proceeding volume involves 24 abstracts on the latest trending and significant challenges in mathematics and physical sciences. The works presented focus on the following areas: statistical and mathematical methods that are relevant to biology, medical and biomedical sciences, computer science, economics, social sciences, music, environmental sciences, climatology, engineering, industry, fluid mechanics and their applications, numerical simulations in various physical, geophysical, chemical, biological and engineering applications. In addition to the usual scientific interaction between participants, this meeting has the presence of PhD students, which we consider relevant.

Considering the original contents, aims, and methodologies of all these valuable studies, it is believed that the topical outputs are of interest to all researchers, practitioners, and students and would mainly provide new scientific insights and knowledge for geoscientists and engineers.

Évora, 15th June 2023

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Invited talks

Application of Banach's fixed point theorem for studying Ulam stabilities for some types of equations

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Talk Abstract

An interesting and famous talk presented by S. M. Ulam in 1940 triggered the study of stability problems for various functional equations. In the following year, D. H. Hyers was able to give a partial solution to Ulam's question that was the first significant breakthrough and step toward more solutions in this area. After that preliminary answer, other approaches emerged, and new orientations were introduced by Th. M. Rassias, introducing therefore the so-called Hyers-Ulam-Rassias stability. Different generalizations were obtained by other researchers, by considering the possibility of using different involved norms, others types of equations, but always resorting to the useful Banach Fixed Point Theorem. In this talk our main goal is to present the various approaches and techniques using the Banach Fixed Point Theorem to study Hyers-Ulam, Hyers-Ulam-Rassias and σ-semi-Hyers-Ulam stabilities. The talk is based on joint works with L. P. Castro from University of Aveiro and Center for Research and Development in Mathematics and Applications, Portugal.

Keywords: Hyers-Ulam stability, σ-semi-Hyers-Ulam stability, Hyers-Ulam-Rassias stability, Banach fixed point theorem, Bielecki metric, Higher order integro-differential equations, Bessel differential equation.

Acknowledgements

This work was partially supported by the Center of Mathematics and Applications of University of Beira Interior (CMA-UBI) through the Portuguese Foundation for Science and Technology (FCT - Fundação para a Ciência e a Tecnologia), under the references UIDP/0 0212/2020 and UIDB/00212/2020, by the Center for Research and Development in Mathematics and Applications (CIDMA) through the Portuguese Foundation for Science and Technology (FCT), under the references UIDB/04106/2020 and UIDP/04106/2020 and by the Research Center in Mathematics and Applications (CIMA) through the Portuguese Foundation for Science and Technology (FCT), under the reference UIDP/04674/2020.

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Stability analysis under restricted resetting

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Talk Abstract

For a reset state switched systems, the state is reset to a value chosen by a linear function of the preceding state at each switching instant. By comparing the trajectories of a switched system with state reset to those of a time-variant system without reset, or with continuous state trajectories, we were able to determine the relationship between the two. The study of the stability of switched systems with state reset has now been approached differently according to the reduction to dynamics with continuous state trajectories. Further, we have identified some families of resets that satisfy a boundedness condition such that allow us to study the stability property based on the new approach. Additionally, we analysis some systems that have a particular type of resetting. In this case, the sets of resets are bounded, which allowed to establish two sufficient conditions for stability.

Keywords: State reset, Stability, Switched linear systems.

Acknowledgements

This talk has been partially supported by the Portuguese Foundation for Science and Technology (FCT), through the Center of Mathematics and Applications (CMA), within the project UIDB/00212/2020, and through the Center in Mathematics and Applications (CIMA), within the project UIDB/04674/2020.

