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BOOK OF ABSTRACTS

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Exploring SO2 Air Pollution in Plovdiv Through Multivariate Adaptive Regression Splines

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This case study delves into the assessment of sulfur dioxide (SO2) air pollution in Plovdiv by employing Multivariate Adaptive Regression Splines (MARS) to model and understand the factors influencing SO2 levels. This research is premised on the hypothesis that advanced statistical techniques can offer insightful perspectives into the dynamics of air pollution, enabling the development of more effective environmental management strategies. By analyzing a dataset characterized by an average SO2 pollution level of 0.43ppm, this study demonstrates the potency of MARS in capturing the non-linear relationships and complex interactions between SO2 concentrations and various predictive variables, including meteorological conditions and urban activities. A significant achievement of this investigation is the attainment of a coefficient of determination (R^2) exceeding 0.95, underscoring the model's exceptional ability to explain the variance in SO2 levels within the urban atmosphere of Plovdiv. This high level of accuracy not only validates the efficiency of MARS as a modeling approach for environmental data but also emphasizes its potential in forecasting pollution trends and contributing to the urban air quality management toolbox. The findings of this study are critical for environmental policymakers and urban planners in Plovdiv, offering a robust analytical framework for identifying key pollution drivers and formulating targeted interventions. Moreover, the methodology and insights gleaned from this research can be extrapolated to other urban settings grappling with similar air quality challenges, making a significant contribution to the global discourse on sustainable urban living and environmental conservation.

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Numerical Study of the classical 1D Boussinesq Equation

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In this paper we evaluate propagating wave solutions to the one-dimensional classical Boussinesq Equation (BE). Two numerical methods are used to obtain a solution. The first is a conservative finite difference scheme, and the second exploits

Taylor series expansions around the time variable t. The solutions are computed over nested meshes to examine the convergence of both approaches. The main tool for testing the convergence rate of all examined finite difference schemes and Taylor expansions is the Runge method. It is shown that for a fixed time interval the numerical methods preserve the shape, mass and maximum of the solution. The waves obtained by the two methods are compared. Both methods produce similar results in case of second approximation order. The outcome of the comparison is very good.

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Analysis of Oscillations for the Goodwin Business Cycle Model with Discrete Delay and Distributed Delay in Induced Investment

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There are two versions of the Goodwin business cycle model [1, 2]: one in the form of an equation with fixed lags in induced investments

$$\epsilon\dot{y} = -cy(t) + \varphi(\dot{y}(t-\theta))$$

and the second version with distributed delays in induced investments

$$\epsilon\dot{y} = -cy(t) + \int\limits_{-\infty}^{t} f(t-x)\varphi(\dot{y}(x))dx + A(t), \quad f(s) = \begin{pmatrix} 0, & s<0 \\ s\geq 0, & \frac{1}{T}e^{-\frac{s}{T}} \end{pmatrix}.$$

Both versions, subject to certain restrictions on the parameters ϵ, s for $\theta < 1, T < 1$, have periodic solutions with a period significantly exceeding θ and T. However, in the version with a fixed delay, parasitic sawtooth oscillations with a period of can also be excited [3–6].

If we assume that the induced investments consist of a weighted sum of investments with a discrete and continuous delay, then it is possible to write the modified Goodwin model

$$\epsilon\dot{y} = -sy(t) + \mu\varphi(\dot{y}(t-\theta)) + (1-\mu)c\int\limits_{-\infty}^{t} f(t-s)\varphi(\dot{y}(s))ds + A(t), \quad 0\leq\mu\leq 1.$$

In this work, we study the influence of the μ parameter on the stability of the stationary state $y = 0$ and the conditions for the appearance of sawtooth-like oscillations.

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Improved Unbiased Stochastic Method for Fredholm Integral Equations

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Integral equations are highly relevant across various fields such as applied mathematics, physics, engineering, geophysics, electromagnetism, the kinetic theory of gases, quantum mechanics, mathematical economics, and queuing theory. This underscores the importance of creating and examining efficient and dependable methods to solve integral equations. In the context of multidimensional issues, traditional biased stochastic algorithms, which rely on a finite set of integration points, are particularly challenged by the complexities of higher dimensionality. Therefore, it is critical to develop sophisticated unbiased algorithms to address these multidimensional challenges, as discussed in this paper. We introduce and evaluate a novel unbiased stochastic approach for solving multidimensional Fredholm integral equations of the second kind. This paper presents a comparison between this new unbiased algorithm and previous unbiased stochastic methods for both one-dimensional and multidimensional problems.

Acknowledgement. Slavi Georgiev is supported by the Bulgarian National Science Fund (BNSF) under Project KP-06-M62/1 "Numerical deterministic, stochastic, machine and deep learning methods with applications in computational, quantitative, algorithmic finance, biomathematics, ecology and algebra" from 2022.

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Understanding Biological Data Through in silico Studies: Strategies for Targeted Antiviral Therapies

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Viral infections can be thought of as a process that impairs the cellвЂ™s normal information flow, hindering regular functions and potentially resulting in cell death. This highlights the sensitive nature of the cellular information system and the dynamic interplay between living beings and the various environmental factors and agents. We explore this concept in the case of SARS-CoV-2 virus. Interestingly, a key role in this context play the two viral proteins which exhibit the highest and the lowest degrees of similarity to the respective SARS-CoV proteins — the helicase NSP13 with 99.8% similarity, and the ORF6, with only 69% similarity. Our results suggest a prospective targeted strategy impeding their blocking action.

Acknowledgements. We acknowledge the inspiring discussions within the DYNALIFE COST Action, CA21169, supported by the European Cooperation in Science and Technology. This work was supported in part by the Bulgarian National Science Fund (grant KP-06-N71/3/2023). Computational resources were provided by the Discoverer supercomputer thanks to Discoverer PetaSC and EuroHPC JU and by the BioSim HPC cluster at the Faculty of Physics, St. Kliment Ohridski University of вЂњвЂќ.

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Road Safety Management System Optimisation Methodology

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In this study, a traffic safety management system for asphalt surfaced roads is developed (TSMS) to improve safety on different classes of roads in Bulgaria. TSMS is a strategic and systematic procedure to improve traffic safety when funding is limited and it is important to determine the most appropriate combinations of traffic safety improvement projects to provide maximum benefits to the population in terms of reducing traffic accidents. The factors included in the developed optimization methodology are the annual report on traffic accidents of the National Institute of Statistics, a study of the roads, a functional classification of the same, historically established, countermeasures to improve safety, costs and determinants of crash reduction in relation to measures to positively modify safety and average daily traffic (ADT). This study demonstrates how the proposed model can determine the best combination of projects to increase safety in order to maximize the benefits in terms of reducing overall crash frequency. The proposed methodology has been applied to highways in Bulgaria. It can be modified for application to roads in a particular city, region and district.

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New Spatial SEIR Epidemic Models with Low Rate of Infected. Applications and Features

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A new spatial SEIR epidemic models are described by a cooperative, weakly-coupled system of parabolic PDEs with time delay. Some qualitative features of such systems are given as well.

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Group Classification and Numerical Solutions of Gross-Pitaevskii Systems

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We briefly review results concerning the Lie point symmetries of Non-Linear Schrödinger equations. Then we carry out the complete group classification of the Gross-Pitaevskii Systems. We find numerical solutions corresponding to specific cases of the obtained classification.

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SQEAIR: An Improved Infectious Disease Dynamics Model

Chenxi Wang

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Traditional infectious disease models may not capture the complexity of modern epidemics, especially when governments implement diverse policies. This study introduces two distinct categories quarantined cases and asymptomatic cases to enhance the traditional SEIR model in depicting disease dynamics. To address the intricate nature of prevention and control efforts, the quarantined cases are further

segmented into three subgroups: exposed quarantined, asymptomatic quarantined, and infected quarantined cases. Consequently, a novel SQEAIR model is proposed to model the dynamics of Covid-19.

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Memory Effects for the Heat Conductivity in a Disordered Two-Phase Media

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Heat conduction of a suspension subjected to a time-dependent spatially constant temperature gradient is studied with the aid of stochastic functional expansions with random-point basis functions. It is argued that the basis function which is appropriate for modelling the chaotic behavior of nonlinear dynamical systems, e.g., turbulence, is not suited for studying composite materials. It is shown that within the first order of approximation with respect to the concentration, the equation for the kernel of the 1st-order functional integral is the equation of the disturbance introduced by a single sphere (filler) in a matrix subjected to a time-dependent temperature gradient. After solving the resulting initial-boundary value problem, the effective correlation between the heat flux and temperature gradient is established. It turns out that the effective law involves a retardation (memory integral) of the temperature gradient. Approximate expression for the memory kernel is found by employing a method based on infinite series expansion. An interesting limiting case of filler material with infinite conductivity is discussed where memory integral becomes the Riemann-Liouville half integral.

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Application Features of Artificial Neural Network Technology of Dielectric Cylinders Discrimination Using Multifrequency Reflectivity Measurements

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Discrimination of various objects using electromagnetic response is a key task in diverse fields, including remote sensing, security screening, and industrial quality control. Known classical approaches often rely on predefined features, and selecting the right features for electromagnetic responses can be a cumbersome task. Neural networks, through layers of abstraction, can automatically extract hierarchical features, improving the adaptability to diverse electromagnetic patterns, which makes them suitable for real-world applications where electromagnetic responses may come from a wide range of sources. In current research, the application of the three-component stacked neural network to classify dielectric cylinders of different radii located in free space based on the analysis of complex reflection coefficient imaged in the microwave range in conditions of the presence of white noise and possible diameter deviation is considered. The network consists of two sparse autoencoders and the softmax unit. For network training, 2D reflectivity images in the coordinates of longitudinal sensing and transverse scanning for cylinders with a series of radius values were obtained using the method of auxiliary sources. For each cylinder in network training and testing, at least 100 variations of added noise were generated in order to achieve the desired probability of classification. The possibility of successful recognition was confirmed for the case of the diameter deviation of 1 mm and the presence of additive Gaussian noise with SNR of down to 0 dB.

