ISMMACS CONFERENCE - 2025

Annual Conference of ISMMACS and the International Conference on Differential Equations: Theory, Mathematical Modelling, and Scientific Computing

and

Pre-conference Workshop on Mathematical Modeling & Dynamical Systems: Computational Approaches and Research Horizons

December 7-10, 2025

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Annual Conference of ISMMACS and the International Conference on Differential Equations: Theory, Mathematical Modelling, and Scientific Computing

Dhirubhai Ambani University

December 8-10, 2025

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Plenary Talk

Stabilized methods for PDEs: Theory, Computation & Application

B V Rathish Kumar
Associate Professor, Vellore Institute of Technology, Vellore, India

Stabilized formulations have transformed the numerical treatment of multiscale partial differential equations, enabling robust and accurate simulation of convection-dominated flows, coupled physics, and complex nonlinear systems. This talk presents a unified perspective on stabilized methods grounded in the multiscale variational finite element framework, highlighting its theoretical foundations, computational realization, and broad impact across engineering and scientific applications. Emphasis is placed on how intrinsic scale separation, residual-based stabilization, and targeted enrichment deliver enhanced stability, improved convergence, and reliable physical fidelity. Recent advances in algorithmic design, efficient solvers, and high-performance implementations will be discussed, along with representative case studies demonstrating the method's effectiveness in challenging real-world PDE problems. The talk aims to connect theory, computation, and application, showcasing stabilized multiscale FEM as a powerful paradigm for next-generation PDE modeling.

Quantum Differential Equations

Manish K Gupta, Director (Academics) and Senior Professor

Kaushalya: The Skill University, Government of Gujarat

Quantum algorithms offer a novel paradigm for numerical computation in which fundamental linear-algebraic tasks are executed using principles from quantum mechanics, including superposition, unitary evolution, and measurement. This talk examines the emerging theory of quantum algorithms for differential equations. After giving a brief overview of the mathematical foundations of quantum computing, modelling qubits as vectors in finite-dimensional Hilbert spaces, quantum gates as unitary operators, and quantum circuits, I will briefly survey quantum algorithms for ordinary and partial differential equations, which typically reduce differential problems to large linear systems.

Keynote

The Atangana integral: Resolving decades of confusion in fractional calculus and bridging the Riemann-Liouville-Caputo divide

Abdon Atangana
Professor, University of The Free State, South Africa

Fractional calculus has long suffered from a fundamental inversion error, treating the Riemann–Liouville integral as the inverse of Caputo-type derivatives, which creates spurious singularities and enforces unphysical initial conditions; this monograph replaces that illusion with the Atangana fractional integral, a new, kernel-adaptive operator built from classical integration, first-order differentiation, and a nonsingular fractional integral that yields three tailored variants (power-law, Mittag-Leffler, and exponential kernels) that genuinely invert Caputo, Atangana–Baleanu, and Caputo–Fabrizio derivatives. We prove a direct Fundamental Theorem of Fractional Calculus for these operators without Laplace transforms and show that initial-value problems with non-singular kernels now automatically satisfy their initial conditions, demonstrating that prior fixes were addressing the wrong object; by reworking the Atangana integral's inner structure we construct true inverses for the non-singular derivatives and remove a major inconsistency in fractional dynamics. Beyond inversion theory, the Atangana integral brings several novel features: it adapts to jump discontinuities and resets memory for shocks and switches; it breaks time-reversal symmetry and thus models irreversible thermodynamic behavior; it exhibits critical-order transitions between local and global memory dominance and allows implicit superposition of multiple memory depths for hybrid dynamics; it admits a full duality across time and frequency domains with explicit transforms; it yields new integral inequalities and norm estimates; and it predicts curvature-driven anomalous transport and coexisting diffusion phases that resolve experimental paradoxes. Finally, the monograph introduces a causal memory resolution framework that restores existence and uniqueness while treating memory as a controlled, physical agent, and outlines broad applications, from quantum resets and adaptive machine learning to regenerative biology and irreversible thermodynamics, positioning the Atangana integral as a foundational shift in fractional theory and applied modeling.

A stitch in time saves lives: Modeling of Health Innovation in the age of AI-Integrating dynamics, evidence, and real-time decision making

Anuj Mubayi
Distinguished IBA Fellow , USA

Mathematical modeling is more critical than ever in healthcare and public health fields, supporting health technology assessment, health policy evaluations, and real-world evidence generation. However, current workflows are slow and manually intensive, requiring extensive literature review, parameter extraction, coding, calibration, and reporting. This talk introduces a new paradigm in which Agentic AI systems accelerate key stages of the modeling pipeline through coordinated use of LLM-driven reasoning, computational agents, and simulation engines, all operating with modeler-guided prompts and decisions. To connect with scientific computing, the talk highlights examples of digital twins and Physics-Informed Neural Networks for disease progression and treatment evaluation, demonstrating how data-driven approaches can complement classical differential-equation-based modeling. A brief India-focused case study illustrates how real-world data integrated with agentic AI enables rapid forecasting of treatment uptake, costs, and patient outcomes. Overall, the talk presents a roadmap toward faster, more precise, and reproducible health-science modeling.

Invited Talk

Modeling the dynamics of atmospheric carbon dioxide and its control strategies.

A. K. Misra
Professor,Department of Mathematics, Institute of Science
Banaras Hindu University, Varanasi

The impact of human activities, particularly since the Industrial Revolution, has significantly increased the emission of greenhouse gases, primarily carbon dioxide (CO_2). The accumulation of CO_2 in the atmosphere traps infrared radiation emitted from the Earth's surface after sunlight absorption, leading to global warming. This ongoing rise in average surface temperatures is driving drastic changes in the climate, which in turn is affecting human populations through increased incidences of vector-borne diseases, pollution, floods, droughts, rising sea levels, and food and water insecurity. To mitigate the impacts of climate change, reducing carbon dioxide emissions is crucial. This can be achieved through various mitigation strategies across sectors such as energy and development. Mathematical modeling can offer valuable insights into the effects of various factors and mitigation strategies on the dynamics of CO_2.

In this lecture, firstly a nonlinear mathematical model is proposed and analyzed to assess the effect of population pressure on atmospheric carbon dioxide dynamics. The model assumes that CO_2 levels increase both naturally and through anthropogenic emissions, while also depleting naturally and through uptake by forestry biomass. It is further assumed that both the human population and forestry biomass follow logistic growth patterns. Population pressure specifically reduces the carrying capacity of forestry biomass. Analytical findings reveal that when the rate of deforestation due to human population pressure exceeds a critical threshold, the system becomes unstable, resulting in oscillations through Hopf bifurcation. This study highlights the significant impact of increasing population pressure on atmospheric CO_2 levels. Currently, governments at both national and international levels use fiscal policies to either discourage carbon dioxide emissions or promote carbon mitigation. With this in mind, we formlate and analyze a mathematical model to examine a strategy for maintaining atmospheric CO_2 levels while pursuing development activities. The proposed strategy involves clearing an area larger than required during land acquisition and planting leafy trees on the excess land to compensate for the reduced absorption of CO_2. Numerical simulations provide insights into the proportion of cleared land that should be used for tree planting to maintain the CO_2 levels in the atmosphere. In line with naturally maintaining atmospheric CO_2 levels, the intensive use of renewable energy could also help reduce emissions from energy production. To explore this further, we formlate and analyze a mathematical model to analyze the impact of renewable energy deployment on the mitigation of atmospheric CO_2. The model assumes that CO_2 levels rise due to human activities and traditional energy production, with the human population's dependence on traditional energy shifting toward renewable sources as CO_2 levels increase. The model analysis reveals a condition under which the equilibrium level of CO_2 can be reduced through sufficient deployment of renewable energy sources.

Keywords: Mathematical model; Carbon dioxide; Stability; Bifurcation.

Immuno-epidemic models: An emerging area of research

Malay Banerjee

Professor, IIT Kanpur

A wide range of mathematical models is available to study the epidemic progression of SARS-CoV-2. Variation in the period of infectivity, the time required for recovery, and days spent at the hospital during the disease severity vary significantly from one patient to another. The main objective of this talk is to discuss a new modeling approach for the COVID-19 epidemic, which involves distributed recovery and death rates and the variable infectivity based upon the immunity level of the individuals. The infection transmissibility rate depends upon the immune response's strength and antibody level due to vaccination and acquired immunity. The proposed model helps to evaluate the COVID-19 epidemic situation in some countries.

Computing with matrices

C S Sastry

Professor, IIT Hyderabad

Sparsity has, of late, become an important concept in Applied Mathematics/Signal Processing. The key idea is that many types of data arising naturally in applications can be described by a small number of significant degrees of freedom (which allows for sensing of data compressively). Such descriptions in general lead to under-determined systems of linear equations. The problem of finding the significant degrees of freedom can be recast as optimization problems whose solvers typically take into account the properties of the associated sensing or system matrix. The talk intends to delve into theory and application of the matrix-based computations that underlie the sparse description of matrix systems.