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S_n-symmetry and nonlinearly coupled phase oscillators

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Talk Abstract

Coupled oscillator models where N oscillators are identical and symmetrically coupled to all others with full permutation symmetry S_N are found in a variety of applications. Much, but not all, working on phase descriptions of such systems consider the special case of pairwise coupling between oscillators. In this talk, I will show this is restrictive - and will characterise generic multi-way interactions between oscillators that are typically present, except at the very lowest order near a Hopf bifurcation where the oscillations emerge. I will examine a network of identical weakly coupled dynamical systems that are close to a supercritical Hopf bifurcation by considering two parameters, ϵ (the strength of coupling) and λ (an unfolding parameter for the Hopf bifurcation). For small enough $\lambda > 0$ there is an attractor that is the product of N stable limit cycles; this persists as a normally hyperbolic invariant torus for sufficiently small $\epsilon > 0$. Using equivariant normal form theory, we derive a generic normal form for a system of coupled phase oscillators with S_N symmetry. For fixed N and taking the limit $0 < \epsilon \ll \lambda \ll 1$, the attracting dynamics of the system on the torus can be well approximated by a coupled phase oscillator system that, to lowest order, is the well-known Kuramoto-Sakaguchi system of coupled oscillators. The next order of approximation genericlly includes terms with up to four interacting phases, regardless of N. Using a normalization that maintains nontrivial interactions in the limit $N \to \infty$, I will show that the additional terms can lead to new phenomena in terms of coexistence of two-cluster states with the same phase difference but different cluster size.

Keywords: Kuramoto model, S_n-symmetry, Coupled oscillators.

Acknowledgements

This communication work at the MatPhys23 was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project CIMA-UIDB/04674/2020.

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A two-phase model for mucosal aggregation and clearance in the human tear film

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Talk Abstract

We discuss a multiscale problem inspired by the dynamics of the occular tear film. While a considerable amount of attention has been paid to understanding various complex physical mechanisms of the eye, some fundamental questions remain open. One of these questions includes the role of mucus which lines the cornea in the eye and is assumed to provide lubrication and protection to the eye. The literature remains vague about the meaning of the term 'protection' in general. In the context of the eye, it is attributed to the fluidity and high viscosity of mucus. However, we hypothesize that the answer is more complex than currently suggested and in fact, could well depend upon various aspects including, mucin distribution, forces of attraction in the system, blinking rate and other material properties of the tear film. The objective of this talk is to elucidate the model and numerical method surrounding the biomechanics of lubrication and protection in a complex, non-Newtonian medium by examining the motion of the tear film coupled with that of embedded mucin proteins and potential foreign particles in the fluid. It has recently been argued that transmembrane mucins could break off, stick to foreign particles, and help them be transported out of the tear film. Our mathematical analysis, based on this hypothesis reveals that the shearing motion of a wall does indeed aid in transporting away any embedded foreign particle towards the moving boundary under the right conditions. Our computations suggest a possible mechanism by which the human eye could clear out any debris beneath the eyelid, under responsive blinking which has consequences on our understanding of pathologies of the eye.

Keywords: Tear film, Modeling, Two-phase flow.

Acknowledgements

This communication work at the MatPhys23 was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project CIMA-UIDB/04674/2020.

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Non-homogeneous chains of damped harmonic oscillators

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Talk Abstract

Considering idealized materials composed of one dimensional chains of damped harmonic oscillators represented by a sequence of particles, springs and dampers, we proposed to study vibrational properties of non-homogeneous materials. This kind of systems are linear and thus they possesses exact explicit solutions, which, nevertheless can have very complicated formulas. Homogeneous chains are used as basic building blocks for characterizing global dynamics of the system. In particular, we determine the solutions for a system composed of two distinct homogeneous chains in terms of the original solutions for these two homogeneous chains, and the original parameters, when uncoupled. Two types of coupling, with distinct physical meaning are considered.

Keywords: Discrete dynamical system, Harmonic oscillator, Non-homogeneous damped chain, Recursion.

Acknowledgements

This work was partially supported by Centro de Investigação em Matemática e Aplicações (CIMA), through the Project UIDB-04674-2020 of FCT-Fundação para a Ciência e a Tecnologia, Portugal.