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Numerical Modeling of Pulsed Pirani Gauge Dynamics: Non-Constant Filament Temperature Analysis

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This study presents a numerical modeling approach to investigate the dynamics of a pulsed Pirani gauge under conditions of non-constant filament temperature. The Pirani gauge is a widely used device for measuring low pressures in vacuum systems, relying on the thermal conductivity of gas molecules to determine pressure.

However, conventional models often assume a constant filament temperature, neglecting potential variations induced by pulsing operations. In this work, we use two numerical models, the ANSYS system and Direct Simulation Monte Carlo method, that accounts for temporal variations in filament temperature during pulsing cycles. By incorporating transient heat transfer and gas flow dynamics, our models provide insights into how the gauge responds to fluctuations in filament temperature, offering a more accurate representation of gauge behavior. Through simulations, we explore the effects of varying pulsing frequencies, duty cycles, and gas properties on gauge performance. Our findings highlight the importance of considering non-constant filament temperature in the design and optimization of pulsed Pirani gauge, offering valuable guidance for enhancing gauge sensitivity and reliability in practical applications.

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ϕ^4 Model under Neumann-Dirichlet Boundary Conditions

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The minimization of the Ginsburg-Landau ϕ^4 functional is at core of the so-called ϕ^4 model, which is one of the basic models of statistical mechanics. The minimization leads to a second order nonlinear differential equation that has to be solved under specific boundary conditions. In the current article we consider a system with a film geometry with thickness L under Neumann-Dirichlet boundary conditions applied along the finite-direction. We study the modifications of the bulk phase diagram for the finite system, as well as the field-temperature behavior of the characterizing the system order parameter profile, the connected to it corresponding response functions and the fluctuation-induced Casimir force.

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Miura Transformations and Large-Time Behaviors of Good Boussinesq Equation and Its Modified Versions

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In this talk, we will build Miura transformations among good Boussinesq equation, Hirota-Satsuma equation and modified Boussinesq equation by the corresponding Riemann-Hilbert problems. Then the large-time behaviors of these equations are studied based on Deift-Zhou nonlinear steepest descent approach.

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Topological, Differential Geometry Methods and Modified Variational Approach for Calculation of the Propagation Time of a Signal, Emitted by GPS-Satellite and Depending on the Full Set of 6 Keplerian Parameters

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In preceding publications [1, 2, 3] a mathematical approach has been developed for calculation of the propagation time of a signal, emitted by a moving along an elliptical orbit satellite and accounting also for the General Relativity Theory (GRT) Effects. So far, in [2, 3] the formalism has been restricted to one dynamical parameter (the true anomaly or the eccentric anomaly angle). In this paper the aim is to extend the formalism to the case, when also the other five Keplerian parameters will be changing and thus, the following important problem can be stated: if two satellites move on two space-distributed orbits and they exchange signals, how can the propagation time be calculated?

This paper requires the implementation of differential geometry and topological methods. In this approach, the action functional for the propagation time is represented in the form of a quadratic functional in the differentials of the Keplerian elements (see [1]) $(a, e, I, \omega, \Omega, f)$, consequently the problem is related to the first and second quadratic forms from differential geometry. Such an approach has a clear advantage, because if the functional is written in terms of Cartesian coordinates

X, Y, Z, the extremum value after the application of the variational principle is shown to be the straight line – a result, known from differential geometry, but not applicable to the current problem of signal exchange between satellites on different orbits. So the known mapping from celestial mechanics [2, 3] is used $(X, Y, Z) \to (a, e, I, \omega, \Omega, f)$, which signifies a transition to a submersion manifold (of more than 3 dimensions). If a variational approach is applied with respect to a differential form in terms of the differentials of the Keplerian parameters, the second variation will be different from zero and the Stokes theorem can be applied, provided that the second partial derivatives of the Cartesian coordinates with respect to the Keplerian parameters are assumed to be different from zero - from topology this requirement is equivalent to the existence of the s.c. Morse functions (non-degenerate at the critical points). At the end, since the result of the variational formalism depends on the permutation of the indices, related to $(a, e, I, \omega, \Omega, f)$, the possibility to account for the symmetry groups from group theory is briefly discussed.

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Criteria for Oscillation of Bounded Solutions of Quasi-Linear Second-Order Impulsive Functional-Differential Equations of Neutral Type with Variable Coefficients

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This paper deals with quasi-linear second-order impulsive functional-differential equations of neutral type with variable coefficients. A criterion for oscillation of the

bounded solutions of such equations is presented. In order to obtain this criterion, a specially constructed function that acts as a boundedness specifier is used.

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Structural Morphologies on the Molecular Parameters of PLGA-b-PEG-b-PLGA and Dtx

Dongmei Liu

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Our simulations show that the PLGA-b-PEG-b-PLGA copolymers in the aqueous solutions could aggregate and form a blank micelle while Dtx drug and PLGA-b-PEG-b-PLGA could aggregate and form a drug-loaded micelle. Under different PLGA-b-PEG-b-PLGA concentrations and drug content, the blank and drug-loaded micelles are observed as spherical, onionlike, columnar, and lamellar structures. The onionlike structures are comprised of the PEG hydrophilic core, the PLGA hydrophobic middle layer, and the PEG hydrophilic shell. As the structure of micelle varies from spherical core-shell structure to core-middle layer-shell onionlike structure, the distribution of the Dtx drugs diffuses from the core to the PLGA middle layer of the aggregate. In addition, the drug release process of the Dtx-loaded micelles under shear flow is also simulated. And the results show that the spherical micelles turn into a columnar structure under a shear rate from 0.2 to 3.4. When the shear rate increases to 3.5, the Dtx drugs released gradually increase until all are released with time evolution. These findings illustrate the dependence of the structural morphologies on the detailed molecular parameters of PLGA-b-PEG-b-PLGA and Dtx.

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Combined Electron and Proton Radiation Effects on Solar Cells for Earth Orbit

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We present a computational approach for accurate calculation the combined electron and proton radiation effects in space on specific orbit, taking into account the entire spectrum of particle energies. The ultra-thin silicon solar cell produced by Solestial, Inc. intended for use in space to provide power for NASA space missions, DOD and commercial satellites. The radiation effects attributed to defect formation are demonstrated to depend on the NIEL (Non-Ionizing Energy Loss), that is a small fraction of the particle (electron or proton, or any ion) energy loss for ionization of the material [1]. The Navy Research Lab developed prediction of the solar cell degradation due to the radiation effects is based on NIEL, and its results compare well with the JPL approach for solar cell degradation prediction, while the latter is more complicated approach [2],[4],[5],[6] and experiments. To calculate NIEL dependence of energy, S(E), for the electrons and protons, we use the ESA NIEL calculation tool [3]. The computational procedures for determining the radiation environment and its impacts will be presented and discussed. The coordinate generator provided by SPENVIS [7] is used for the spacecraft trajectories (LEO, MEO or GEO). The trapped particle (proton and electron) fluxes are simulated with the International Radiation Environment Near Earth (IRENE) model, available as well in SPENVIS, that has different options (mean, percentile, perturbed and Monte Carlo), that depend on the launch date and duration of the space mission.

Obtained proton and electron particle fluxes (integral and differential) are used to calculate the Displacement Damage Dose (DDD) by integrating the product of NIEL with the differential particle fluxes over the actual particle energy range. The specific software tools have been developed to provide the extraction of the particle fluxes from SPENVIS data, interpolation and integration them to obtain DDD values for protons and electrons, as well as combined DDD. The equivalent proton and electron fluences are provides, for example as 3 MeV protons and 1 MeV electrons. The developed tools help to provide an efficient approach for evaluation of the radiation environment and its effects on solar cells during the planning of the space mission, formulate the requirements for materials and design and provide the data for prediction of the space power generation during a mission.

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Simulation of Space Radiation-Induced Defects in Silicon Solar Cell Using Density-Functional Theory

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The computational approach based on Density-Functional Theory presented in this work is used to quantify the effects of electron and proton radiation on the ultra-thin silicon solar cell produced by Solestial, Inc. in space environment.

Solar cells deployed in outer space, as well as in Lunar or Martian environments, are subject to high-energy particles bombardment, resulting in radiation-induced degradation. Despite the widespread of in silicon photovoltaic (Si PV) technology, the mechanisms underlying radiation damage is not yet well understood.

Meticulous determination of the defect and impurity signatures (apparent activation energy, capture cross-section for holes and electrons as well as their concentration) can considerably facilitate the defect engineering strategies for doping and thermal processing to achieve the desired materials properties. Experimental measurements of defects are typically done using Deep Level Transient Spectroscopy (DLTS), which is costly, time-consuming and provides limited information on the specification of occurred radiation damage.

To address this challenge, Density-Functional Theory (DFT) calculations [3, 4] are employed. DFT is a powerful computational tool for atomic-scale materials science, widely used to study defects in semiconductors and predict their structural and electronic properties, vibrational and diffusion dynamics as observed by the various experiments [Drabold 2007].

Previous studies by Adey [1, 2] have demonstrated the accuracy of DFT calculations of energy level computations, particularly ones responsible for the degradation of boron-doped CZ-Si solar cells. Specifically, calculations using the AIMPRO DFT code have provided insights into the optical and electrical activity of boron interstitial defects in silicon as well as the formation of various boron-related defects (BiOi, BiCs, and BiBsHi), or boron-containing clusters as a result of electron irradiation or ion-implantation.

In this work, specific defect energy calculations are conducted using first-principles DFT and implemented in the SIESTA code, an open-access and open-source DFT code developed as part of the Spanish Initiative for Electronic Simulations with Thousands of Atoms. SIESTA [5] offers a wide range of accuracy and cost tuning, making it suitable for both exploratory calculations and highly accurate simulations. By leveraging SIESTA, the proposed computational approach aims to develop prototype structures and data relevant to solar cell devices and materials in space radiation environments. These calculations are validated against experimental data for silicon material [6].