Data driven WENO weights: Outliers are not liars

Ritesh K Dubey

Professor, SRM Institute of Science and Technology

Weighted essentially non-oscillatory weights (WENO) weights often fail to achieve critical linear weight for desired order of accuracy even for smooth solution region.

In this work a data driven approach is proposed and utilised to show that weighted essentially non-oscillatory weights (WENO) corresponding to discontinuities are outlier weights which are significantly far from the critical linear weights.

In order to do so, outlier detection using quantile function is used with kernel density estimation. The weno weights data set is generated using Riemann data samples drawn from discontinuous functions and .... As the WENO weights are scaled invariant, therefore the sampled data does not require normalization.

Mathematical Analysis of Growing Tumour and its Treatments with Chemotherapy and Immunotherapy

Sanjeev Kumar
Professor, Vice Chancellor, MSD University, Azamgarh

Cancer is one of the most painful and harmful diseases in the present scenario. It is a non-infectious or non-communicable, acute, sub-acute, and chronic disease. The history of cancer started in Egypt and dates back to about 3000 BC. The Greek Physician Hippocrates (460-370 BC), the Father of Medicine, gave the words 'Cancer' The word cancer is derived from the ancient Greek word "carcinomas and carcinoma", which means Crab or Tumor.

The three main Ayurvedic classic texts, the Sushruta Samhita, Charaka Samhita, and the Ashtanga Hridaya, mention conditions like "Arvuda," "Granthi," and "Gulma," which are thought to correspond to tumors or growths. A tumor is an abnormal mass of tissue that is formed when normal cells begin to change and grow uncontrollably. A basic definition of cancer can be given as a class of diseases characterized by uncontrolled growth of cells and invasion into the surrounding tissue. Tumors divide into two categories i) Benign Tumor, and ii) Malignant Tumors. In the body tissue, the cancer cell is present and develops rapidly.

On quenching phenomena of two-dimensional semilinear wave equation

Rajesh K Pandey
Professor, Indian Institute of Technology (BHU) Varanasi

We study a 2D semilinear wave equation exhibiting quenching behavior. Using Kaplan's first-eigenvalue method, we show that on sufficiently large domains the classical solution remains bounded while its second-order time derivative blows up. A uniform-step finite-difference scheme—based on an unconditionally stable alternating-direction implicit (ADI) approach—is proposed to resolve the quenching profile and estimate quenching time. Extensive computational experiments verify our theoretical findings, demonstrating the method's stability, energy preservation, convergence, and oscillatory behavior near quenching.

Non-positive solutions in some delayed population models

Bapan Ghosh
Associate Professor, IIT Indore

Delay differential equations are widely used in modeling where action of any event is not instantaneous. Time delays have potential to alter dynamics of non-delayed systems. For instance, delayed linear equation with one state variable can even exhibit chaos. On the other hand, delay can prevent blow-up in a non-delayed model. Positive solutions are essential for in ecological and epidemiological models. However, positivity property is often unchecked or it is incorrectly established in delayed systems. In this presentation, we show that a class of real-world models can exhibit (i) non-positive transient solutions converging to a positive equilibrium, (ii) non-positive transient solutions leading to a positive limit cycle, and (iii) non-positive limit cycles. In the context of non-positive solutions, we also highlight that software based bifurcation diagrams may mislead ecological interpretation. This presentation will pose some challenges to propose modified delayed models preserving positivity.

Discontinuous Galerkin Finite Element Schemes for Singularly Perturbed Problems

Pratima Rai
Associate Professor, University of Delhi

Singularly perturbed problems are differential equations characterised by an asymptotically small parameter multiplying the highest order derivative. These problems arise in many areas of engineering and science, such as shock waves in gas dynamics, boundary layer flows, semiconductor device modeling, groundwater transport, and chemical reactor theory. The solution of these problems exhibit sharp gradients resulting in boundary/ interior layers. Accurately resolving these layers presents significant challenges for classical numerical methods.
In this talk, we discuss discontinuous Galerkin finite element methods (DGFEMs) and its application to such problems.

We will explore various versions of DGFEMs, with particular focus on non-symmetric interior penalty Galerkin (NIPG) methods. Error estimates and layer-adapted mesh strategies are presented to demonstrate the capability of DGFEMs to capture the layers effectively. Numerical experiments will also be presented to showcase the robustness of the proposed schemes.

Evolution of B Splines based Numerical Techniques for Nonlinear PDEs

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The anisotropic reaction–diffusion equation plays a pivotal role in modeling complex spatiotemporal phenomena such as tumor growth, pattern formation, and chemical transport. In this study, we present a novel Cubic B-spline Hybrid Differential Quadrature Method (CB-HDQM) for the efficient and accurate numerical solution of the anisotropic reaction–diffusion equation. The proposed approach combines the high-order accuracy of spline-based quadrature in space with a compact finite-difference discretization in time, achieving an optimal balance between precision and computational cost. Cubic B-splines are employed to approximate the spatial derivatives, while boundary conditions are seamlessly incorporated into the spline weights—eliminating the need for ghost points outside the computational domain. This formulation transforms the governing equation into a manageable system of algebraic equations in time, significantly simplifying the numerical process.

The CB-HDQM is rigorously tested on a range of benchmark problems, from smooth Gaussian profiles to sharp, propagating reaction fronts. The method demonstrates excellent stability, accuracy, and efficiency in capturing the intricate diffusion and proliferation patterns of glioma cells over time. Overall, the proposed CB-HDQM provides a flexible and powerful computational framework for simulating and analyzing two-dimensional reaction–diffusion systems relevant to biological and physical processes.

Inverse problems of dynamic equations on time scale

Syed Abbas
Professor, IIT Mandi

In this talk, we discuss some identification problems related to dynamic equations on time scale. We illustrate the results using several examples.

Differential Equations with Multiple Delays and PINNs

Muslim Malik
Professor, IIT Mandi

In this talk, we propose a scientific machine learning approach based on Physics Informed Neural Networks (PINNs) to solve the delay differential equations (DDEs) of higher order with multiple delays, neutral DDEs (NDDEs), and systems of DDEs. Using optimization algorithms and automatic differentiation, we modify the network parameters in PINNs to minimize the loss function. As a result, delay differential equations (DDEs) can be numerically solved without the grid dependency and polynomial interpolation that are inherent to conventional numerical techniques. Numerous numerical examples have demonstrated the high precision of our method in various challenges, showcasing its efficacy and great potential in addressing different DDEs.

How Multivalency, Linkers, and Competitive Binding Govern Memory

Vikas Pandey
Assistant Professor, Osaka University, Japan

The molecular basis of memory formation in the brain remains incompletely understood. Recent work by Hosokawa et al. (Nature Neuroscience, 2021) proposed an alternative mechanism of long-term potentiation in which multicomponent biomolecular condensates act as stable molecular substrates for memory. CaMKII, a highly multivalent and nonlinear protein, is central to organizing these condensates at the synapse, the fundamental molecular unit of the brain. Here, we investigate how CaMKIIs' multivalency and linker length shape the architecture of multilayered condensates, with other component proteins. Linker length can be interpreted as an effective molecular radius, influencing how CaMKII networks pack and self-assemble. Our results show that CaMKII is a dominant regulator of multilayered condensate formation and stability, establishing a plausible physical pathway by which synaptic memories may be stored. These insights also extend to broader biophysical systems, highlighting how nonlinear multivalent proteins generate complex, multilayered condensates across diverse biological contexts.

The Singular Perturbation Models: Issues and Remedies

Kapil Sarma
Professor, South Asian University

The mathematical model involving small perturbation parameters is known as the perturbed model. The perturbed model may be regularly or singularly perturbed depending upon the solution behavior of the model. The singularly perturbed models are ubiquitous in mathematical modeling of several real life phenomena and provide a realistic simulation of the phenomena.

The solution of the singularly perturbed differential equation models exhibits layer behavior in narrow regions. These narrow regions are known as layer regions and the rest part of the domain is known as outer regions.

The classical computational methods for the differential equations cannot be implemented straightforward. In this talk, the challenges and remedies in implementation of the existing methods for singularly perturbed problems will be discussed. Further, the audience will be enlightened with the recent developments in this area.

Fuzzy Component Approximation for Nonlinear Differential Equations

Navnit Jha
Professor, Faculty of Mathematical Sciences
South Asian University, New Delhi

We describe the fuzzy transform method to analyze two-point singular and non-singular boundary value problems with high-order solution accuracies. The present framework implements a fuzzy transform that approximates solutions with fourth-order accuracy at the interior mesh points. The fuzzy components and the triangular base function are locally arranged with a three-point linear combination of solution values. It yields a tri-diagonal Jacobian matrix that can be easily computed in a space-time efficient manner. Since a linear system relates solution values and fuzzy components, it is easy to obtain solution approximations via fuzzy components by a tri-diagonal matrix inversion. In addition to the numerical solution, it is easy to determine approximate analytic solution by cubic spline interpolating polynomial from the data available with fuzzy components. The error estimates for approximate analytical solutions and numerical solutions are obtained by integrated absolute error and maximum absolute errors. The new mechanism is analyzed for convergence using matrix theory. Several linear and nonlinear equations of practical importance related to sewage diffusion and polytropic gas flow model are simulated to corroborate the new scheme's utility and fourth-order convergence.