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Music composition in the style of Johann Sebastian Bach using mathematical transformations

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Talk Abstract

The composition of new musical pieces in the style of classical composers has fascinated and stimulated musicians and non-musicians alike for a long time. The task became easier with the development of computers in the ’50s when scientists joined this quest by writing algorithms capable of composing music both autonomously and assisted by musicians. The rapid progress in the field of machine learning lead to an abundance of methods and algorithms that can generate different styles of music from South Indian classical music to jazz. Johann Sebastian Bach is considered one of the greatest composers of 18th century, famous for the beauty of his compositions and his technical mastery of harmony and counterpoint. His highly mathematical knowledge often translated into his music which contained unique combinations of tones and intricate structures. Many have tried to imitate his style and compose pieces that have similarities in style and harmonies with the famous composer. In this talk we describe a new method for music composition in the style Johann Sebastian Bach using geometrical transformations of the plane. The method consists of analyzing a classical opus, identifying the motif and map the occurrences of this motif and its transformations throughout the original work. Then compose a new musical motif and use this map to create an entirely new piece while preserving the motivic structure and the style of the original composition. We provide an example in both musical notation and audio format.

Keywords: Music composition, Motif, Johann Sebastian Bach, Geometrical transformations, Math and music.

Acknowledgements

This communication work at the MatPhys23 was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project CIMA-UIDB/04674/2020.

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Numerical semigroups with fixed multiplicity and concentration

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Talk Abstract

A numerical semigroup is a subset S of $\mathbb{N}$ that is closed under addition, contain 0 and has finite complement in $\mathbb{N}$. Given a nonempty subset A of $\mathbb{N}$ we will denote by $\langle A\rangle$ the submonoid of $(\mathbb{N},+)$ generated by A, that is,

$$\langle A\rangle = \{\lambda_1 a_1 + \cdots + \lambda_n a_n \mid n \in \mathbb{N}\backslash\{0\},\ a_i \in A,\ \lambda_i \in \mathbb{N},\ \forall i \in \{1,\ldots,n\}\}\,.$$

It is well known that $\langle A\rangle$ is a numerical semigroup if and only if $gcd\,(A) = 1$. If S is a numerical semigroup, then

$$m(S) = \mathsf{min}(S\backslash\{0\}),\ \ F(S) = \mathsf{max}\,\{z \in \mathbb{Z} \mid z \notin S\}$$

and $g(S) = card(\mathbb{N}\backslash S)$ (cardinality of $\mathbb{N}\backslash S$) are three important invariants called multiplicity, Frobenius number and genus of S, respectively. We define the concentration of a numerical semigroup S as

$$\mathsf{C}(S) = \mathsf{max}\,\{\mathsf{next}_S(s) - s \mid s \in S\backslash\{0\}\}\,,$$

wherein

$$\mathsf{next}_S(s) = \mathsf{min}\,\{x \in S \mid s < x\}\,.$$

In this talk, we study the class of numerical semigroups with multiplicity m and concentration less or equal to k, denoted by $\mathsf{C}_k[m]$. We give algorithms to calculate the whole set $\mathsf{C}_k[m]$ with given genus or Frobenius number. In addition, we show that if $S \in \mathsf{C}_k[m]$ with $k \leq \sqrt{\frac{m}{2}}$, then S verifies the Wilf's conjecture.

Keywords: Numerical semigroup, Concentration, Frobenius number, Genus, Multiplicity, Wilf's conjecture.

Acknowledgements

This work was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project UIDB/04674/2020.

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Marginal and large diferences

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Talk Abstract

We propose a new theory based on the notions of marginal and large difference which has natural models in the context of nonstandard mathematics. We introduce the notion of finite marginality and show a representation result which ensures, for finitely marginal countable models, the existence of a homomorphism of the structure of marginal and large difference into a nonstandard model of the natural numbers, and show the extent to which any such homomorphism is unique. Finally, we show that our theory constitutes part of the underlying abstract structure of three distinct philosophical theories of vagueness: Dean's neofeasibilism, Itzhaki's theory of nonstandard heuristics, and our own initial sketch of a nonstandard primitivism about vagueness.

Keywords: Vagueness, Sorites paradox, Measurement theory, Nonstandard models, Nonstandard primitivism.

Acknowledgements

Both authors acknowledge the support of FCT – Fundação para a Ciência e Tecnologia under the projects: UIDP-04561-2020 and UIDP-04674-2020 (first author) and UIDB-00678-2020, and CEECIND-04761-2017-CP1387-CT0008 (second author).