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Minimization Principle for Analytical Solution of Turbulent Flow in Channels

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The analytical solution for turbulent flow in channel presented in [1], described the mean turbulent flow velocity as a superposition of the laminar (parabolic) and turbulent (superexponential) solutions.

In this study, the coefficients of superposition are proposed to obtain through the minimization principle, the principle of minimum viscous dissipation [2, 3]. The obtained analytical solutions agree well with the experimental data for turbulent flow in channels.

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Efficient Preconditioned IDR Solver for Scientific and Industrial Applications

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A review of preconditioned solver for large-scale applications in science and industry is presented. The analysis, parallelization, and optimization approach for large unstructured sparse matrices using IDR methods are considered for modern multicore microprocessors.

CNSPACK is an advanced solver successfully used for the coupled solution of stiff problems arising in multiphysics applications, such as Computational Fluid Dynamics (CFD) for high Reynolds number turbulent flows, turbulent boundary layers, hypersonic and rarefied flows, carrier transport in semiconductors, and kinetic and quantum mechanics problems [2,3,4,5,6]. CNSPACK employs an iterative IDR algorithm with ILU preconditioning (where the user chooses the ILU order).

Originally, CNSPACK was implemented and optimized for early sequential processors, considering their arithmetic and memory-size limitations. In the early 1990s, the first optimization exercise was performed to accelerate the algorithm by 6 times for emerging superscalar microprocessors, such as the Intel i860 [1].

However, there has been a significant shift in processor architectures and computer system organization since that time. Nowadays, desktop computers and cluster nodes utilize high-performance pipelined superscalar multicore processors with out-of-order execution of instructions, deep cache hierarchies, and high-throughput memory capabilities.

As a result, performance criteria and methods have been revisited, along with consideration of parallelization involving the solver and preconditioner using the OpenMP environment [7]. Results of the successful implementation for efficient parallelization are presented for computer systems based on Intel Core i7 or Xeon multicore multiprocessor architectures.

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Advanced Stochastic Method for Finance Applications

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S. Apostolov

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In this study, we tackle the complexities of multidimensional option pricing, a cornerstone in today's vast finance-related challenges. Specifically, we explore the valuation of European call options, which grant the buyer the right (but not the obligation) to purchase a specified amount of an underlying asset (S) at a predetermined price (strike price, E) on a fixed date (maturity, T). The usage of Monte Carlo and quasi-Monte Carlo methods has become increasingly prevalent in modern finance due to their robustness in solving various complex financial problems. This paper discusses the efficacy of these methods in determining the fair value of multidimensional European style options. Monte Carlo methods are particularly advantageous in higher dimensions and are employed extensively in option pricing scenarios. We present simulation optimization techniques that utilize low discrepancy sequences and variance reduction strategies to significantly enhance the precision of traditional models for pricing European style options. This increase in accuracy is vital for generating more dependable outcomes in European option pricing. Moreover, the approaches we propose can be particularly beneficial in scenarios where traditional deterministic methods might be inadequate, such as in high-dimensional contexts or with complex contract stipulations.

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Advanced Stochastic Method for Multidimensional Integrals in Statistics

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In Bayesian statistics, evaluating multidimensional integrals is a crucial yet challenging task, especially in the context of high-dimensional spaces. This paper presents a comprehensive experimental study that explores the efficacy of quasi-Monte Carlo algorithms for this purpose. Our numerical tests are designed to assess the efficiency of these stochastic algorithms in handling multidimensional integrations, with a particular focus on high-dimensional integrals which are prevalent in areas like Bayesian statistics and machine learning. The results demonstrate that the quasi-Monte Carlo methods significantly outperform traditional methods in terms of accuracy and reliability.

The findings underscore the potential of advanced quasi-Monte Carlo methods in providing more precise and dependable results for Bayesian statistical analyses, which is vital for robust applications in machine learning and other data-intensive fields. This study not only contributes to the understanding of stochastic algorithm performance in high-dimensional statistical computations but also highlights the importance of choosing appropriate integration techniques for improving the interpretation of Bayesian models.

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First Order Approximation of First Derivative and Applications

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The paper proposes a construction of an approximation of the first derivative and applications of this approximation for numerical solutions of differential equations. The approximation and its asymptotic formula have a generating function which is a transformation of the formula for the sum of a geometric series. The coefficients of the approximation contain the powers of the parameter, and the last two coefficients are determined using Taylor's formula. Applications of the approximation for numer-ical solutions of first-order ordinary differential equations and the heat conduction equation are considered. The properties of the coefficients of the approximation allow numerical solutions of ordinary differential equations to be computed with $O(n)$ operations on a uniform grid with n nodes. The numerical solutions of partial differential equations are computed with $O(mn)$ operations where m and n are the number of nodes in space and time. The efficiency of the proposed numerical methods are compared with the first-order implicit Euler method using backward differences for approximating the first derivative. The results of numerical experim-ents are presented in the paper.

The paper proposes a construction of an approximation of the first derivative and applications of this approximation for numerical solutions of differential equations. The approximation and its asymptotic formula have a generating function which is a transformation of the formula for the sum of a geometric series. The coefficients of the approximation contain the powers of the parameter, and the last two coefficients are determined using Taylor's formula. Applications of the approximation for numer-ical solutions of first-order ordinary differential equations and the heat conduction equation are considered. The properties of the coefficients of the approximation allow numerical solutions of ordinary differential equations to be computed with $O(n)$ operations on a uniform grid with n nodes. The numerical solutions of partial differential equations are computed with $O(mn)$ operations where m and n are the number of nodes in space and time. The efficiency of the proposed numerical methods are compared with the first-order implicit Euler method using backward differences for approximating the first derivative. The results of numerical experim-ents are presented in the paper.

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Riemann–Hilbert Problems and Integrable Equations

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This talk is based on the paper [1]. The standard approach to integrable nonlinear evolution equations (NLEE) usually uses the following steps, see [2,3,4]:

1. Lax representation $[L, M] = 0$;
2. construction of fundamental analytic solutions (FAS);
3. reducing the inverse scattering problem (ISP) to a Riemann-Hilbert problem (RHP)
$$\xi^{+}(x,t,\lambda) = \xi^{-}(x,t,\lambda)G(x,t\lambda)$$
on a contour Γ with sewing function $G(x,t,\lambda)$.
4. soliton solutions and possible applications. Step 1 involves several assumptions: the choice of the Lie algebra g underlying L, as well as its dependence on the spectral parameter, typically linear or quadratic in λ.

Our idea is to use another approach that substantially extends the classes of integrable NLEE. Its first advantage is that one can effectively use any polynomial dependence in both L and M. We use the following steps [1]:

A. Start with canonically normalized RHP with predefined contour Γ, say $\Gamma = \mathbb{R} \cup i\mathbb{R}$
$$\xi^{+}(x,t,\lambda) = \xi^{-}(x,t,\lambda)G(x,t,\lambda), \qquad \lambda \in \mathbb{R} \cup i\mathbb{R};$$

B. Specify the x and t dependence of the sewing function defined on Γ, say by:
$$i\frac{\partial G}{\partial x} - \lambda^{2}[J, G(x,t,\lambda)], \qquad i\frac{\partial G}{\partial t} - \lambda^{4}[J, G(x,t,\lambda)];$$
where J is a constant diagonal matrix.

C. Introduce convenient parametrization for the solutions

$$\xi^{\pm}(x,t,\lambda) = \exp(\mathcal{Q}(x,t,\lambda,))$$

compatible with the canonical normalization of RHP. Here

$$\mathcal{Q}(x,t,\lambda) = \sum_{s=1}^{\infty} \lambda^{-s} Q_s(x,t).$$

D. This RHP gives rise to a Lax pair

$$L\psi = i\frac{\partial\psi}{\partial x} - U(x,t,\lambda)\psi(x,t,\lambda) = 0, \quad M\psi = i\frac{\partial\psi}{\partial t} - V(x,t,\lambda)\psi(x,t,\lambda) = 0,$$
$$U(x,t,\lambda) = \left(\lambda^2 \xi^{\pm} J \hat{\xi}^{\pm}(x,t,\lambda)\right)_+, \quad V(x,t,\lambda) = \left(\lambda^4 \xi^{\pm} J \hat{\xi}^{\pm}(x,t,\lambda)\right)_+, \quad (1)$$

where the subscript + means the polynomial part in λ of the corresponding expression. One can check that $U(x,t,\lambda)$ and $V(x,t,\lambda)$ are parametrized by by Q_1, Q_2 and their x-derivatives and give rise to a system of nonlinear evolution equations (NLEE) of NLS type.

E. Use Zakharov-Shabat dressing method to derive their soliton solutions. This requires correctly taking into account the symmetries of the RHP.

G. Define the resolvent of the Lax operator and use it to analyze its spectral properties.

These results may be generalized also to Lax pairs with more complicated contours, such as $\Gamma = \mathbb{R} \cup i\mathbb{R} \cup \mathbb{S}^1$, where $\mathbb{S}^1$ is the unit circle. Such contours are due to additional symmetries of the Lax pair involving mappings $\lambda \to \lambda^{-1}$. Examples of NLEE with such additional symmetries will be presented.

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Approach to Optimizing and Managing Warehouse Stock in a Car Service

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Auto repair shops face many challenges in their day-to-day operations, one of the most important of which is maintaining efficient inventory management. Inventory management involves not only maintaining a sufficient amount of auto parts in stock, but also balancing the costs of purchasing and storing the auto parts. A particularly complex aspect of this problem is the choice of suppliers. In real life, workshops often have the option of purchasing from different suppliers who may offer different prices and terms. Supplier selection can have a significant impact on overall inventory costs. In this article, we will look at an inventory management model in an automotive repair shop that takes these complexities into account. In particular, the model will consider the case where there are multiple suppliers and "either-or" constraints. Inventory management is a critical aspect of the efficient operation of any automotive repair shop. From maintaining appropriate levels of auto parts to selecting the right suppliers, each decision can have a significant impact on a dealership's operational efficiency and financial results.