Higher order numerical scheme for a singularly perturbed problem with an interior turning point

Vikas Gupta
Professor, The LNM Institute of Information Technology Jaipur

In this work, we construct and analyze a finite difference scheme for solving a class of time-fractional singularly perturbed convection-diffusion problems. The time-fractional derivative is taken in Caputo sense with the order $\alpha\in (0,1)$. The solution to this class of problems possesses weak singularity in the vicinity of the initial time $t=0$ and an exponential boundary layer at the right lateral surface as the singular perturbation parameter $\varepsilon \rightarrow 0$. To tackle the initial layer at time $t=0$, a classical $L1$ finite difference scheme is employed on a graded mesh to discretize the time-fractional derivative. Further in the spatial direction, a standard upwinding procedure is used on piecewise uniform Shishkin mesh. It is shown that the resultant fully discrete scheme is parameter uniformly convergent with the order of convergence $O(M^{-p}+N^{-1}\log N)$, where $p=\min \{2-\alpha,\,r\alpha\}$, r is the graded mesh exponent and $N,\,M$ are the number of mesh subintervals in space and time direction respectively. Lastly, numerical results illustrate that the proposed scheme is simple, efficient, robust and accurate as well as validate the error estimates presented in the paper.

Deterministic and Stochastic Studies on Additional Food Provided Prey- Predator Systems with Group Defence among Prey and Mutual Interference among Predators

D K K Vamsi

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The interplay between competition and additional food provision in prey-predator systems has drawn significant interest in mathematical biology due to its implications for ecological management [1, 2]. In this study [3], we develop a prey-predator model incorporating Holling type-IV functional response and mutual interference among predators, with additional food supplied to enhance predation efficiency. We establish the existence and uniqueness of global positive solutions and analyze the stability and bifurcation behavior of equilibria with respect to competition intensity and food supplementation. We examine the global dynamics to understand the broader ecological effects of additional food. To identify efficient pest control strategies, we formulate a time-optimal control problem using the quality and quantity of additional food as control variables, characterized through Pontryagin's Maximum Principle. We further extend this model to account for environmental variability by incorporating both continuous and discrete stochastic perturbations, and the associated stochastic control problem is solved using the Sufficient Stochastic Maximum Principle. Numerical simulations validate the theoretical findings, highlighting the model's potential applications in designing sustainable, biologically driven pest management strategies.

References

[1] Srinivasu PDN, Prasad BSRV, Venkatesulu M (2007) Biological control through provision of additional food to predators: a theoretical study. Theor Popul Biol 72(1):111–120

[2] Prakash, D. B., & Vamsi, D. K. K. (2023). Stochastic Time-Optimal Control and Sensitivity Studies for Additional Food provided Prey-Predator Systems involving Holling Type-IV Functional Response. Frontiers in Applied Mathematics and Statistics, 9, 1122107. [Online]

[3] Prakash, D. B., & Vamsi, D. K. K. (2025). Deterministic and Stochastic Studies on Additional Food Provided Prey-Predator Systems with Group Defence among Prey and Mutual Interference among Predators. arXiv preprint arXiv:2504.21114. [Online]

Controllability Results For Hilfer Frcational Dynamical Systems

V. Vijayakumar
Assistant Professor , VIT Vellore

Fractional calculus has emerged as a powerful tool for modeling memory-driven and hereditary phenomena in complex dynamical systems. Among various fractional operators, the Hilfer fractional derivative occupies a unique position as an interpolation between the classical Riemann-Liouville and Caputo derivatives, offering enhanced flexibility for capturing intermediate memory effects. This talk presents recent progress on the controllability analysis of Hilfer fractional dynamical systems in abstract spaces. We discuss different notions of controllability including exact, approximate, and null controllability and explore the role of evolution operators, semigroup theory, and fixed-point techniques in establishing controllability criteria. Special attention is given to systems with nonlocal conditions, delays, and perturbations, which frequently arise in engineering, biological, and economic models. Furthermore, we highlight the interplay between fractional order, interpolation parameters, and system structure that influences controllability outcomes. Illustrative examples and application perspectives are provided to demonstrate the practical relevance of Hilfer fractional systems in real-world scenarios. The talk concludes with open problems and future directions in fractional control theory, emphasizing emerging challenges in stochastic, impulsive, and hybrid frameworks.

Optimal Control Problems for Semilinear Evolution Systems and Applications

Anurag Shukla
Department of Applied Sciences, Rajkiya Engineering College Kannauj, Kannauj, Uttar Pradesh

This talk focuses on optimal control problems for semilinear evolution systems in infnite-dimensional spaces, covering both rst-order and second-order dynamics. Such systems arise naturally in models governed by partial di erential equations, including di usion-reaction, dispersion, thermoelastic, and population-dynamics processes. The state evolution is described by a nonlinear operator equation in a Hilbert or Banach space, while the control enters either as a distributed source or through boundary actions. The objective is to minimize a performance functional measuring the deviation of the system state from a desired trajectory together with a control cost term. The analysis addresses well-posedness of the state system, existence of optimal controls, di erentiability of the control-to-state map, and derivation of rst- and second-order optimality conditions in the innite-dimensional framework. The study employs tools from semigroup and cosine operator theory, and basics of functional analysis. Applications illustrate the theoretical results: in dispersion systems, in thermoelastic systems, and in population dynamics.

Keywords: Lagrange's problem, Mild solution, Optimal control, Semigroup theory.
Mathematics Subject Classication 49J15; 34A08; 34K35

Reflections on Proximality

Anima Nagar
Associate Professor, IIT Delhi

We review some known theory of proximality and elaborate on some new associated study.

Synchronous cycles in migrating population dynamics

Anshaya Mohapatra
Assistant Professor, BITS PILANI, K.K Birla Goa Campus

Temporal synchronization is a fairly common ecological phenomenon in population dynamics. Example range from annual and biennial plants to Salmon to Cicadas. In discrete-time matrix population models, competition between stages may result in synchronous cycles in which stages are temporally separated. In this talk, we discuss how spatial density-dependency dynamics can have a crucial role in population stability through synchronization in a migratory population. Migration is a diverse phenomenon and can be categorized into many forms. The most common type of migration is partial migration, in which some individuals migrate between habitats and others remain in a single habitat during their entire life. Using a discrete stage structure matrix model, we discuss which kind of density dependence mechanisms would cause a stable cyclic behavior with alternating and separated generations of juveniles and migrant and nonmigrant adults. We will also discuss the subsequent adaptive dynamics, which require investigating whether a mutant can invade the dynamic 2-cycle.

Overlapping multi-domain paired quasilinearization technique applied to themixed convective flow of Jeffrey nanofluid with microorganism and activation energy

Md. Sariffudin Ansari

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Abstract: This study introduces a novel numerical algorithm, the overlapping multi-domain paired quasilinearization (OMD-PQLM), developed for solving strongly nonlinear system of partial differential equations (PDEs) comprising coupled equations. The OMD-PQLM involves the use of pairing and solving equations simultaneously, enhancing computational efficiency by decreasing the size of the coefficient matrix to be inverted while maintaining the high accuracy associated with spectral-based decoupling methods. The approach entails partitioning the entire computational interval of integration into multiple smaller, overlapping subdomains. Solutions in each sub-domain are obtained using boundary conditions and solutions from preceding subdomains. To evaluate the efficiency of the proposed technique, a coupled set of differential equations describing the mixed convection flow of a Jeffrey nanofluid containing microorganisms and activation energy is analyzed. The novelty of the OMD-PQLM lies in its combination of overlapping multi-domain techniques with paired quasilinearization, which improves convergence rates and solution accuracy. Findings reveal that OMD-PQLM provides highly accurate results, achieving rapid convergence with errors reaching as low as 10^{-14}. Residual and solution error validate the effectiveness and robustness of the method. The proposed OMD-PQLM shows significant potential for solving complex systems of nonlinear PDEs emanating from scientific and engineering fields.

Keywords: overlapping sub-domains, paired quasilinearization, spectral method, non Newtonian nanofluid, bio-convection, activation energy,

Mathematical Model to Study the Effect of Chemotherapy Drug on Cancer Dynamics

Hardik Joshi
Assistant Professor, LJ Institute of Engineering and Technology, LJ University

In this paper, we present a cancer model to study the complex interplay among stem cells, effectors cells, and tumor cells in the presence and absence of chemotherapy. We employed the novel fractal-fractional operator with a generalized Mittag-Leffler kernel to capture the non-local nature of cancer dynamics. The existence and uniqueness criteria of the fractal-fractional cancer model are derived. Also, the stability analysis is performed. The numerical experiment is performed to validate the theoretical results and examine the dynamic interaction among cells, the impact of chemotherapy, and various orders of fractal-fractional operators.