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Pseudo random number generators using cellular automata genetic algorithms

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Talk Abstract

We here consider the generation of pseudo random numbers with evolving cellular automata. The methods are based on the algorithms introduced in [1] and [2]. We consider an initial population of cellular automata, obtained randomly using classical pseudo random number generators. Using genetic algorithms we produce new cellular automata rules, selecting the more suitable. We choose the best cellular automata rules, taking into account the most common NIST tests.

Keywords: Pseudo random number generators, Cellular automata, Genetic algorithms.

Acknowledgements

This talk has been partially supported by FCT “Portuguese Foundation for Science and Technology through the Research Center of Mathematics and Applications of University of Evora (CIMA), project CIMA-UIDB/04674/2020.

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F-tests with random sample sizes: An overview

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Talk Abstract

Analysis of variance (ANOVA) is one of the most frequently used statistical analyses in several research areas, namely in medical and biomedical sciences, social sciences or agriculture. Despite being widely used on the assumption that sample dimensions are known, there are many relevant situations in which these dimensions are not known in advance. Such situations frequently occur when a fixed time period is established for collecting the observations. This may be overcome when we carry out ANOVA assuming the sample sizes as realizations of independent random variables. The current approach must be based on the adequate choice of the distribution of these random variables, which must be reasoned on practical situations. With this presentation, we intend to give an overview of our latest advances in this field, considering fixed and mixed effects models. Some applications, based on real and simulated data, are considered to illustrate the proposed approach.

Keywords: Fixed effects models, Mixed models, Random sample sizes, Applications to real data, Simulation studies.

Acknowledgements

This talk has been partially supported by national founds of FCT-Foundation for Science and Technology under UIDB/00212/2020 and UIDB/04674/2020.

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Multivariate Statistics Applied to Air Pollutants, Meteorological Variables and Cardiorespiratory Mortality in Portugal

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Talk Abstract

Two multivariate statistical analysis studies were performed aiming to enhance the understanding of the effects of air pollution and meteorological factors on health outcomes in Portugal. The first study focused on the impact of fire-pollutant-meteorological variables on cardiorespiratory mortality during wildfire seasons from 2011 to 2020. Principal component analysis was employed to create two indices: Pollutant-Burning Interaction (PBI) and Atmospheric-Pollutant Interaction (API). PBI showed strong correlations with atmospheric pollutants and burned area, while API exhibited strong correlations with temperature, relative humidity, and ozone (O3) levels. Cluster analysis was applied to the PBI and API indices, dividing the data into two clusters. Cluster 1 represented colder and wetter months with higher concentrations of nitrogen dioxide (NO2), while Cluster 2 represented warmer and drier months with elevated levels of particulate matter (PM10, PM2.5), carbon monoxide (CO), and O3. Principal Component Linear Regression analysis was conducted to explore the relationship between mortality and the PBI-API indices within each cluster. Significant correlations (p-value $<$ 0.05) were found between the indices and specific causes of mortality. In Cluster 1, RSDxPBI (respiratory system diseases) and PNEUxPBI (pneumonia) showed statistically significant correlations. In Cluster 2, significant correlations were observed between RSDxPBI, PNEUxPBI, COPDxPBI (chronic obstructive pulmonary disease), CSDxAPI (circulatory system diseases), RSDxAPI, PNEUxAPI, and COPDxAPI. The analysis of Cluster 2 indicated that the warmest, dryest, and most polluted months of the fire season were significantly associated with cardiorespiratory mortality. The second study focused on the seasonal characterization of pollutant-meteorological factors and cardiorespiratory mortality in Portugal from 2011 to 2020. The study revealed that cardiorespiratory mortality rates were 44% higher during winter compared to summer. Particulate matter (PM10, PM2.5), carbon monoxide (CO), and nitrogen dioxide (NO2) exhibited seasonal variability, with the highest concentrations observed during winter, while ozone (O3) concentrations were higher during spring and summer.

PM10, PM2.5, and NO2 showed positive correlations between seasons, indicating similar patterns of behavior. Canonical correlation analysis (CCA) was applied to examine the relationship between pollutant-meteorological factors and cardiorespiratory mortality. The analysis demonstrated a strong linear correlation between these variables. The first canonical correlation, with a value of 0.889, and the second canonical correlation, with a value of 0.545, were both statistically significant (p-value $<$ 0.0000). The results of the CCA suggested a strong association between near-surface temperature, relative humidity, PM10, PM2.5, CO, NO2, and health outcomes. The findings contribute to a better understanding of the impacts of air pollution and climate on public health.