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On the N-Wave Hierarchy with Constant Boundary Conditions

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In this talk, we will present the direct scattering transform for the N-wave resonant interaction equations with non-vanishing boundary conditions. For special choices of the boundary values $Q_{\pm}$, we outline the spectral properties of L, the direct scattering transform and construct its fundamental analytic solutions. Then, we generalise Wronskian relations for the case of constant boundary conditions.

Finally, using the Wronskian relations we derive the dispersion laws for the N-wave hierarchy and describe the NLEE related to the given Lax operator. The results are illustrated by an example of 4-wave resonant interaction system related to the algebra $sp(4, \mathbb{C})$.

Acknowledgement. Based on a joint work with Vladimir S. Gerdjikov [1,2].

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Reparametrization Invariance and Its Relation to the Dark Energy and Dark Matter Phenomena

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The nature of Dark Energy (DE) remains an enigma, currently hypothesized to be the source of the Universe's accelerating expansion. This work explores the non-zero Einstein Cosmological Constant (Λ_E) as a potential manifestation of DE, interpreting it through the lens of Reparametrization Invariance (RI). The scale factor λ relevant for cosmic reparametrization, its defining equations, and their relations to Λ_E are derived. Furthermore, by insisting on a reparametrization symmetry for the equation of motion, it is demonstrated how to address the missing mass problem at galactic and extragalactic scales. This approach leads to the derivation of the Modified Newtonian Dynamics (MOND) fundamental relation $g^2 = (a0 g_N)$ within the RI paradigm, where g is the gravitational acceleration, $a0$ is the MOND fundamental acceleration, and g_N is the Newtonian gravitational constant. Remarkably, the derived values for Λ_E and $a0$ are found to be consistent with their observed orders of magnitude.

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Mathematical Modeling of the Vortex Couple Dynamics in a Stratified Fluid

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The problem of the dynamics of the vortex pair in stratified liquid is considered. The pair is two vortexes arranged symmetrically relative to the vertical axis, but with the opposite direction of rotation, so that it begins to rise upwards. The mathematical model of a pair of vortices in a viscous stratified medium was studied. Salinity is chosen as a stratifying component, just as it can be implemented in the laboratory. The task is described by the Navier-Stokes equations in the Boussinesq approximation. To solve the problem, the SMIF method is used, of course, the finite different scheme of which has such properties as the second order of approximation on spatial variables, minimal scheme dissipation and dispersion, performance in wide range of Reynolds and Froude numbers and, most importantly, when solving wave processes are a property of monotony. The dynamics of such a pair are studied depending on its geometric sizes, the intensity of the vortexes and the depth of their initial immersion.

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Machine Learning/Artificial Intelligence (ML/AI) Models: Explainable and/or Causal

G. Haynatzki, R. Haynatzki

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ML/AI models have become more complex and it is increasingly difficult to understand how they make predictions and what those predictions really mean. Two emerging fields, (i) causal and (ii) explainable ML/AI, aim to address this challenge. Causal and explainable ML/AI find applications in medicine and other fields, where ML/AI are a main tool. We will review (i) and (ii) and consider case studies from practice.

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Exploring Predictive Models in Myocardial Infarction: A Comparative Study of LASSO Logistic Regression and XGBoost within a Causal Mediation Framework

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The prediction of myocardial infarction (MI) outcomes remains pivotal for advancing treatment strategies in cardiology. This study proposes to compare the variable selection efficacy and predictive power of LASSO logistic regression and XGBoost, incorporating a causal mediation approach to elaborate on the underlying mechanisms influencing MI risks. Leveraging the Gusto dataset on MI patients, this research will employ LASSO logistic regression to facilitate variable selection, aiming to identify critical predictors with substantial impacts on MI outcomes. Alternatively, the XGBoost algorithm will be utilized to assess its approach to variable selection and prediction. Both methods will be evaluated based on their Area Under the Receiver Operating Characteristic Curve (AUC) to determine their predictive accuracy. Furthermore, causal mediation analysis will be integrated to explore the putative effects of key predictors, identified in previous studies. The analysis aims to reveal which method offers superior predictive performance and how well each can be interpreted in a clinical context. This study can contribute valuable insights into the comparative advantages of using LASSO logistic regression versus XGBoost in the field of cardiovascular disease research. By integrating causal

mediation analysis, we aim to extend beyond mere prediction to offer a deeper understanding of the causal relationships and mechanisms at play.

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Computer-Aided Diagnosis Models for Breast Cancer Detection Decision Support Systems

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Computer-aided diagnosis (CADx) technology is crafted to mitigate the observational errors made by physicians and reduce the occurrence of false-negative results when interpreting medical data. Prospective clinical studies have demonstrated an enhanced efficacy in breast cancer detection using CADx, particularly crucial during the initial evaluation of patients by primary care physicians. The current stage of development in breast cancer diagnosis and prevention necessitates the development of novel, user-friendly auxiliary computer aids accessible directly to frontline medical practitioners, thereby obviating the need for costly computer systems.

We have devised a non-relational database of factual data designed to house the results of patient studies, which can be harnessed for machine learning in computer-aided breast cancer diagnosis systems. This database encompasses a heterogeneous vector of primary measurements (metadata, files adhering to the DICOM standard, alongside other images and data) for each patient, facilitating the construction of a neural network for tumor recognition and preliminary classification. We have populated the database with new, region-specific data pertinent to the health status of women in Ukraine amidst severe stress induced by the ongoing conflict. This initiative aims to enhance the efficiency of the primary diagnostic process and expedite the development of a comprehensive integrated computer system.

Additionally, we have developed a system for concurrent monitoring of ultrasound, computed tomography, and mammography results, complemented by a decision support system for simultaneous cross-verification of neoplasm diagnoses based on density and spatial correlation.

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Instability of Three-Body Periodic Collisionless Equal-Mass Free-Fall Orbits

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In our recent work [1] we have increased 400-fold the number of the known three-body periodic collisionless equal-mass free-fall orbits. In the present work we show the numerical results for the stability of the found in [1] periodic orbits. The stability is investigated by high precision computations of the eigenvalues of the corresponding monodromy matrices. All found periodic orbits are unstable, more precisely, they are from hyperbolic-hyperbolic or hyperbolic-elliptic type. We discuss the distribution of Lyapunov exponents as functions of scale invariant quantities, and their general (in) significance for astro-dynamics and chaos theory.

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Solving Nonlinear Wave Equations Based on Barycentric Lagrange Interpolation

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In this paper, we deeply study the high-precision barycentric Lagrange interpolation collocation method to solve nonlinear wave equations. Firstly, we introduce

the bar-ycentric Lagrange interpolation and provide the differential matrix. Secondly, we construct a direct linearization iteration scheme to solve nonlinear wave equations. Once again, we use the barycentric Lagrange interpolation to approximate the (2+1) dimensional nonlinear wave equations and (3+1) dimensional nonlinear wave equations, and describe the matrix format for direct linearization iteration of the nonlinear wave equations. Finally, the comparative experiments show that the barycentric Lagrange interpolation collocation method for solving nonlinear wave equations have higher calculation accuracy and convergence rate.

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Title TBA

N. Ivanov

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We give an asymptotic estimate for the Folner function of the Baumslag-Solitar Groups BS(1,n).

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Understanding Biological Data Through *In Silico* Studies: Strategies for Targeted Antiviral Therapies

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Viral infections can be thought of as a process that impairs the cell's normal information flow, hindering regular functions and potentially resulting in cell death. This highlights the sensitive nature of the cellular information system and the dynamic interplay between living beings and the various environmental factors and agents. We explore this concept in the case of SARS-CoV-2 virus. Interestingly, a key role in this context play the two viral proteins which exhibit the highest and the lowest degrees of similarity to the respective SARS-CoV proteins — the helicase NSP13 with 99.8% similarity, and the ORF6, with only 69% similarity. Our results suggest a prospective targeted strategy impeding their blocking action.

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Internal Waves over Uneven Bottom and Soliton Equations

R. Ivanov

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The the effects of a variable bottom on the internal wave propagation in the presence of stratification and underlying non-uniform currents is studied by employing the Hamiltonian approach in the problem formulation. The presented models incorporate both wave-current interactions and a variable bathymetry. A physical example is given by the equatorial internal waves in the presence of the Equatorial Undercurrent. The internal wave is formed at the interface between two fluid layers with different characteristics. Physically the interface coincides approximately with the so-called thermocline and the pycnocline. The motion of the interface in the long wave approximation is modeled by a the Gardner equation with depth-dependent variable coefficients. This allows for the study of nonlinear phenomena like soliton propagation, birth and decay of solitons.

The talk is based on joint works with Calin I. Martin (Babes-Bolyai University, Cluj-Napoca, Romania) and Michail D. Todorov (Bulgarian Academy of Sciences).

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Visual Analysis of Flow and Diffusion of Hemolytic Agents and Hematomas

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The elimination of intracranial hematomas has received widespread attention and the interactions between hemolytic agents and hematomas have become a hot research topic. In this study, we used the Navier-Stokes equation to describe the flow control equation for hemolytic agents in a tube and used Fick's law and the Maxwell- Stefan diffusion theory to describe the diffusion and mass transfer of hemolytic agents and hematomas. The physical fields and initial boundary conditions were set according to the parametric properties of the fluid and drainage tube. The COMSOL Multiphysics software was used to simulate the streamline distribution of hemolytic agents in a bifurcated drainage tube. Additionally, the diffusion behaviors of the hemolytic agents into hematomas were simulated and visual analysis of coupled multiphysics was performed to realize the digitization and visualization of engineering fluid problems and contribute to the field of medical engineering.