Integrating Artificial Intelligence with Mechanistic Epidemiological Modeling: Opportunities and Challenges

Yang Ye
Associate Research Scientist in Epidemiology,Yale School of Public Health

Integrating prior epidemiological knowledge embedded within mechanistic models with the data-mining capabilities of artificial intelligence (AI) offers transformative potential for epidemiological modeling. While the fusion of AI and traditional mechanistic approaches is rapidly advancing, efforts remain fragmented. In this talk, I will review the key challenges facing traditional mechanistic approaches and provide an overview of emerging integrated models applied across a wide range of infectious diseases. I will summarize major application areas, illustrate the practical value of these models for understanding transmission and informing policy, and conclude by outlining the methodological and translational gaps that define the next frontier for the field.

An overview of the AI/ML/DL methods in ID Prediction/Classification with application to Monkeypox

Prof. B V Rathish Kumar

Professor, IIT Kanpur

This talk will provide an overview on contemporary AI, ML, and deep learning approaches for infectious disease prediction and classification, with a focus on Monkeypox. The talk will also provide details on the classification of MPV based on clinical input.

Mathematical Modeling of Moose Wolf Interaction of Isle Royale National Park using SINDY Algorithm

Nitu Kumari
Professor, IIT Mandi

In this talk, I will discuss an SIRS epidemic model with convex incidence and saturated treatment under both autonomous and non-autonomous frameworks. For the autonomous system we characterize the disease-free and endemic equilibria and perform bifurca#on analysis, showing backward and saddle-node bifurca#ons, Hopf bifurca#ons that generate endemic bubbles. Also, bifurca#on analysis reveal a codimension-two double-zero bifurca#on arising from the intersec#on of saddle-node and Hopf bifurca#ons. The non-autonomous extension incorporates seasonal varia#ons in transmission and recovery rates, capturing realis#c periodic forcing observed in diseases such as influenza. Using data from the Democra#c Republic of the Congo, we confirm December as the peak influenza season. Analy#cal results establish condi#ons for the existence and global stability of a posi#ve periodic solu#on, while numerical simula#ons show that seasonality induces complex behaviors, including mul#-periodic and chao#c oscilla#ons. Low seasonal intensity sustains coexistence, whereas high-intensity forcing leads to popula#on ex#nc#on. The emergence of quasi-periodic (torus) and chao#c (strange) a/ractors demonstrates how seasonal forcing can transform regular epidemic cycles into irregular outbreaks, offering new insights into the role of seasonality in infec#ous disease dynamics and control.

Age-Structured Modeling and Retrospective Analysis of COVID-19 Dynamics in the Basque Country, Spain(online)

Akhil Srivastava
Researcher, KU Leuven

In collaboration: Bechir Salah Naffeti[2], Nico Stollenwerk[2], Maira Aguiar[2]
[1]Access-To-Medicine (ATM) Research Centre, KU Leuven, Belgium

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Abstract: The emergence of COVID-19 in early 2020 posed an unprecedented challenge to public health systems worldwide. In the absence of vaccines and treatments during the initial phase, non-pharmaceutical interventions became the main control strategy. Age was quickly identified as a critical determinant of disease severity, with older individuals facing substantially higher risks of hospitalization and mortality.

We develop a deterministic age-structured compartmental model to investigate COVID 19 dynamics in the Basque Country, Spain, over the first two years of the epidemic. The population is stratified into two groups (<70 and > 70 years), reflecting differences in transmission and disease severity. Using phase-wise retrospective analysis, the model reconstructs epidemic evolution and quantifies age-specific contributions to transmission and burden.

With the mathematical study of the model, the basic reproduction number (R_0) is computed to characterize the potential for disease transmission. In addition, a global sensitivity analysis based on Partial Rank Correlation Coefficients (PRCC) is performed to identify the parameters most strongly influencing the model outcomes. Results show that individuals under 70, while less likely to develop severe illness, were the primary drivers of transmission. Control measures were captured by two intervention parameters, allowing assessment of differential effects across age groups.

The findings underscore the value of age-structured modeling for epidemic forecasting and highlight the importance of targeted interventions in mitigating age-dependent infectious disease threats.

Keywords: Epidemiology, COVID-19 Modeling, Reproduction number, Stability analysis, Data analysis, age-structure.

COVID-19: The Retrospective Insights and Prospective Outlook via Mathematical Modeling

P K Srivastava
Associate Professor, IIT Patna

In this talk, we shall emphasize on the mathematical modeling of COVID-19 including multiple features of the disease such as vaccination, limited medical resources and contact tracing or screening. We would also model the effect of non-pharmaceutical interventions such as quarantine, isolation and information induced behavior changes. Further, via a multi-patch model we shall explore the dynamics of COVID-19 disease in 3 states in India. The conclusions will be drawn from both models via mathematical analysis and data fitting. We also provide a cost effective analysis of the applied control interventions on our model and provide the best strategy to be implemented so that not only the infective population is reduced but also the cost of implementation of interventions is minimal.

Some Modeling Perspectives Across Scales: From Onchocerciasis to COVID-19

Shakir Bilal
Postdoctoral Research Associate, University of Galway

TBA…

Close-to-convexity of harmonic functions associated with hypergeometric functions

Swadesh Kumar Sahoo

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In this talk, we discuss about the univalence characteristics of several nontrivial harmonic functions associated with Gaussian hypergeometric functions of type

$$z\,{}_2F_1(a,b;c;z)+\overline{z^2\,{}_2F_1'(a,b;c;z)} \quad \text{and} \quad z\,{}_2F_1(a,b;c;z^2)+\overline{z^2\,{}_2F_1'(a,b;c;z^2)}$$

for $|z| < 1$. We see that these results follow by establishing monotone conditions on the coefficients of the power series

$$f(z)=z+\sum_{n=2}^{\infty}a_nz^n+\overline{\sum_{n=2}^{\infty}b_nz^n}$$

to ensure its close-to-convexity (univalency) in the unit disk.

Keywords: Hypergeometric functions, harmonic functions, close-to-convex functions, univalent functions.

This talk is based on the article: S. K. Sahoo and S. Wankhede, Monotone coefficients of univalent harmonic functions with applications to special functions, J. Math. Anal. Appl. 554 (2026), no. 1, Paper No. 129898, 16 pp.

Some special entire functions and their zeros

Sanjeev Singh
Associate Professor, IIT Indore

In this talk, we discuss the real and complex zeros of certain special entire functions, including the Wright function, hyper-Bessel functions, and a particular case of the generalized hypergeometric function. Several classical results due to Laguerre, Obreschkoff, Pólya, and Runckel play a crucial role in this investigation. These findings extend Hurwitz's well-known theorem concerning the exact number of nonreal zeros of Bessel functions of the first kind.

On integral means for certain classes of univalent functions

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Let A be the class consisting of functions h that are analytic in the unit disk $D = \{z : |z| < 1\}$ and normalized by the condition $h(0) = 0 = h'(0) - 1$. For $h \in A$, estimation of the integral means

$$L(r,h) = \frac{r^2}{2\pi} \int_{-\pi}^{\pi} \left| \frac{1}{h(re^{i\theta})} \right|^2 d\theta$$

is an important quantity for certain problems in fluid dynamics, especially when the functions $f(z)$ are nonvanishing in the punctured unit disk $D - \{0\}$. In this talk, we will discuss the integral means extremal problems of finding the maximum value of $L(r, h)$ as a function of r when h belongs to certain classes of univalent functions. For$\mu > 0$, we consider the non-vanishing analytic function $(z/h)^{\mu}$, where $(z/h)^{\mu}$ represents principal powers. In particular, we will also determine the maximum value of $L(r, h)$ for function of the form $(z/h)^{\mu}$ when h ranges over the classes of the starlike functions of order β and α-spiral-like functions of order β in D. The maximum value of $L(r, h)$ comes in the form of Gaussian hypergeometric function $2F1(a, b; c; z)$. A particular case of the related theorem includes the solution of a problem of Gromova and Vasil'ev.

This talk is based on the following articles:

1. M. F. Ali and V. Allu, Integral Means and Dirichlet integral for certain class of analytic function, J. Aust. Math. Soc., 99(3) (2015),315–333.

2. M. Obradovi´c, S. Ponnusamy, and K.-J. Wirths, Integral meansand Dirichlet integral for analytic functions, Math. Nachr., 288(2-3) (2015), 334–342.

3. Navneet Lal Sharma, On integral means for starlike and spiral-like functions, Journal of Analysis. 31 (2023), 2409–2418.

On Poisson Distribution Series Connected with Linear Operators for a Certain Class of Normalized Analytic Functions

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This study explores the inclusion characteristics of operators associated with the Poisson distribution series. The objective is to determine the sufficient and necessary conditions under which the operators belong to distinct subclasses of univalent functions. The results are obtained by using the coefficient bound from a certain class of analytic functions, which provides valuable insights into the behavior of these functions under transformation.