Keywords: Atmospheric pollutants, Environmental health, Cardio-respiratory mortality, Environmental risks, Multivariate statistical techniques, Air quality.

Acknowledgements

The work is funded by national funds through FCT - Fundação para a Ciência e Tecnologia, I.P., in the framework of the ICT project with the references UIDB/04683/2020 and UIDP/04683/2020, and by the CILIFO (0753-CILIFO-5-E), FIREPOCTEP (0756-FIREPOCTEP-6-E) and TOMAQAPA (PTDC/CTAMET/29678/2017) projects.

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Existence and localization results for coupled systems of differential equations

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Talk Abstract

In this paper, we consider some boundary value problems composed by coupled systems of second-order differential equations with full nonlinearities and general functional boundary conditions verifying some monotone assumptions. The arguments apply the lower and upper solutions method, and defining an adequate auxiliary, homotopic, and truncated problem, it is possible to apply topological degree theory as the tool to prove the existence of solution. In short, it is proved that for the parameter values such that there are lower and upper solutions, then there is also, at least, a solution and this solution is localized in a strip bounded by lower and upper solutions. As far as we know, it is the first paper where Ambrosetti-Prodi differential equations are considered in couple systems with different parameters.

Keywords: Coupled systems, Lower and upper solutions, Nagumo condition, Degree theory, Ambrosetti-Prodi problems.

Acknowledgements

This work was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project UIDB/04674/2020.

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Structural equation modeling in the assessment of stress in Portuguese workers

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Talk Abstract

Structural equation modeling (SEM) can be used to investigate the relationships between observed (manifest) and unobserved (latent) variables, as occupational stress (and burnout syndrome), which carries up a huge economic burden. A medium Portuguese version of the COPSOQ (Copenhagen Psychosocial Questionnaire) was applied in a Portuguese industrial company with the aim of measuring its workers' perception about their irritation and anxiety feelings, which are manifest variables, considered as reflections of the latent variable/construct 'stress'. A reflective causal (theoretical) model was proposed, based on the research hypotheses, which are consistent with the specialized literature as well as the authors' empirical experience. The estimated model was obtained using the PLSc (consistent Partial Least Squares) method, which is supported by data collected in a survey and verifies the required statistical criteria for both measurement and structural submodels. Here, the latent constructs 'quality of leadership', 'justice', 'job satisfaction' and 'quantitative demands' appear as significant predictors for 'stress'. At a time when much is being discussed about workers' happiness levels and the 4-day week possible contributions to productivity, this study may hopefully come up with a greater awareness about workers' health and wellbeing at workplace. Therefore, it can indirectly contribute to promote lower stressful moments and, consequently, minimize the prevalence of workers' burnout syndrome, with clear benefits for everyone (stakeholders, organizations and the economy in general).

Keywords: Likert-type scale, Nonnormal data, PLSc estimator, Primary data, Psychosocial risks.

Acknowledgements

This work was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through CIMA, under the scope of project UIDP/04674/2020.

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Convertible Subspaces of Hessenberg-Type Matrices and its connection to graphs

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Talk Abstract

A subspace of generalized Hessenberg matrices is a subspace where the determinant is convertible into the permanent by affixing $\pm$ signs. An explicit characterization of convertible Hessenberg-type matrices is presented. From a simple graph G with n vertices, labeled with distinct elements $\{1, 2, \cdots, n\}$, we can construct $G-$ lower Hessenberg $(0, 1)-$ matrices. We show that the convertible subspaces can be arise from different numberings of the vertices of G. This numbering process allows to obtain some well-known sequences of integers (one of them is the sequence of Fibonacci numbers). It has been proved that the graphs that admit an enumeration of its vertices that gives rise to a convertible subspace are caterpillars. Moreover, we present the current research work and a conjecture for future work.

Keywords: Hessenberg matrix, Determinant, Permanent, Graphs, Convertibility, Minimum permanent.