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Modeling of the Noise Emissions of Centrifugal Fan with Different Impellers Geometry

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In this paper, an empirical analysis of the noise emitted by a hydraulic system with a centrifugal fan is performed. Four impellers with different geometrical shapes are examined. By means of correlation and factor analysis, the influence of the angle of the impeller leading edge on the emitted noise is determined. The dependence of the noise, in individual octave bands, on impeller type and fan flow rate is modeled. A comparative analysis of different models is made. At the nominal flow rate of each impeller, a continuous noise measurement is performed to determine the statistical parameters that illustrate the stability of the noise emissions, estimated with the variance and coefficient of variation, as well as the parameters of the distribution law of the obtained values. The flow rate was measured with a standardized flow meter, a nozzle that was installed as a smooth inlet to the suction line. The nozzle and its metering characteristic were designed and calculated according to

the ISO 5801 standard. The error of the measured quantities - flow rate and noise level is determined. Confidence intervals for the noise emissions have been constructed, taking into account the measurement errors. Noise is an important hygienic, diagnostic and technical parameter determining the safety of man-machine systems, quality of life and work. The results of the present work could be used for optimizing the operating mode of fan-assisted systems and the emitted noise.

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Noise as a Factor of Useful Signal Amplification Based an the Effect of Stochastic Resonance

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The effect of stochastic resonance is investigated. The principles of the effect are considered on the basis of a Brownian particle moving in a system with a symmetric bistable potential. Different from the widely existing noise elimination methods, stochastic resonance enables a new method to utilize the energy of noises, nonlinear system, and signal frequency to reach certain weak signal enhancement effects that noise elimination cannot perform well. The presence of noise at the input of nonlinear systems possessing the effect of the stochastic resonance allows to stand out a weak signal from an additive mixture with white Gaussian noise. The equation and structural scheme of stochastic resonance are considered The conditions for the occurrence of stochastic resonance are formulated and the determining role of noise dispersion in the realization of this effect is shown. For the first time, a numerical calculation of standing out of harmonic oscillation from an additive mixture with white Gaussian noise based on the stochastic resonance effect is carried out. The output signal-to-noise ratio dependence of the stochastic resonator on the intensity of input noise and the input signal frequency is investigated. The frequency dependencies of the output signal are investigated and the components of this signal are analysed. It is shown that the stochastic resonator acts as a low-pass filter and reduces the output noise level. Numerical modeling of the stochastic resonance effect also shows that the output signal of the stochastic resonator contains odd harmonics of the input oscillation, which is characteristic of nonlinear systems.

It is shown that the stochastic resonance effect can be widely used in radio engineering and telecommunications to amplify the useful signal.

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The Covid-19 Pandemic in Bulgaria: Models, Applications, Retrospection, and Lessons Learnt

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In the present lecture we survey the development of the Covid-19 pandemic in Bulgaria in the period 2020-2022. We provide some compartmental deterministic epidemiological models which have been used for modeling the course of the pandemic, as well as web-based tools for creating scenarios for short and long-term forecasts of the epidemic curves. We estimate the forecasts by the models and the related containment measures (NPIs, non-pharmaceutical interventions) and vaccinations which have been introduced by the health authorities in Bulgaria. We survey the most important and dramatic periods of the pandemic and try to summarize the lessons learnt from it.

The author acknowledges the support by projects KP-06-N52-1 and KP-06-N42-2 with Bulgarian NSF.

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Application of Machine Learning and Artificial Intelligence Techniques To Study Cannabinoid Compounds

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Recently, machine learning and artificial intelligence techniques have been widely used to predict the biophysical properties of chemical compounds. The successful application of these methods depends highly on the appropriate presentation of the compounds. In the present study, we comprehensively evaluate the performance of descriptor-based models for predicting cannabinoid receptor regulators and find that they offer excellent performance for regression and classification tasks. The derived features will facilitate cannabinoid receptor research by guiding preferred properties for compound modification and new drug design. Machine learning-based decision-making models are an alternative method to molecular docking and virtual screening. This study could provide useful results for further research on the application of machine learning in drug design.

Keywords: computer modeling, machine learning, biological efficacy

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Commutative Poisson Algebras from Deformations of Noncommutative Algebras and Non-Abelian Hamiltonian Systems

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By a well-known procedure, usually referred to as "taking the classical limit", quantum systems become classical systems, equipped with a Hamiltonian structure (symplectic or Poisson). From the deformation quantisation theory we know that a formal deformation of a commutative algebra $\mathcal{A}$ leads to a Poisson bracket on $\mathcal{A}$ and that the classical limit of a derivation on the deformation leads to a Hamiltonian derivation on $\mathcal{A}$ defined by the Poisson bracket. In this talk I present a generalisation of it for formal deformations of an arbitrary noncommutative algebra $\mathcal{A}$ [1]. A deformation leads in this case to a commutative Poisson algebra structure on $\Pi(\mathcal{A}) := Z(\mathcal{A}) \times (\mathcal{A}/Z(\mathcal{A}))$ and to the structure of a $\Pi(\mathcal{A})$-Poisson module on $\mathcal{A}$, where $Z(\mathcal{A})$ denotes the centre of $\mathcal{A}$. The limiting derivations are then still derivations of $\mathcal{A}$, but with the Hamiltonians belong to $\Pi(\mathcal{A})$, rather than to $\mathcal{A}$. We illustrate our construction with several cases of formal deformations, coming from known quantum algebras, such as the ones associated with the Kontsevich integrable map, the quantum plane the quantised Grassmann algebra and quantisations of the Volterra hierarchy [2,3,4].

Acknowledgement. This talk is based on a joint work with Pol Vanhaecke [1].

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On the Estimation of Uncertainty in Noise Studies of a Centrifugal Fan

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This work describes an experimental setup for investigating the noise characteristics of a centrifugal fan under different operating modes. The apparatus enables to study the noise during operation of the fan with impellers of different blade geometry. A standardised free inlet nozzle, manufactured to ISO 5801:2007, is used to measure the flow rate Q at the inlet of the suction line. The analytical form of the flow rate as a function of the measured vacuum (conversion function) is obtained based on values calculated according to the standard over the whole measuring range. When investigating the fan noise, it is necessary to take into account the uncertainty of the measured sound pressure level and the total uncertainty of the fan flow calculated by the conversion function using the measured vacuum. Since the flow rate is an indirect measurand, the uncertainty of all quantities in the flow measurement and determination chain must be taken into account to estimate its total uncertainty. For this purpose, the uncertainty of the measured vacuum, the uncertainty of the flow rate calculated according to the ISO 5801:2007 standard and the uncertainty coming from the approximation of the flow rate with the transformation function are investigated and described. The estimation of the uncertainty of the measured quantities is necessary in order to be able to account for it subsequently in the analysis of various experimental data.

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A New Application of the Kinetic Type Theory in Immunology

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The kinetic type theory for active particles is a methodology actively used for modeling processes and phenomena in biology and life sciences. One of the

fields of its application is immunology, in particular the processes observed in the competition between immune system and foreign antigens. In this paper we present a new mathematical model describing such a complex system and possible occurrence of contemporary diseases.

Preliminary qualitative analysis of the model is presented. The role of some of the main model parameters is studied using simulations.

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Forecasting Strategies in Retail: Utilizing Advanced Machine Learning Methods while Safeguarding Privacy

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In this study a group of mathematicians and data experts lead the investigation into using machine learning to analyze sales data focusing on time series analysis. This examination takes place within the context of privacy regulations such as GDPR and CCPA. The main goal is to leverage sales information to predict market trends and improve customer satisfaction all while upholding consumer privacy.

The methodology we have employed combines models with machine learning techniques placing emphasis on time series analysis for its effectiveness in forecasting sales trends. This is complemented by the application of decision trees and neural networks to gain insights into the market. In order to comply with privacy laws we have integrated anonymization strategies like privacy and k anonymity to strike a balance between data analysis and privacy protection.

Our findings highlight the potential of machine learning in predicting trends confirming that ethical handling of data can align with rigorous analysis practices. This research presents a method for utilizing analytics in retail settings offering a roadmap, for making data driven decisions while adhering to data privacy regulations thus reinforcing the importance of maintaining consumer confidence.

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Affine Yangian and 3D Young Diagrams

Na Wang and Ke Wu

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3D (3-dimensional) Young diagram is a generalization of 2D Young diagram. In this talk, we construct the symmetric functions corresponding to 3D Young diagrams, which are called 3-Jack functions. 3-Jack polynomials is the generalization of Jack polynomials and Schur functions. Then we consider the integrability on 3D Young diagrams.

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Mathematical Modeling of the Human Head and Neck: Problems and Possible Solutions

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Geometrical modeling is one of the modern ways of determining the mass-inertial characteristics of parts of the human body or the whole body. Up to now in most models head + neck have been modeled as an ellipsoid. Obviously, this is not satisfactory enough because at least to a contact of the neck with the torso of the body which is just a point. In the current study, we addressed this issue and do model the head + neck in a different way: i) the head is modeled as prolonged spheroid that is cut with horizontal plane forming cross section such that there it connects smoothly with the neck; ii) the neck is modeled as a cylinder. Performing the modeling in this way we were able to keep all vertical sizes exactly as measured by Yordanov *et al* (2006) including the length of the head + neck, the length of the head separately and also we kept all orthogonal sizes as measured by the same authors. Doing all that we were able to reproduce very well the mass of the head + neck as follows from the corresponding regression equations. In the current work, we use mathematical modeling to determine the mass-inertial characteristics of the segments under consideration and present analytical expressions for the mass, centre of mass, volumes and principal moments of inertia of the two segments head + neck as well as of the combination of them.

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Dynamic Analysis and Optimal Control Strategy of a SEIR-Type Infectious Disease Model with Reinfection and Vaccine Inefficacy

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In this paper, a SEIR-type epidemic model with reinfection and vaccine inefficacy is proposed. The existence, uniqueness, boundedness, and nonnegativeness of the model are derived. Based on the basic reproduction number R_0, locally stability and globally stability are analyzed. The sensitivity analysis evaluates the influence of each parameter on the R_0 and rank key epidemiological parameters. Finally, the necessary conditions for implementing optimal control are obtained by Pontryagin's maximum principle, and the corresponding optimal solutions are derived for mitigation disease transmission. With a lot of real data, the state trajectory of the model converges to the endemic equilibrium point. Compared with a combination of non-pharmaceutical interventions and vaccination strategy, the vaccine-only strategy has little difference in the number of infections and deaths. Furthermore, it is particularly important to develop new vaccines with higher protection rates.