Keywords: Univalent functions, Starlike functions, Convex functions, Spirallike functions, Poisson distribution series

MSC Classification: 30C45 , 30C50 , 33C90

On Zeros of Harmonic Polynomials

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In this talk, we explore the distribution and localization of zeros of harmonic polynomials. In their seminal work, Khavinson and Swiatek resolved Wilmshurst's conjecture by establishing a sharp upper bound on the number of zeros of harmonic polynomials of the form $h(z) - \bar{z}$; where $h(z)$ is an analytic polynomial of degree greater than one. Subsequently, Dor et al. and Liu et al. determined, respec- tively, the number of zeros and a compact region containing all zeros of harmonic trinomials. We extend these results by providing a complete characterization of the precise compact region that contains all zeros of general harmonic polynomials. Furthermore, by employing the harmonic analogue of the argument principle, we examine the distribution of zeros, supported with illustrative examples to aid intuition. Sete and Zur introduced the pioneering iterative root-nding method for complex harmonic functions, generalizing Newton's method. However, their approach left unresolved questions regarding convergence and the choice of initial points. To address these issues, we present a novel root-nding algorithm for harmonic polynomials that guarantees convergence and successfully determines all zeros of a given harmonic polynomial. Our approach improves upon Sete and Zur's method, and is supported with concrete examples illustrating its effectiveness.

Automorphisms of subalgebras of bounded analytic functions(online)

P Muthukumar
Assistant Professor, Department of Mathematics & Statistics,
ISI, Chennai

In this talk, we will discuss about (algebra) automorphisms of the Banach algebra of bounded analytic functions and its various subalgebras.

Ref: Kanha Behera, Rahul Maurya and P. Muthukumar, Automorphisms of subalgebras of bounded analytic functions, J. Math. Anal. Appl., 552 (2), 2025, Art. 129804, 15pp.

Structural sensitivity of Chaotic Dynamics in Hastings-Powell's Model

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IIT, Kanpur

The routes to chaos and the global bifurcations leading to chaotic behavior are two fascinating areas of research in nonlinear dynamics. Chaotic dynamics are observed in a wide range of mathematical models across various disciplines of science and engineering. In recent years, the structural sensitivity of models with respect to their bifurcation structures leading to chaos has received increasing attention. The main objective of this talk is to discuss the structural sensitivity of the bifurcation structure associated with the classical Hastings–Powell model and the global bifurcations that give rise to chaotic regimes. A systematic bifurcation analysis, incorporating both local and global bifurcations, provides deeper insights into the routes to chaos and the nature of transient dynamics.

Stability and bifurcation analysis of prey-predator systems with food-limited growth rate

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This presentation, aims to investigate two interacting population models in deterministic environments through the framework of nonlinear dynamics. We begin with a two-dimensional interacting population models capturing resource-limited growth, Holling type-I as well as type-II responses with and without time-lag. We analyze the boundedness of the proposed systems and establish the conditions for the existence and stability of ecologically feasible equilibrium states. A detailed bifurcation analysis reveals complex behaviors, including co-dimension-I and co-dimension-II bifurcations (saddle-node, transcritical, Hopf bifurcation and Bogdanov-Takens). At the end, captivating results from numerical simulations are offered to explore the dynamics of proposed systems.

References

[1] R. P. Gupta, Shristi Tiwari, Shivam Saxena, The qualitative behavior of a plankton-fish interaction model with food-limited growth rate and non-constant fish harvesting, Discrete Contin. Dyn. Syst. Ser. B, (AIMS), 57:5, (2022), 2791-2815.
[2] R.P. Gupta, Shristi Tiwari, Arun Kumar, A comprehensive study of bifurcations in an interactive population model with food limited growth, Differ. Equ. Dyn. Syst. (Springer), https://doi.org/10.1007/s12591-023-00672-9, (2024).

A modified May Holling Tanner Model: the role of dynamic alternative resources on species' survival

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The present paper investigates the dynamical behavior of the modified May Holling Tanner model in the presence of dynamic alternative resources. We study the role of dynamic alternative resources on the survival of the species when there is prey rarity. Detailed mathematical analysis and numerical evaluations, including the situation of ecosystem collapse, have been presented to discuss the coexistence of species, stability, occurrence of different bifurcations (saddle-node, transcritical, and Hopf) in three cases in the presence of prey and alternative resources, in the absence of prey, and in the absence of alternative resources. It has been obtained that the multiple coexisting states and their stability are outcomes of variations in predation rate for alternative resources. Also, the occurrence of Hopf bifurcation, saddle-node bifurcation, and transcritical bifurcation is due to variations in the parameters of dynamic alternative resources. The impact of dynamic alternative resources on species density reveals the fact that if the predation rate for alternative resources increases, then the prey biomass increases (under some restrictions), and variations in the predator's biomass widely depend upon the quality of food items. This study also points out that the survival of predators is possible in the absence of prey. In the theme of ecological balance, the present study suggests some theoretical points of view for the eco- managers.

References

[1] Pal, Saheb, Nikhil Pal, Sudip Samanta, and Joydev Chattopadhyay. ”Effect of hunting cooperation and fear in a predator-prey model.” Ecological Complexity 39 (2019): 100770.

[2] May, Robert M. ”Stability and complexity in model ecosystems.” In Stability and Complexity in Model Ecosystems. Princeton University Press, 2019.

[3] Van Baalen, Minus, Vlastimil Kˇrivan, Paul CJ van Rijn, and Maurice W. Sabelis. ”Alternative food, switching predators, and the persistence of predatorprey systems.” The American Naturalist 157, no. 5 (2001): 512-524.

[4] Sahoo, Banshidhar, and Swarup Poria. ”Effects of additional food in a delayed predator–prey model.” Mathematical biosciences 261 (2015): 62-73.

Global Analysis of Predator-Prey Dynamics under Different Harvesting Strategies in a Patchy Habitat with Refuge and Alternate Food

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Abstract: A predator–prey dynamic reaction model is investigated in a two-layered water body where only the prey is subjected to harvesting. The surface layer (Layer1) provides food for both species, while the prey migrates to deeper layer (Layer-2) as a refuge from predation. Although the prey is the preferred food for the predator, the predator can also consume alternative food resources that are abundantly available. The availability of alternative food resources plays a crucial role in species' coexistence by mitigating the risk of extinction. The main objective of the work was to explore the effect of different harvesting strategies (nonlinear and linear harvesting) on a predator–prey model with effort dynamics in a heterogeneous habitat. The analysis incorporates a dual timescale approach: the prey species migrate between the layers on a fast timescale, whereas the growth of resource biomass, prey– predator interactions, and harvesting dynamics evolve on a slow timescale. The complete model involving both slow and fast timescales has been investigated by using aggregated model. The reduced aggregated model is analyzed analytically as well as numerically. Moreover, it is demonstrated that the reduced system exhibits the bifurcations (transcritical and Hopf point) by setting the additional food parameter as a bifurcation parameter. A comparative study using different harvesting strategies found that there is chaos in the system when using linear harvesting in the predator–prey model. However, nonlinear harvesting gives only stable or periodic solutions. This concludes that nonlinear harvesting can control the chaos in the system. Additionally, a one-dimensional parametric bifurcation, phase portraits, and time series plots are also explored in the numerical simulation.

Keywords: predator–prey model; effort dynamics; linear and nonlinear harvesting; alternative food; aggregation of variables; stability; periodic solutions; chaos; numerical simulations.

References

[1] H. Molla, Sabiar Rahman, S. Sarwardi, Dynamics of a predator–prey model with Holling type II functional response incorporating a prey refuge depending on both the species, Int. J. Nonlinear Sci. Numer. Simul., 20 (2019), 89–104. https://doi.org/10.1515/ijnsns-2017-0224
[2] T. K. Kar, Stability analysis of a prey–predator model incorporating a prey refuge, Commun. Nonlinear Sci. Numer. Simul., 10 (2005), 681–691. https://doi.org/10.1016/j.cnsns.2003.08.006
[3] S. Pandey, U. Ghosh, D. Das, S. Chakraborty, A. Sarkar, Rich dynamics of a delay-induced stage-structure prey-predator model with cooperative behaviour in both species and the impact of prey refuge, Math. Comput. Simul., 216 (2024), 49–76. https://doi.org/10.1016/j.matcom.2023.09.002
[4] W. Lu, Y. Xia, Y. Bai, Periodic solution of a stage-structured predator-prey model incorporating prey refuge, Math. Biosci. Eng., 17 (2020), 3160–3174. https://doi.org/10.3934/mbe.2020179
[5] J. Ghosh, B. Sahoo, S.Poria, Prey-predator dynamics with prey refuge providing additional food to predator, Chaos, Solitons Fractals, 96 (2017), 110–119. https://doi.org/10.1016/j.chaos.2017.01.010
[6] S. Samaddar, M. Dhar, P. Bhattacharya,Effect of fear on prey–predator dynamics: Exploring the role of prey refuge and additional food, Chaos: Interdiscip. J. Nonlinear Sci., 30 (2020). https://doi.org/10.1063/5.000696

Exploring Machine Learning Models for Schizophrenia Detection-A systematic review

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Schizophrenia is a neurological disorder that is associated with several genetic, environmental, and neurobiological factors. The various prediction, detection, and classification techniques that can be used to catch the disease in early stages are noted in this paper. Some of the common machine learning algorithms, such as convolutional neural networks (CNNs), support vector machines (SVMs), random forest, logistic regression, and also certain models that have been developed, particularly those by the PRONIA project and ENIGMA consortium, are compared in terms of their results and accuracy in schizophrenia detection. The aim is to identify which of these machine learning models performs the best. While a lot of developments have been made, there is much more that can be done in this field of psychosis. Additionally, a potential new model is proposed for future work.