Acknowledgements

This talk has been partially supported by the Portuguese Foundation for Science and Technology (FCT), through the Center of Mathematics and Applications (CMA), within the project UIDB/00212/2020, and through the Center in Mathematics and Applications (CIMA), within the project UIDB/04674/2020.

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Earth tomography: How seismic waves travel inside the Earth

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Talk Abstract

Seismic tomography is a methodology based on generating a 3D-velocity model showing the structure of the Earth's interior in specific regions of the world. This technique is used worldwide in seismology and is mainly based on the inversion of travel times. When an earthquake occurs, seismological stations implanted around an area, record the wave propagation. The time that the wave travels through the Earth from the seismic source until the station varies in function of the distance and the velocity of the geological structures it crosses. Depending on the density and composition of the materials that the wave will propagate through, seismic rays will travel at different speeds to reach the station. Seismological sensors are instruments that can record any seismic activity on large and small scales. They are used to collect information that is important for the determination of the wave path used to generate velocity distribution within depth. Therefore, from the data collected at the stations, basic principles of physics and the application of mathematical approaches are used to run calculations of velocities. The forward problem is generally used to predict the measurements from known model parameters and properties. On the contrary, in the case of seismic tomography, it is from measurements that the model parameters are estimated through the use of the inverse problem based on the least square method. The main equation to solve relates the travel times to the velocity and the distance the ray travels to reach the station. Therefore, the travel time is calculated and then inverted to generate the velocity distribution. All the computations are based on the minimization of the residuals; which is simply the difference between observed and calculated travel times; to get a velocity model closest to reality. To run the computation of velocities, it is important to determine first (a) the model parametrization; (b) the seismic wave path through the ray tracing method; (c) the inversion of travel times and (d) the analysis of the resolution and uncertainty of the obtained tomographic structure. In this case study, this methodology was applied to Arraiolos region (central Alentejo), after the Mw4.9 magnitude earthquake of January 15th, 2018 occurred. The travel times of 467 aftershocks, recorded by 34 seismological stations, merged with 54 seismic events, registered by 12 stations, were inverted to obtain the spatial distribution of velocities in three dimensions.

Keywords: Seismic tomography, Inverse problem, Least square method, Travel time calculation, Ray propagation.

Acknowledgements

Thanks are due to FCT for the financial support to the ICT project (UID-GEO-04683-2013) with the reference POCI-01-0145-FEDER-007690 and to the IDL project (UIDB-50019-2020-IDL).

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Shintani Descent and Supercharacter Theory

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Talk Abstract

The problem of describing the representation theory of the unitriangular group (the group of upper triangular matrices with diagonal entries set to 1) led to the development of supercharacter theory, first by C. André for the unitriangular group over a finite field and later, for a general finite group, by I.M. Isaacs and P.Diaconis. The Shintani Descent, first introduced by T. Shintani, was used to describe the relation between F-stable irreducible characters of an algebraic group $G(\mathbb{F}_{q^n})$ and characters of $G(\mathbb{F}_q)$. Whereas, in the case where G is abelian, we get a bijection between F-irreducibles and irreducibles, but for general cases, we do have such correspondence. In this talk, I will give an introduction to the usual supercharacter theory defined on a unitriangular group over a finite field and, using the Shintani Descent, describe a relation between the supercharacter theory of the unitriangular group of a finite field and over a finite extension of such a field. Lastly, some connections with the representation theory of the unitriangular group over an infinite field will be explored.

Keywords: Representation Theory, Supercharacter Theory, Unitriangular group, Algebraic groups.

Acknowledgements

This talk is partially supported by Centro de Investigação em Matemática e Aplicações, through project IDB/04674/2020 of FCT- Fundação para a Ciência e a Tecnologia, Portugal.

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Alternative reliable ways to assess risk in Statistics of Extremes

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Talk Abstract

In the field of statistical extreme value theory, risk is generally expressed either by the value at risk at a level q (VaRq), the size of the loss occurred with a fixed probability, q, the upper (1-q)-quantile of the loss function, or by the conditional tail expectation (CTE), defined as $CTEq = E[X|X > VaRq]$, $q \in (0, 1)$. We consider heavy-tailed models, i.e., Pareto-type underlying cumulative distribution functions, with a positive extreme value index (EVI), quite common in many areas of application. For these Pareto-type models, the classical EVI-estimators are the Hill (H) estimators, the average of the k log-excesses over a threshold $X_{n-k:n}$. The Hill estimator is crucial for the semi-parametric estimation of both the VaR and the CTE. We present improvements in the performance of the CTE-estimators, using reliable EVI-estimators based on generalized means and possibly reduced-bias.