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Technology of Using the Matrix Pencil Method for Processing Data with Impulse Noice

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Matrix pencil method is known to be a robust and reliable algorithm for parametric spectral analysis. It is used in a multitude of applications and thus is a great candidate for additional improvements. The problem considered in the

current paper is one of impulse noise present in data. Such noise may lead to the breakdown of the standard method since its bursts are too rare for purely statistical methods to operate. In order to allow the method to process signals with white noise, several techniques are applied. These techniques include the segmentation of the signal and subsequent analysis of individual segments. For each of the segments, either the linear prediction coefficients (based of the Vieta's formulas), frequency, or frequency and amplitudes are estimated along with some segment fitness criterion. This fitness criterion can take the form of, for example, local SNR value, or signal deviation measure. This criterion is then used in either weighted mean or median procedures, or for excluding some segments from the analysis entirely. It is well-known, that the usual root mean square measure for the signal deviation. Thus, the measure based on the minimum duration principle is tested for this task. The techniques are tested for sweeps of a single frequency and randomized multifrequency signals. The optimal parameters for the methods are chosen based on the discrete local search computation.

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Acoustic Recognition of Anthropogenic Underground Voids Using Machine Learning Methods

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The development of hostilities in Ukraine, Israel, Yemen and other countries demonstrates that in the modern war against terrorists, those states that use the latest scientific developments have an advantage. Underground storage facilities and tunnels of terrorists are still a problem for legitimate authorities; their identification is difficult, despite the almost two thousand years of development of recognition methods and the use of satellites. Government troops often do not have direct access to the earth's surface above bunkers and passages; above-ground structures may be located there; the soil structure may be heterogeneous and contain dense layers and inclusions that reflect radio waves. Therefore, it is promising to use acoustic recognition methods, which are already used in geophysics. In contrast to known methods for monitoring vibration waves during earthquakes, the initiation of vibration waves during the fight against terrorists can be carried out by delivering precise artillery or air strikes of known power to specified surface points on the terrorist side, which simplifies calculations. But solving the inverse problem for the propagation of acoustic waves is problematic due to the small relative sizes of these structures and their small influence on the parameters of the acoustic wave. The solution to this problem must be sought in the use of machine learning methods. Repeated calculations of a model for the propagation of underground vibrations in combination with satellite observation data on the presence and shape of above-ground structures makes it possible to build a neural network for analyzing vibrations of sensors located in government-controlled territory.

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Air Pollution Modelling of Accidents Involving Hazardous Substances

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Air pollution modeling for accidents involving hazardous substances is a critical aspect of emergency response and environmental protection. This modeling aims to predict the dispersion and impact of toxic substances released into the atmosphere during accidents, such as industrial spills, transport accidents, chemical plant incidents or acts of terrorism. Such dangers are among the challenges which the modern society is facing and has to overcome. In this talk we propose a systematic approach for organizing monitoring, collecting data from mobile sensors, creating situation development scenarios, modeling the spread of potential toxic-element pollution in dependence with the current meteorological conditions. The multi-energy method for calculation the overpressure during explosion, as well as the UNI-DEM model for simulation of the pollutants' dispersion and transport in the air are involved in this study.

Finally, depending on the comprehensive analysis of the modelling results, an adequate response to such severe situations can be proposed. Assessment of safety, healthcare and environmental impacts should be the final result and the most socially important application of our work. The calculated pollutant concentrations can be compared with regulatory standards or health-based guidelines to assess potential health risks to exposed populations and environmental impacts on ecosystems. The importance of this information for emergency response planning, public health interventions, and environmental management strategies is beyond dispute.

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Spreading and Leveling of Finite Thin Films with Elastic Interfaces: An Eigenfunction Expansion Approach

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The flow of a thin viscous liquid layer under an elastic film [1] arises in natural processes, such as magmatic intrusions between rock strata [2], and industrial applications, such as coating of surfaces with cured polymeric films [3]. We study the linear dynamics of small perturbations to the equilibrium state of the film in a closed trough (finite film). Specifically, we are interested in the spreading (early time) and leveling (late time) dynamics as the film adjusts to equilibrium, starting from different initial perturbations. We consider various forms of spatially symmetric initial conditions of initially localized perturbations. We find the exact series solutions for the film height using the sixth-order completely orthonormal eigenfunctions, associated with the posed initial-boundary-value problem, derived in our previous work [4]. We show that the evolution of the perturbations begins with the spreading of the localized perturbations, followed by their mutual interaction as they spread, and finally, interactions with the finite lateral boundaries of the domain as the perturbations level. In particular, we highlight various scalings of key quantities with time, which sometimes (but not always) exhibit self-similar features (such as power-law behavior with time), as discussed in [5].

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On Oppermann conjecture

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Oppermann conjecture states that there exists a prime between $n2$ and $n(n+1)$ and between $n(n+1)$ and $(n+1)2$, respectively. In this paper, on the basis of the characteristic function of odd primes, we introduce some conditional extreme values problems related to above conjecture and use the method of Lagrange multiplies and the induction to confirm the conjecture. Here the technique of"adding a new variable"and the infinitude of odd primes are used.

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Object-Oriented Zero-Information-Optimised Product of Monte Carlo Integrations

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We propose an object-oriented Monte Carlo framework for computation of definite integrals with a primary focus on generality. We introduce an optimised sampling method for a product of Monte Carlo integrations. The method does

not require any a-priori knowledge of the integrands or the integration domains, and can be combined with other optimisation methods. Using the object-oriented framework, we implement a naive uniform sampling method and the optimised one, and empirically compare them on the Monte Carlo computation of volumes of N-dimensional balls. The experiments confirm our theoretical expectations.

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Design and Realization of Self-Tuned Power Absorber Control System

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A self-tuning vibration absorber is capable of adjusting its intrinsic frequency in real time to track the excitation frequency and achieve effective vibration control over a wide frequency range. In this study, a self-tuning vibration absorber control system based on STM32 is proposed. The system acquires vibration signals using MPU6050 sensors, calculates the vibration frequency in real time, and controls the motor rotation to achieve self-tuning vibration absorber control. The system employs the STM32F407ZGT6 as the core control chip and is designed in terms of the overall scheme, hardware circuit, and software. For hardware, the system uses the STM32F407 as the control core and the MPU6050 sensor to obtain vibration signals while controlling motor rotation using the TMC2209 motor driver chip. Keil ?Vision software is applied for program writing and debugging. The system mainly includes modules for data acquisition, signal processing, control algorithm, and drive output. The signal processing module employs the fast Fourier transform (FFT) algorithm, which can achieve fast frequency calculation and vibration frequency tracking. Finally, experiments verify the system's feasibility and effectiveness. The experimental results demonstrate that the system can accurately control the self-tuning vibration absorber, with excellent control performance and practicality.

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Mathematical Modeling and Enhancing the Carrying Capacity of National Parks in the United States

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A rapid growth in the number of visitors has been observed for many national parks in the United States. As a result, public transit and parking resources have been stretched closer and closer to their capacities in these parks. In response, some National Park Services have started to implement crowd control measurements, such as the timed entry reservation systems, where visitors have to reserve their slots to visit the park during certain time periods of the year. However, such policy does not touch on the fundamental issue of the subject, that is, the carrying capacity

of the park. This paper utilizes polynomial approximation on historical recreation visit data to forecast a continued uptrend in visitor numbers in the near future, which means that a capacity boost is inevitable. Fortunately, we also observe that if we can fix some key bottlenecks, then we can dramatically increase the capacity of the park without destroying more natural land.

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Mathematical Modeling of the Operation of a Hydrophoric Installation

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In this paper, the performance of a pumping system in its operation with a hydrophore vessel connected in parallel is considered. The filling and emptying processes of the hydrophore and their influence on the flow rate to the system and the pump outlet pressure are experimentally investigated.

An automated measuring system are used for the measurements of the flow and the pressure, which cyclically recorded the values at equal time intervals. The measurement cycles are synchronised in time and the maximum errors of the measured quantities are known. From the experimental data, empirical relationships for flow rate and pressure as a function of time, as well as the relationships between the two quantities, are obtained. The time periods of each of the two processes and the average cycle length are also empirically determined. Confidence intervals of the flow rate are constructed for vessel filling and emptying, respectively, and measurement errors were accounted for. Codes have been created to determine the filling time of a hydrophore vessel and to calculate confidence intervals for this type of pumping systems, thanks to which all calculations have been automated. The described dependencies can be used in planning future experiments.

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The Application of the Melnikov Method in Multi-Steady-State Systems

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The SD oscillator represents a significant class within the realm of non-smooth mechanical models. In recent years, there has been a growing interest among scholars in exploring such models. This paper delves into the study of homoclinic orbits and subharmonic orbits within the context of multi-steady-state systems. To achieve this, we establish a theoretical framework for Melnikov analysis applicable to abstract non-smooth dynamical systems. Careful consideration is given to selecting an appropriate initial Poincarй section to prevent solution extensions near switching manifolds. Within this framework, Menikov functions play a crucial role in determining the threshold function for the occurrence of chaos in homoclinic orbits. Additionally, subharmonic Melnikov functions are derived to identify the initial conditions necessary for the existence of corresponding subharmonic orbits. To illustrate the efficacy of our developed Melnikov method in multi-steady-state systems, we present an example wherein an oscillator designed based on the SD oscillator is employed.To address the challenge of Melnikov integration along unperturbed systems, we introduce a numerical integration method. Through numerical simulations, we present phase portraits, time history diagrams, and spectrum diagrams, providing empirical evidence of the effectiveness of the developed Melnikov method. These simulations vividly showcase the motion characteristics, offering valuable insights into the dynamics under consideration.