Mathematics Behind Memory Chaos and Realistic Pattern Formations

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First, by using the real-order linear time-varying theory, it is shown that memory chaos in an incommensurate food chain nonlinear system can be controlled when the system starts at a non- zero initial time. Then, we show that the chaotic states of two identical models of such systems can be synchronized whenever the initial time becomes non-zero. A famous hidden memory chaotic attractor is the typical class of attractor that does occur in nonlinear fractional order systems without any known bifurcations of any existing attractors. It has been found that such attractors are fundamental and localized with nonlinear fractional-order systems with no equilibrium points. In this talk, we try to answer the following:
(i) Is it possible to develop new mathematical tools to verify the stability of hidden memory chaotic attractors in nonlinear fractional order systems?
(ii) Is it possible to verify the attractivity of non-periodic open orbits in fractional order systems?
Existing textbooks and research monographs on theoretical/mathematical ecology, when addressing its spatial and spatiotemporal pattern dynamics, practically never go beyond the classical Turing scenario of pattern formation. The dynamics of a simple ecological system is described by a system of three reaction-diffusion equations with biologically reasonable non-linearities (logistic growth of the prey, Holling type functional response of the predator). When the reaction terms or local kinetics of the system is oscillatory for a wide class of initial conditions, the evolution of the system leads to the formation of a non-stationary irregular pattern corresponding to spatiotemporal chaos. We show the mechanism of spatiotemporal pattern formation resulting from the Hopf bifurcation analysis, which can be a potential candidate for understanding the complex spatiotemporal pattern dynamics of ecological systems. These spatial patterns serve as a realistic model for patchiness found in aquatic systems (e.g.,marine and oceanic), terrestrial systems and disease dynamics. We will pick up different realistic pattern observed in real-life and see how it can be generated and what is the mathematics behind its mechanism. We found that Wave of Chaos (WOC) is an effective mechanism for the propagation of chaotic dynamics in predation and competitive systems. These results offer crucial new understandings of the intricate pattern dynamics of prey-predator interactions in ecological networks.

A High-Contrast Optimal Control Problem in a highly Oscillating Domain - Multi-scale Analysis*

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In PDEs, quite often it is become necessary to approximate the PDEs by a family of PDEs involving a parameter which may go to 0 or ∞. It can also happen the other way that the physical systems produces a family of PDEs and we may need to find the limiting PDE. It can be due to several reasons, for example from the presence of multi-scales. Multi scales arise in many physical and industrial problems, and industrial constructions which lead to very complicated structures. Homogenization is a branch of science where one try to understand the microscopic structures via a macroscopic medium by taking care of the various scales involved in the problem which appears through the solutions.

In this talk, we consider a domain with high oscillating boundaries, where the oscillatory part consists of two high contrast materials which leads to a family of non-uniform (with respect to the parameter) elliptic operators. We consider an associated optimal control problem in such a domain and we study the asymptotic analysis of the same to obtain the limit problem. We present results from the work of A. K. Nandakumaran and A. Sufian, Strong contrasting diffusivity in general oscillating domains: Homogenization of optimal control problems, Journal of Differential Equations, 291(2021) 57-89.

https://doi.org/10.1016/j.jde.2021.04.031
We briefly recall two-scale method and method of unfolding operators and obtain the limits using the method of unfolding.

Parameter Uniform Hybrid Approach for Singularly Perturbed Two-Parameter Parabolic Problem with Discontinuous Data

Anuradha Jha
Assistant Professor, IIIT Guwahati

In this talk, we discuss the singularly perturbed two-parameter parabolic problem of the reaction-convection-diffusion type in two dimensions. These problems exhibit discontinuities in the source term and convection coeffi cient at particular domain points, which result in the formation of interior layers. The presence of perturbation parameters leads to the formation of boundary layers with varying widths. We implement a hybrid monotone difference scheme for the spatial direction, on a specially designed piece wise uniform Shishkin mesh, combined with the Crank-Nicolson method on a uniform mesh for the temporal direction. The point of discontinuity is resolved using a five point scheme. The resultant scheme resolves the boundary and interior layers. The resulting scheme is proven to be uni formly convergent, with almost second order of convergence in the spatial direction and exactly two in the temporal direction. Numerical experi ments corroborate the theoretical results.

Critical Neumann problem for nonlocal elliptic equations

Prof. Jagmohan Tyagi
Professor, Indian Institute of Technology Gandhinagar

We prove the existence of solutions for critical Neumann problems involving the fractional Laplacian. The key challenge is that the critical exponent prevents the use of standard variational methods because the Palais-Smale condition is not met. To overcome this, we establish a bound for the Rayleigh quotient and use a nonlocal version of Cherrier's optimal Sobolev inequality in bounded domains to find solutions. This is a joint work with Somnath Gandal.

Global well-posedness and asymptotic analysis of a nonlinear heat equation with constraints of finite codimension

Manil T Mohan
Associate Professor, IIT Roorkee

We prove the global existence and the uniqueness of the $L^p\cap H_0^1-$valued ($2\leq p < \infty$) strong solutions of a nonlinear heat equation with constraints over bounded domains in any dimension $d\geq 1$. Along with a modified \textit{Faedo-Galerkin} approximation method and the compactness arguments, we utilize the monotonicity and the hemicontinuity properties of the nonlinear operators to establish the well-posedness results. In particular, we show that a Hilbertian manifold $\mathcal{M}$, which is the unit sphere in L^2 space, describing the constraint is invariant. Finally, in the asymptotic analysis, we generalize the recent work of [P. Antonelli et al., \emph{Calc. Var. Partial Differential Equations}, 63(4), 2024] to any bounded smooth domain in $\mathbb{R}^d$, $d\geq1$, when the corresponding nonlinearity is a damping. In particular, we show that, for positive initial datum and any $2\le p < \infty$, the unique positive strong solution of the above mentioned nonlinear heat equation with constraints converges in $L^p\cap H_0^1$ to the unique positive ground state.

Mathematical Modeling of Food Adulteration-Induced Diseases with Media Awareness

Kunwer Singh Mathur
Associate Professor, Jawaharlal Nehru University New Delhi

Food adulteration poses a serious threat to public health, contributing to a wide range of diseases that often remain underreported and poorly understood. This talk presents a comprehensive mathematical modeling framework to analyze the dynamics of food adulteration-induced diseases in a population. By integrating epidemiological models with socio-behavioral components, we explore how the spread and impact of these diseases can be influenced by varying levels of media awareness. The model captures the interaction between disease transmission, public response to health risks, and the role of media in altering consumer behavior and regulatory actions. We discuss stability analysis, threshold parameters, and numerical simulations that illustrate critical intervention points. The findings highlight the importance of sustained media campaigns and public education in mitigating health risks. This interdisciplinary approach offers valuable insights for policymakers, health professionals, and media stakeholders to design more effective strategies for combating food adulteration and its consequences.

Stabilization of droplets in viscous fluid

Sumit Malik
Associate Professor, Bennett University

In recent years, the creation and stabilization of small toroidal drops have attracted significant attention due to their potential applications and the fundamental challenges they pose. Understanding the appearance and dynamics of such drops in various ambient flow fields is essential for advancing this area. Our recent investigation into Newtonian toroidal drops embedded in linear viscous flows of immiscible fluids reveals that stationary states exist only within a narrow range of flow intensities, and these states are inherently unstable. Stabilizing toroidal drops is a complex phenomenon, particularly since such structures are not confined to single-phase flows.

We began by examining singly connected rotating drops in axisymmetric force fields and identified a stability domain in the phase plane of Bond and capillary numbers. Building on this, we extended our study to toroidal drops and found that inherently stable tori occur only in extensional flows with large major radii, whereas drops subjected to bi-extensional flows remain highly unstable regardless of size. These findings motivated the development of a feedback control strategy to stabilize toroidal drops in extensional and bi-extensional viscous linear flows. This approach not only stabilizes previously unstable stationary shapes but also enables the formation of nearly collapsed states—configurations never achieved in earlier studies.