Keywords: Conditional tail expectation, Generalized means, Heavy-tailed parents, Semi-parametric estimation.

Acknowledgements

This work was partially financed by FCT - Fundação para a Ciência e a Tecnologia, through national funds, within the projects UIDB/04674/2020 (CIMA) and UIDB/00006/2020 (CEA/UL).

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Passive remote sensing from space: methods and applications

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Talk Abstract

Remote sensing is a powerful technique used to gather information about a target or phenomenon without establishing physical contact with it. Remote sensing requires some type of energy interaction between the target and the sensor and includes the analysis and interpretation of the acquired data. This technique is applied in numerous and diverse areas such as medicine and health care, business, crime investigation, military defense, disaster monitoring, engineering, agriculture, environmental monitoring, among many others. Passive remote sensing refers to the use of a natural source of energy that is detected by the sensors, either due to reflection or emission processes. Space based platforms are suitable for Earth observation and monitoring, enabling the development of value-added services valuable to decision-makers and society end-users. The radiative transfer theory, which constitutes the physical basis to retrieve information from remote sensing measurements, allows to deal with light scattering and absorption processes. These physical processes are represented in models, commonly used by the scientific community. Its combination with passive remote sensing from space, which may employ electromagnetic radiation in the ultraviolet, visible, infrared or microwave spectral regions, allows to retrieve information on the Earth's surface or atmospheric characteristics. Applications related with atmospheric and surface characterization will be presented.

Keywords: Passive remote sensing, Earth Observation, Satellite retrievals, Atmospheric radiative transfer, Atmospheric constituents, Atmospheric remote sensing, Atmospheric and surface characterization.

Acknowledgements

This work is co-funded by National funds through FCT – Fundação para a Ciência e Tecnologia, I.P. (projects UIDB/04683/2020 and UIDP/04683/2020).

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On first order fully nonlinear coupled functional systems

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Talk Abstract

This talk is concerned with the existence of solutions for first order fully coupled systems with coupled functional boundary conditions, which generalize the usual boundary assumptions and may be applied to most of the classical cases. The arguments used are based on the Arzèla Ascoli theorem and Schauder's fixed point theorem. Two applications will be considered: a mathematical model of the thyroid-pituitary interaction and their homeostatic mechanism and a SIRS model.

Keywords: Coupled nonlinear systems, Functional boundary conditions, Schauder fixed point theory, Thyroid-pituitary homeostatic mechanism, Mathematical modelling.

Acknowledgements

This work was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project CIMA UIDB-04674-2020.

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Best Fit of Nonlinear Implicit Models Using a TLS Algorithm

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Talk Abstract

The adaptation of mathematical models to physical measurements is a cross-cutting issue in scientific activities. The complexity of the problem lies in the type of model and the optimization criterion or cost function. Generally, in engineering and physics, the use of the Total Least Squares (TLS) criterion is avoided, and Ordinary Least Squares (OLS) is preferred because it is easier to implement, especially when monitoring and controlling real-time processes. In this work, we will demonstrate that the introduction of the TLS criterion for certain models related to the inverse problem leads to a better estimation of the parameters of these models. We will also present an algorithm that is easy to implement and fully satisfies the requirements of convergence and computation time.

Keywords: Total Least Squares, Digital Signal Processing, Best Fit, Sensor's Characterization.

Acknowledgements

This work was partially supported by the program Agenda Mobilizadora, Project: Automated & Integrated Large Aircraft NDI Assisted by Virtual Reality (Ref: C645727867-00000066).