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Integrable Rosenau-Hyman Equations

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Based on work with N. Euler, M. Euler, R. Hernández-Heredero, A. Benson, E. Diaz and J. L. D. Palencia

I will present a classification of all integrable equations in the Rosenau-Hyman family $D_t(u)+(u^m)_x+(u^n)_{xxx} = 0$. It is known that if $m = n = 2$, the corresponding Rosenau-Hyman equation admits compactons; the integrable Rosenau-Hyman equations do not, but they are very interesting to study. I will show that they all have

Lax pairs, non-trivial symmetry algebras, and at least some of them admit peakon solutions.

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The Newton-Cotes Quadrature Formulas with Error Term

Shuxia Li

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In this talk, we will present a direct and elementary proof of the Newton-Cotes Quadrature Formulas with Error Terms. We also arrive at a slightly more general theorem.

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The Inviscid Limit for Some Keller-Segel Equations

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In this talk, we consider the qualitative analysis for a general form of n-dimension Keller-Segel system with logistic sources. By the transport-diffusion theory, we first establish the local existence and uniqueness of strong solutions to PEKS and HEKS for the initial data in $B^s_{p,r}(\mathbb{R}^n)$ with $s > \max\{\frac{n}{p}, \frac{1}{2}\}$, $1 \leq p, r \leq \infty$ (or $s = \frac{n}{p}$, $1 \leq p \leq 2n, r = 1$), and also obtain the continuity of the solution map with respect to the initial data in the space $\mathcal{C}([0;T]; B^{s'}_{p,r}(\mathbb{R}^n))$ for every $s's$ when $r = +\infty$ or $s' = s$ when $r + \infty$, and then derive a continuation criterion result for HEKS. In addition, we prove this data-to-solution map for PEKS is discontinuous in the metric of $B^s_{2,\infty}$.

Furthermore, we show that the inviscid limit of the PEKS converges to the HEKS in the same topology of Besov spaces as the initial data $u_0 \in B^s_{p,r}(\mathbb{R}^n)$.

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On Solving and Optimizing 3D Contact Problems Taking the Nonlinear Law of Roughness Deformation into Account

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A detailed study of the real properties of contacting bodies stimulated the development of the theory of contact problems in the direction of considering these properties. As a result, contact problems for rough surfaces were formulated. In this paper, an indentation of a doubly connected punch into an elastic rough half-space is investigated taking into account a nonlinear law of change in the deformation of the surface roughness. With a power dependence of the displacement due to the deformations of microasperity on the pressure, the main integral equation is the Hammerstein equation. A solution to the integral equations by the small parameter method is proposed. The punch shape is taken as the desired function, and the role of the minimizing functional is played by the root-mean-square deviation of the normal pressure distribution arising under the punch from a certain optimal distribution. The obtained expansion of the potential of the simple layer at an internal point of the domain distributed over a doubly connected domain close to a circular ring is applied to the solution of pressing a non-circular annular punch into an elastic rough half-space. Two-dimensional integral equations are transformed into one-dimensional ones. Nonlinear integral equations are reduced to a sequence of linear equations in the case where the integration boundaries depend on a parameter. The result of the solution is shown by examples.

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Analysis of Method Based on Repeated BURA for Approximating Matrices on Fractional Power $\alpha > 1$

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Fractional diffusion has many application in science and engineering as it models non-local processes and phenomena. However, numerically solving such problems involves systems of linear algebraic equations with dense matrices. For practical problems such systems can be extremely large and applying the usual *LU* factorization methods becomes an extremely expensive computational task. The BURA (Best Uniform Rational Approximation) and related methods have

been developed in order to compute an approximation of the inverse $\mathbb{A}^{-\alpha}$ of a symmetric positive definite matrix $\mathbb{A}$ via an approximation of the scalar function $z^\alpha, \alpha \in (0,1), z \in [0.1]$. Thus solving a system of linear algebraic equations $\mathbb{A}^\alpha \mathbf{u} = \mathbf{f}$ can be computed approximately with

$$\mathbf{u} = \mathbb{A}^{-\alpha}\mathbf{f} \approx \lambda_1^{-\alpha} E_{\alpha,k} \left[\prod_{i=1}^{k} (\lambda_1 I - \zeta_i \mathbb{A})(\lambda_1 I - d_i \mathbb{A})^{-1} \right] \mathbf{f}. \tag{1}$$

Here λ_1 is the smallest eigenvalue of $\mathbb{A}$, k is the degree of the rational approximation and $E_{\alpha,k}$ is the pointwise error of the BURA approximation. It is proven that for $\alpha \in (0,1)$ the poles d_1, d_n and zeroes $\zeta_1, \ldots, \zeta_n$ of the rational approximation have the following interlacing property

$$0 > \zeta_1 > d_1 > \zeta_2 > d_2 > \cdots < \zeta_n > d_n > -\infty. \tag{2}$$

This property ensures the stability of the solution for $\alpha \in (0,1)$. However for $\alpha > 1$ some of the poles and zeroes are nonnegative which makes direct BURA approximation of power $\alpha > 1$ unsuitable. In this work we consider applying m repeated BURA approximations $\alpha_i \in (0,1]$ of lower power such that $\alpha = \sum_{i=1}^{m} \alpha_i,\ \alpha \in (1, +\infty)$. Thus for $\alpha > 1$ we solve problem (1) as

$$\mathbf{u} = \mathbb{A}^{-\alpha}\mathbf{f} = \mathbb{A}^{-\alpha_1} \cdots \mathbb{A}^{-\alpha_m}\mathbf{f}.$$

This allows us to compute only the stable BURA approximation for the $\mathbb{A}^{-\alpha_i}, \alpha_i \in (0,1]$.

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Non-Abelian Divisibe Groups

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In the present work, we consider the divisibility property for classical matrix groups by two approaches - purely linear algebraic and by theory of Lie groups and Lie algebras.

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Environmental Modeling by Using Advanced Stochastic Approaches

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In this study, we enhance multidimensional sensitivity analysis using novel stochastic methods to simulate air pollution on a grand scale, focusing on the long-range transport of air pollutants through the Unified Danish Eulerian Model (UNI-DEM). This crucial mathematical model plays a significant role in various studies aimed at understanding the detrimental effects of high levels of air pollution. We will employ it to address critical questions concerning environmental protection. The paper introduces refined Monte Carlo and quasi-Monte Carlo techniques, which incorporate specialized lattice and digital sequences to enhance digital ecosystem modeling and refine existing stochastic approaches. We have evaluated the computational efficiency of these advanced Monte Carlo algorithms for multidimensional numerical integration, focusing on their ability to analyze how sensitive the UNI-DEM model output is to changes in input emissions of anthropogenic pollutants and variations in several chemical reaction rates. These algorithms are applied to calculate global Sobol sensitivity indices, which measure the impact of various input parameters on the concentrations of key air pollutants. This analysis will cover several European cities with diverse geographical characteristics.

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An Intercriteria Approach to Assessing the Impact of Air Pollutants on Premature Deaths in the European Union

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Air pollution is the largest environmental health risk in Europe, with heart disease and stroke being the most common causes of premature death due to air pollution. This study estimates the health effects of exposure to fine particulate matter (PM2.5), nitrogen dioxide (NO2), and ozone (O3) in terms of years of life lost (YLL) and premature mortality within the European Union over a five-year period from 2018 to 2022. The InterCriteria Approach (ICrA) is employed, utilizing data provided by the European Environment Agency. ICrA, which is based on the theories of intuitionistic fuzzy sets (IFSs) and index matrices (IMs), offers a modern interpretation of classical correlation analysis under parameter uncertainty. ICrA refrains from using the term "correlation" between criteria and instead employs the terms "positive consonance", "negative consonance", and "dissonance". IFS theory, an extension of Zadeh's fuzzy sets, handles uncertain data, while IMs digitize intuitionistic fuzzy information for ICrA application. The results highlight the primary air pollutants that significantly influence years of life lost and premature mortality, providing valuable insights for public health policies in the European Union.

Key words: Air pollutant, InterCriteria analysis, Intuitionistic fuzzy logic, Premature deaths

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Entropic EMPIRISM in Describing the State of the Complex System: Biosphere-Technosphere-Noosphere and Human Health

M. Petrov, V. Traneva and S. Tranev

Prof. Asen Zlatarov University, Burgas, Bulgaria

This paper refers to the study of human states in interaction with the environment. The Biosphere with all its components ensures the unique complex homeostasis of the Biosphere-Technosphere-Noosphere complex system. By applying the results of the bioeconophysical conception, it is shown that the consumption of food by humans depends on the states of the Biosphere and the Technosphere. Throughout historical evolution, human metabolism depends on the states of the Biosphere and the Technosphere. Currently, some recent studies show at the level of observations and measurements that the temperature of the human body decreases over time, which denotes the change in human metabolism that originates from the symbiosis of human being with the Biosphere and Technosphere and the states of the Biosphere and Technosphere vary depending on the intensification of anthropogenic activities. The calculation expression of the human body temperature is obtained empirically by using the entropy conception of the Biosphere and the Technosphere. It is quantitatively shown that the temperature of the human body, from mathematical point of view is a function of the following parameters: the number of the population of the Earth, the energy metabolism of the human during a day; entropy variations of the Biosphere and the Technosphere. Namely, the source of maintaining the human temperature and its continued existence is necessary from a mathematical point of view, the existence of the entropy variation of the Biosphere and the Technosphere. From this expression can be seen that the excessive accumulation of emitted heat which comes from the anthropogenic activity, the temperature of the human body decreases slowly over time. The importance of this study shows that a quantitative expression is developed based on the bioeconophysical integrational platform which allows estimation of some parameters that vary depending on the variation of other parameters.

Key words: Anthropogenic activity, Entropy, Bioeconophysical conception, Metabolic rate, Temperature of human body

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Power Series Method for Nonlinear Fluid Dynamics Equations

V. Vatchev

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In the talk we discuss a Frobenius method for studying partial differential equations with a polynomial type of nonlinearity. Equations of this type are regularly used to model the dynamics of fluids and are often related to the Euler equations. We show that we can obtain a wide range of traveling wave solutions to well-known equations, KdV, Boussinesq, Camassa-Holm, and more, by using the proposed method.