Propagation of shock waves in magnetic field

Sanjay Yadav
Associate Professor, Alliance university banglore

The study of shock wave propagation in a magnetic field is of fundamental importance in plasma physics, astrophysics, and magnetohydrodynamics (MHD). This work investigates the dynamic behavior of shock waves under the influence of an external magnetic field, emphasizing the interplay between magnetic pressure, plasma density, and flow velocity. Using the magnetohydrodynamic (MHD) framework, the governing conservation equations for mass, momentum, and magnetic induction are analyzed to determine the structure and stability of magneto-shocks. Both fast and slow magnetosonic shocks are characterized based on the orientation of the magnetic field relative to the propagation direction. Numerical simulations and analytical modeling reveal that the presence of a magnetic field significantly alters the shock strength, compression ratio, and energy dissipation mechanisms. The results demonstrate that the magnetic field acts as a stabilizing factor, reducing the shock steepening rate while introducing anisotropic wave propagation. These findings have direct implications for solar wind dynamics, supernova remnant evolution, and controlled fusion devices, where understanding magnetically influenced shocks is essential for predicting plasma behavior in high-energy environments

Stabilization of steady-states in a three-dimensional network of ferromagnetic nanowires

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Abstract

In this work, we analytically investigate the stability of steady-states in a three-dimensional network of ferromagnetic nanowires. We construct a three-dimensional network nanostructure comprising an array of straight nanowires aligned parallel to each other at an equidistance. The analysis is performed within the classical framework of the Landau-Lifshitz equation. We consider the finite network model consisting of infinite- and finite-length nanowires. For each case, we derive sufficient conditions demonstrating that the steady-states are exponentially stable. We remark that these conditions depend on the damping and anisotropy coefficients and remain unaffected by the overall size of the network and the lengths of the nanowires.

Keywords: Nanowires; Micromagnetics; Landau-Lifshitz equation; Stability; Network nanostructures.

AMS Subject Classification: 35B35, 35K55, 35Q60.

The Cantor set: From a pair of discontinuous functions

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The existence of the Cantor set is corroborated via a pair of continuous mappings, particularly contraction mappings, under the application of Banachs metric fixed point theorem. Can the Cantor set be obtained via a pair of discontinuous mappings? To assertively answer this question, for the first time in the literature, the present work employs the metric fixed point theorem of a generalized contraction, and it need not require Blaschkes result of completeness. Thereby, Hutchinson- Barnsley theory of fractal is revised, and it is given a new direction with relaxation in the continuity of the mappings and completeness of the Hasudorff space.

Modeling Calcium Dynamics Under Fuzzy Environment

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Calcium ions in astrocytes play a crucial role in various physiological processes, including neurotransmitter regulation, synaptic plasticity, and communication within the central nervous system. Traditional modeling of calcium signaling often relies on deterministic differential equations, which may not fully capture the inherent uncertainties and complexities of biological systems. In this study, we propose a novel approach to model calcium dynamics in astrocytes using fuzzy differential equations (FDEs). FDEs allow for the incorporation of uncertainty, variability, and imprecision inherent in biological systems, providing a more flexible and realistic framework for modeling calcium signaling. In this model of intracellular calcium concentration to account for fuzzy parameters, such as receptor sensitivity, channel permeability, and intracellular buffering is incorporated. The fuzzy system is represented using linguistic variables and fuzzy sets, which offer a way to describe the uncertain or imprecise nature of physiological processes. The fuzzy differential equations using appropriate numerical methods, ensuring the stability and robustness of the model under varying conditions. Our results demonstrate that the fuzzy differential equation framework is effective in simulating calcium dynamics in astrocytes, providing insight into how fluctuations and uncertainties in biological parameters affect calcium signaling. Ultimately, this model can be applied to study the impact of perturbations, diseases, or therapeutic interventions on astrocyte function and neural network activity.

Keywords: Calcium ions, Buffers, Fuzzy system

Mathematical Modeling and Optimal Control Aspects of Infectious Diseases

Anuj Kumar
Assistant Professor, Thapar Institute of Engineering & Technology, India

In this study, we investigate how information influences the transmission of vector-borne diseases by developing a compartmental mathematical model that incorporates individuals' behavioral changes—specifically, self-protective actions driven by information. We analyze the model to establish the local and global stability of its equilibrium points and show that a forward bifurcation arises when the basic reproduction number exceeds one. Furthermore, we apply Pontryagin's Maximum Principle to formulate an optimal control problem involving three time-dependent control strategies: information-driven self-protection, medical treatment, and insecticide application. Based on these interventions, seven distinct control strategies are constructed and numerically examined to identify the most effective and economically viable approach for reducing disease burden. The results demonstrate that implementing all three controls simultaneously yields the greatest reduction in both infection levels and overall cost, although the other strategies also provide significant benefits under certain conditions. We also explore how the proposed control strategies perform over a range of reproduction numbers to assess their impact on epidemic peaks (maximum prevalence). Additionally, a cost-effectiveness evaluation using the average cost-effectiveness ratio (ACER), infection averted ratio (IAR), and incremental cost-effectiveness ratio (ICER) confirms that the combined use of all control measures is the most economically efficient option.

Plenary Talk

Stabilized methods for PDEs: Theory, Computation & Application

B V Rathish Kumar
Associate Professor, Vellore Institute of Technology, Vellore, India

Stabilized formulations have transformed the numerical treatment of multiscale partial differential equations, enabling robust and accurate simulation of convection-dominated flows, coupled physics, and complex nonlinear systems. This talk presents a unified perspective on stabilized methods grounded in the multiscale variational finite element framework, highlighting its theoretical foundations, computational realization, and broad impact across engineering and scientific applications. Emphasis is placed on how intrinsic scale separation, residual-based stabilization, and targeted enrichment deliver enhanced stability, improved convergence, and reliable physical fidelity. Recent advances in algorithmic design, efficient solvers, and high-performance implementations will be discussed, along with representative case studies demonstrating the method's effectiveness in challenging real-world PDE problems. The talk aims to connect theory, computation, and application, showcasing stabilized multiscale FEM as a powerful paradigm for next-generation PDE modeling.

Quantum Differential Equations

Manish K Gupta, Director (Academics) and Senior Professor 2nd December 2025

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Abstract: Quantum algorithms offer a novel paradigm for numerical computation in which fundamental linear-algebraic tasks are executed using principles from quantum mechanics, including superposition, unitary evolution, and measurement. This talk examines the emerging theory of quantum algorithms for differential equations. After giving a brief overview of the mathematical foundations of quantum computing, modelling qubits as vectors in finite-dimensional Hilbert spaces, quantum gates as unitary operators, and quantum circuits, I will briefly survey quantum algorithms for ordinary and partial differential equations, which typically reduce differential problems to large linear systems.

Four Centuries Of Fermat's Last Theorem And Elementary Proofs Of Particular Cases

R P Agrwal

Emeritus Research Professor,Department of Mathematics and Systems Engineering, Florida Institute of Technology

TBA…

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The Atangana integral: Resolving decades of confusion in fractional calculus and bridging the Riemann-Liouville-Caputo divide

Abdon Atangana
Professor, University of The Free State, South Africa

TBA…

A stitch in time saves lives: Modeling of Health Innovation in the age of AI-Integrating dynamics, evidence, and real-time decision making

Anuj Mubayi
Distinguished IBA Fellow , USA

TBA…

Contributory Talk

Influence of Habitat Complexity and Prey Escape on Degenerate Hopf and Bogdanov–Takens Bifurcations in Ecological Systems

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This study presents the development and comprehensive analysis of a two-dimensional predator-prey model that incorporates prey escape behavior reducing the predator's capture success, effects of spatial habitat complexity, and predator mortality trade-offs that escalate with increased foraging activity. The model integrates a classical Holling type II functional response, which is then extended to reflect the impacts of habitat complexity and prey escape on predator-prey dynamics. We established the non-negativity and boundedness of the system's steady states and thoroughly examined their stability characteristics. Our investigation identified multiple codimension-one and codimension-two bifurcations, including saddle-node, both supercritical and subcritical Hopf, supercritical and subcritical homoclinic, Bautin (generalized Hopf), Bogdanov–Takens, and generalized homoclinic bifurcations. The system exhibits multi-stability with regions of bi-stability and tri-stability, as well as global stability across different parameter regimes in the biparametric space. Extensive numerical simulations supported the analytical findings, and sensitivity analysis highlighted the key parameters influencing system dynamics and species persistence. The main goal of this work is to understand how balanced predator-prey interactions can be maintained in environments characterized by habitat complexity and prey escape strategies.
Keywords: Habitat complexity, Prey escape mechanisms, bifurcations, sensitivity, multistability.

SEIQHR Model for the Dynamics of Herpes Simplex Virus (HSV)

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In this paper, we formulate a nonlinear compartmental model of type SEIQHR (Susceptible–Exposed–Infected–Quarantined–Hospitalized–Recovered) to describe the progression of the Herpes Simplex Virus (HSV). The basic reproduction number $R0$ is derived using the next-generation matrix method, serving as a threshold parameter that determines whether the disease dies out or persists in the population. The local and global stability of both the disease-free and endemic equilibria are rigorously analyzed by using Routh-Hurwitz criterion to understand the long-term dynamics. Furthermore, a sensitivity analysis is performed to assess the influence of key epidemiological parameters on $R0$, thereby highlighting their relative importance in controlling disease transmission.
Keywords: Herpes Simplex Virus (HSV), basic reproduction number $R0$, local and global stability, Routh-Hurwitz criter.