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Hammerstein-type integral systems with application to a suspension bridge bending model

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Talk Abstract

Hammerstein integral equations are especially relevant in physics and are often used to reformulate or rewrite mathematical problems. They are equations that have been studied extensively in various topics, such as: the existence, non-existence and multiplicity of solutions, and applications to real phenomena. In this context, this work generalizes coupled systems of two integral equations of Hammerstein-type where the kernel functions may change sign, as well as remain positive on some subintervals, and the nonlinearities may have discontinuities. The results are obtained using the fixed point theorem on a special cone, where some requirements may be satisfied only on some subintervals of the domain. Finally, the results are applied an application to a coupled system composed by a fourth and second order equations, which models the bending of the main-road of suspension bridges.

Keywords: Coupled systems, Hammerstein integral equations, Sign changing kernels, Guo-Krasnoselskii Theorem, Arzelà-Ascoli Theorem, Bending of suspension bridges.

Acknowledgements

This work was partially supported by the Fundação para a Ciência e Tecnologia (Portuguese Foundation for Science and Technology) through the project UIDB/04674/2020.

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Geophysical data fusion of ground-penetrating radar and magnetic datasets

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Talk Abstract

Geophysical data gathered in archaeological sites have a lack of perceptibility regarding buried structures, i.e., it is not possible to recognize useful information related to structures in the signal. This issue might be caused by soil conditions, which raise the signal to noise ratio and limit proper interpretation of the results. A beginning hypothesis was proposed to overcome this problem: low perceptibility data may contain useful information that is intermingled with background noise and may be revealed by combining two geophysical datasets taken at the same location. Data fusion is a concept that allows two input datasets to be combined to create a new dataset that is more informative, sharper, and of higher quality than the inputs alone. This method is commonly utilized in brain tumor identification in medical imaging methodologies. When used to geophysical datasets, data fusion can improve the information extracted from the results. The suggested geophysical data fusion method was applied to datasets gathered at an archaeological site using ground-penetrating radar (GPR) and vertical magnetic gradient (MAG) [1]. The technique employs the 2D Wavelet transform [2,3], multiresolution singular value decomposition [4], and image gradient [5]. This is a decision-level data fusion technique used in the transformed domain. The results of the testing reveal that the suggested data fusion approach yields a more detailed output with higher clarity and quality than the input data alone, even when processed using standard processing operations with the best user parametrization. The increase in sharpness and quality was graphically validated and monitored in different stages by calculating the sharpness and BRISQUE quality index.

Keywords: Geophysical data fusion, 2D Wavelet transform, multiresolution singular value decomposition, image gradient, GPR and MAG datasets.

Acknowledgements

The work was supported by the Portuguese Foundation for Science and Technology (FCT) project UIDB-04683-2020, ICT (Institute of Earth Sciences).

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Logical Thinking in an AI Context

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Talk Abstract

In this talk we will discuss the application of formalisms and tools based on Logic Programming in the context of multi-agent AI systems. We will briefly go over the Prolog language, extensions thereto such as Tabling, Constraint Logic Programming and Contexts. Related approaches such as Answer-Set Programming will also be discussed. This family of problem-description formalisms is put in context as a tool for program and logical formula validation and verification, namely in the context of subsymbolic AI systems such as neural-network architectures.

Keywords: Logic Programming, Logical Thinking, Contextual Logic Programming, Constraint Programming, Answer-Set Programming.

Acknowledgements

This work was partially supported by the Portuguese Foundation for Science and Technology (FCT) through the project under grant UIDB/04516/2020 (NOVA LINCS).

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Existence and localization of periodic solutions in first order non-linear coupled systems

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Talk Abstract

We present some existence and localization results for periodic solutions of first-order coupled nonlinear systems of two equations, with and without impulses, without requiring periodicity for the nonlinearities. The arguments are based on Schauder's Fixed Point Theorem [1] together with the upper and lower solution method, where the upper and lower solutions are not necessarily well-ordered. In addition, for the impulsive analysis, results on equi-regulated functions [2,3] are required. We apply our methodology to a Wilson-Cowan system of two strongly coupled neurons [4] to illustrate one of the main results.

Keywords: Impulsive nonlinear systems, Upper and lower solutions, Periodic solutions, Existence and localization of solutions, Equi-regulated functions, Wilson-Cowan model.

Acknowledgements

This work research was supported by national funds through the Fundação para a Ciência e Tecnologia, FCT, under the project CIMA-UIDB/04674/2020.

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