For the classical Euler equations (EE) with a slightly modified kinematic equation we obtain an exact solution for the boundary conditions and the solution is a uniform approximation to the exact solution of the complete system. Furthermore, we show that in the context of asymptotic approximations the proposed method provides approximate solutions to the EE of exponential order. We also discuss properties, convergence, and extensions of the method.

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Particular Solutions to a Magnetic Type Nonlinear Evolution Equation

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We consider a 1+1-dimensional nonlinear partial differential equation that generalizes classical Heisenberg ferromagnet equation. This nonlinear evolution equation is integrable through inverse scattering method which allows one to construct special solutions in closed form. The integration procedure to be discussed is based on dressing technique. We shall present two classes of solutions over constant background: soliton-like solutions and quasi-rational solutions. Both classes of solutions have their counterparts in the case of the Heisenberg ferromagnet equation.

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Research on the Difference of Plant Evolutionary Rates Based on Semiparametric Model

Wang Yao
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Polyploidy or whole genome duplication (WGD) is a significant genomic replication event in biological evolution, playing a crucial role in the evolution of plants, particularly angiosperms.

If there are shared polyploidy events among species, the peak of the synonymous substitution rate (Ks) indicates the timing of the polyploidy event. In theory, the timing of this polyploidy event should be identical across different species, and the Ks peak values should be equal. However, in practical research, the fact that plant genomes often experience more than one polyploidy event results in considerable variation in the Ks peak values for shared polyploidy events among different species. The higher the Ks value, the faster the species' evolutionary rate, indicating that there are certain differences in the evolutionary rates between species. The variation in plant evolutionary rates is one of the key factors in the formation of biodiversity and the maintenance of ecosystem functions. Understanding the causes of these variations and their impacts is of great importance for uncovering the intrinsic mechanisms of biological evolution.

This research deeply explores the variability in plant evolutionary rates, using Ks peak values to gauge the evolutionary rates of species, and simultaneously establishes a semi-parametric regression model to analyze the factors influencing Ks peak values, offering a novel perspective for understanding the evolution of plant genomes and the process of speciation.

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Study on Impact Load Mitigation for High-Speed Water Entry Projectiles Using Aluminum Foam Buffering Structure

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This paper investigated the fluid-solid coupling nonlinear problem of water entry by a high-speed projectile, considering cavitation, air cushion effect, and water vapor generated by the high-speed relative motion between the projectile and the fluid. To this end, a sandwich structure containing aluminum foam attached piston was studied and designed. The numerical simulation of the entry process was analyzed by LS-DYNA. The results show that the sandwich structure reduces the peak impact load. 87.47% reduction in peak force during water entry and aluminum foam has good cushioning effect.

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Generalized Discrete Lotka-Volterra Equation, OPs and Generalized ε-Algorithm

Xiaomin Chen, Xiangke Chang, Yi He, Xingbiao Hu

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In this talk, I will introduce a generalized fully-discrete Lotka-Volterra (dLV) equaiton under the boundary condition $u_0^n \neq 0$, and provide its solution in terms of Hankel determinant. It turns out that this generalized dLV equaiton could be linearized in sense of equivalence to a discrete Riccati equation. Besides this, its Lax pair in terms of symmetric orthogonal polynomials is also presented. Moreover, a generalized ε-algorithm is also derived, which is connected to the obtained generalized dLV equaiton. All these results are obtained by Hirota's bilinear method and determinant techniques. Finally, the numerical effects of the generalized ε-algorithm is investigated by applying it to some linearly and logarithmically convergent sequences as well as a certain divergent series.

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Existence of Topological Defects in the Georgi-Machacek Model

Xiaosen Han

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In this talk we report some existence results of topological defects in the Georgi-Machacek model. We first review the classical Abelian-Higgs model and

related results. Then we present the Georgi-Machacek Model and main existence results. At last we give a sketch of the proof of the existence results.

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Infectious Disease Prediction Based on Statistics and Deep Learning Models

Yongchao Jin

North China University of Science and Technology, Tangshan, Hebei, P. R. China

Considering the coexistence of both linear and nonlinear factors in pandemic data, conventional machine learning or traditional forecasting models encounter challenges in accurately predicting pandemic trends. In our study, to better capture the linear and nonlinear factors present in pandemic data, we attempt to combine deep learning models with traditional statistical models for predicting confirmed infectious disease data. We have successively proposed ARIMA-LSTM models (Autoregressive Integrated Moving Average model, ARIMA. Long short-term memory, LSTM), PSO-LSTM-ARIMA (Particle Swarm Optimization, PSO) models, MLR-LSTM-ARIMA (Mixed Logistic Regression, MLR) models, BPNN-LSTM-ARIMA (Back Propagation Neural Network, BPNN) models, CNN-LSTM-ARIMA (Convolutional Neural Network, CNN) models, TCN-LSTM-ARIMA (Temporal Convolutional Network, TCN) models, and SSA-LSTM-ARIMA (Sparrow Search Algorithm, SSA) models. The prediction accuracy of these models has greatly improved compared to single statistical models or deep learning models.

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A Distance-Based Microbiome Kernel Association Test with Multi-Categorical Outcomes

Yuying Chen, Han Sun, Lina Ji

Henan Agricultural University, Zhengzhou City, Henan Province, P. R. China

The homeostatic balance of microbial community plays a vital role in maintaining human health. Examining the variability of microbial communities across host

phenotypes in different states could provide key information about human health or disease. High-throughput sequencing technology, which performs parallel sequence determination of abundant nucleic acid molecules at one single time, has enabled the exploration of human microbiome in disease etiology and exposure response. Massive microbiome sequencing data is usually high-dimensional and phylogenetic, consisting of thousands of Operational Taxonomic Units(OTU), with one-to-one or many-to-one mapping relationship between OTU and species. In this paper, the microbiome regression-based kernel association test based on distance is used to evaluate the relevance between overall microbiome composition and outcomes. Considering the abundance and phylogenetic relationship of association signals, we applied the multi-categorical association method to conduct real data experiments and calculated the test statistic. Our simulations demonstrated that it can correctly control type I error and provide sufficient power in testing the overall correlation. Therefore, with the increasing interest in applying the microbiome to complex clinical and population-based research, the extension of distance-based microbiome kernel association test with multi-categorical outcomes results to more emerging fields could open up new avenues on biomathematics.

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Periodic Orbits and Bifurcations of Four-Dimensional Non-Autonomous Piecewise Smooth Discontinuous Systems

Yujiao Cui, Jing Li, Shaotao Zhu

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Vibration problem is one of the research topics in the field of mathematics and engineering. As a typical Filippov non-smooth system, the study of periodic solution and bifurcation theory of dry friction coupled vibration system is of great significance for system control in engineering applications, important safe operation and the establishment of engineering standards. In this paper, the periodic orbit and bifurcation theory of a class of high dimensional piecewise smooth discontinuous systems are explored and analyzed based on the need of mathematical theory and practical application problems, and applied to study the dynamic characteristics of a class of four-dimensional non-autonomous dry friction-coupled vibration systems. By constructing the combinational Poincar'e mapping, the central manifold method in smooth system is extended to obtain sufficient and necessary conditions for the existence of invariant cones. Based on Floquet theory, the stability of an invariant cone composed of periodic orbits is proved. The phenomenon of border-collision bifurcation and the existence persistence of an invariant cone are investigated. The parameter conditions of periodic orbit generated by Hopf-like bifurcation caused by nonlinear disturbance are further considered and the stability of periodic orbit is determined. Corresponding phase diagram, Poincaré cross section diagram and time response diagram of the system are given to verify the correctness of the theory. It provides a theoretical basis for parameter optimization and vibration control of high dimensional dry friction-coupled vibration system in engineering practice.

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Post-Groups, Post-Groupoids and the Yang-Baxter Equation

Yunhe Sheng

Jilin University, P. R. China

We introduce the notion of post-groups, which are the underlying structures of Rota-Baxter operators on groups. The differentiation of post-Lie groups gives post-Lie algebras. Post-groups are also related to braces and Lie-Butcher groups, and give rise to set-theoretical solutions of Yang-Baxter equations. We further introduce the notion of post-groupoids, whose differentiations are post-Lie algebroids. We show that post-groupoids give quiver-theoretical solutions of the Yang-Baxter equation on the underlying quiver of the subadjacent groupoids.

The talk is based on the joint work with Chengming Bai, Li Guo, Rong Tang and Chenchang Zhu.

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A Large Class of Two-Component Peakon Systems and Reductions

Zhijun (George) Qiao and Baoqiang Xia

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In this talk, we will present a large class of two-component peakon systems and then show integrability with Lax pair. Some reduced integrable examples are given with showing peakon solutions.

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Quantum Mechanics at the Planck Length

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We discuss the breaking of the Lorentz symmetry at the Planck length in quantum mechanics. We use three-dimensional P-adic vectors as position variables while the time remains a real number. In this setting, the Planck length is 1/P, where P is a prime number, and the Lorentz symmetry is naturally broken. The P-adic the Planck length is independent of the speed of light and is determined by the group of symmetries of the space. In the Dirac and von Neumann formalism framework for quantum mechanics, we introduce a new P-adic Dirac equation that predicts the existence of particles and antiparticles and charge conjugation like the standard one. The discreteness of the P-adic space imposes substantial restrictions on the solutions of the new equation. This equation admits localized solutions, which is impossible in the standard case. We show that an isolated quantum system whose evolution is controlled by the P-adic Dirac equation does not satisfy the Einstein causality, which means that the speed of light is not the upper limit for the speed at which conventional matter or energy can travel through space. This fact does not imply immediately that the speed of light is infinite. The new P-adic Dirac equation is not intended to replace the standard one; it should be understood as a new version (or a limit) of the classical equation at the Planck length scale.