Transfer Learning Based Wavelet-CNN Model for Diabetic Retinopathy Classification Using EyePACS Dataset

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Abstract: Diabetic Retinopathy (DR) is a major contributor to vision loss in diabetic patients worldwide. This study introduces a novel hybrid framework that synergistically combines Discrete Wavelet Transform (DWT) with transfer learning for robust classification of DR severity from EyePACS fundus images. The DWT decomposes the green channel into four sub-bands (LL, LH, HL, HH), effectively capturing multi-scale spatial–frequency features, while pretrained CNNs extract rich semantic representations. A two-branch Wavelet–Transfer Learning (WTL) model fuses these complementary feature sets to classify images into five DR grades. Experimental evaluation on a subset of EyePACS demonstrates that WTL improved accuracy, outperforming conventional CNN baselines. The integration of wavelet coefficients with deep transfer features ensures robust performance under limited data and variable illumination, underscoring its potential for automated, reliable DR screening in clinical practice.
Keywords: Diabetic Retinopathy, Discrete Wavelet Transform, Convolutional Neural Networks, EyePACS dataset.

Study of Classical Solution to a Time-Fractional Abstract Neutral Integro-Differential Equations with State Dependent Delay and Nonlocal Initial Conditions

In this work, we study a class of time-fractional neutral integro-differential equations with state-dependent delay subject to a nonlocal initial condition. We establish the existence of classical solutions under two different sets of assumptions. Recently, a significant development has been reported on the existence of a classical solution to integer order problems. In those works, the author used the Banach contraction mapping principle in the Lipschitz function space with uniformly bounded Lipschitz constant, i.e., in $\{u \in CLip([-\tau, T];X) : [u]CLip([-\tau,T];X) \leq R\}$, where $R > 0$ is fixed. However, for the fractional-order case, it is not possible to find a solution in Lipschitz function space. In fact, the solution for the homogeneous version of the problem is H¨older continuous even for initial data that are strong enough (for instances $x \in D(A)$). This is due to the singularity of the resolvent families $T\alpha(t)$ at $t = 0$. Krasnoselskii's fixed point theorem have been employed to overcome this situation. In addition, we present a complementary result on the existence strict solution.

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Fractional Differential Equations with Multi-Delays: Existence, Ulam-Hyers Stability,

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This article studies nonlinear fractional multi delay differential equations, specifically focusing on Caputo's fractional derivative of order α within the interval (0, 1). The authors demonstrate the existence and uniqueness of solutions by employing the weighted-norm method alongside the Banach Fixed Point Theorem. Additionally, the Ulam-Hyers stability of these solutions is thoroughly investigated and confirmed. A robust numerical approach based on interpolation is then introduced, achieving an accuracy of O(h4−α), followed by a thorough error analysis. Finally, the effectiveness of the proposed numerical method is demonstrated through various examples.

Dynamic analysis of fractional-order Richards-type logistic equation with multi-delays

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This work investigates the stability analysis of the equilibrium points of a fractional-order Richards-type logistic differential equation incorporating two distinct delays. By introducing small perturbations around the equilibrium points and employing linearization alongside the Laplace transform, we derive the characteristic equation to examine stability regions. Our findings indicate that the stability region is significantly influenced by the values of the fractional-order parameter α and the two
delay components. This study contributes to a deeper understanding of the dynamical behavior of this class of differential equations, which is pertinentin various applications such as population dynamics and resource management.

Ordinary differential equations based Modelling and Pole-Placement Controller Design for Synchronous Generator Dynamics

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The dynamic behaviour of synchronous generators under various operating conditions plays a crucial role in ensuring power system stability. In this work, a detailed mathematical model of a synchronous generator is developed in the form of ordinary differential equations (ODEs) to capture rotor-angle, speed dynamics, excitation-system effects under the disturbances. The model is implemented in MATLAB and transient responses, damping performance, and overall robustness are verified. The concepts of controllability and observability are employed to verify the system's controllability and observability. Using these concepts, a state-feedback controller based on the pole-placement technique is designed. Eigenvalue analysis of the closed-loop system demonstrates the efficacy of this controller in shifting system poles to yield improved stability margins. A state-space formulation for different system configurations is presented to provide deeper insight into the analysis. The simulations of a synchronous generator connected to a bus system under different operating conditions and fault scenarios are plotted, and the results including transient responses and eigenvalue shifts are validated which shows the effectiveness of the proposed control design.

Keywords: synchronous generator, ODE modelling, state-space formulation, controllability, observability, pole-placement control, eigenvalue analysis, dynamic stability, MATLAB simulation

Network Modeling and Dynamical Systems Framework to Unravel Cell Fate Dynamics in Cancers

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Cell fate plasticity – the ability of cells to reversibly switch among multiple phenotypic states – underlies diverse normal biological processes and fuels pathogenesis such as tumor heterogeneity, cancer initiation, and metastasis formation [1]. These transitions are tightly regulated by complex gene regulatory networks enriched with feedback loops, non-linear cooperative interactions, and logical dependencies. In a series of studies, we have developed a unified theoretical framework that connects network topology, logic-based regulation, and nonlinear dynamics to explain the emergence and controllability of multistable cell-fate landscapes.

We show that combinatorial gene interactions and feedback connectivity collectively determine whether a regulatory system exhibits binary, tristable, or continuumlike phenotypic regimes [1, 2]. Topology metrics predict network architectures predisposed to phenotypic hybridization, while bifurcation and sensitivity analyses reveal how feedback strength and coupling asymmetry shape transition pathways [3]. Importantly, a logic-incorporated minimal model establishes a universal design principle: multistable decision-making can arise from minimal yet logically structured motifs, offering a plausible explanation of cellular plasticity [4].

This integrative framework generalizes across biological contexts, linking structural features of regulatory networks to emergent dynamical repertoires. It provides mechanistic insights and quantitative tools to decipher and control phenotypic decision landscapes – a central bottleneck in controlling cancer cell plasticity and tumor heterogeneity.

References

[1] Rashid, M., Hari, K., Thampi, J., Santhosh, N.K., Jolly, M.K. (2022). Network topology metrics explaining enrichment of hybrid epithelial/mesenchymal phenotypes in metastasis. PLoS Comput. Biol. 18. https://doi.org/10.1371/journal.pcbi.1010687

[2] Rashid, M., Devi, B.M., Banerjee, M. (2024). Combinatorial cooperativity in gene feedback networks can control cell-fate transitions. Bull. Math. Biol. 86. https://doi.org/10.1007/s11538-024-01277-1

[3] Rashid, M., Hegade, A. (2025). Operating principles of interconnected feedback loops driving cell-fate transitions. npj Syst. Biol. Appls. 11. https://doi.org/10.1038/s41540-024-00483-w

[4] Srivastava, A., Rashid, M. (2025). A logic-incorporated 'minimal' tristable regulatory network explains fundamental cell-fate decisions. is SIAM J. Appl. Dyn. Syst. 24. https://doi.org/10.1137/24M1663090

A Robust Stabilized FEM for Singularly Perturbed Parabolic Delay Differential Equation with Degenerate Coefficient

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In this study, we address a singularly perturbed parabolic convection-diffusion-reaction problem with a large space delay argument and a degenerate convection coefficient. When the convection term dominates over the diffusion term, the solution exhibitstwo strong boundary layers, while the presence of a delay argument in the reaction term produces a weak interior layer. An implicit finite-difference scheme based on a θ-method is applied for time discretization on an equidistant mesh, and the streamline diffusion finite element method (SDFEM) is used for space discretization on various Shishkin-type layer-adapted meshes. The stability analysis of SDFEM is conducted by utilizing the discrete Green's function estimates and a suitable stabilization parameter. A robust convergence of the proposed method has been proved in both spatial and temporal directions in the maximum norm. Some test problems are considered for numerical validation and to demonstrate the efficiency of the proposed numerical scheme. Additionally, a comparison of the convergence outcomes has been presented on various Shishkin-type meshes, and solution plots are provided to illustrate the impact of the delay term effectively.

Turing Pattern Formation in a Seasonally Forced Predator-Prey Model with Fear Effects and Prey Refuge

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Seasonal variations critically influence species movement and migration, with profound implications for ecological stability as evidenced by numerous natural phenomena. In this work, we modify the traditional Lotka-Volterra model by incorporating three key mechanisms: predator-induced fear effects on prey reproduction and mortality, prey refuge dynamics, and periodic environmental fluctuations. For the autonomous system, we conduct a comprehensive stability analysis and uncover rich dynamics, including key bifurcation such as saddle-node, Hopf, and codimension-two bifurcations specifically Bogdanov-Takens and cusp bifurcations as well as global homoclinic bifurcations. Building upon the temporal case, we explore the non-autonomous dynamics, by including seasonal changes in the fear and refuge parameters, where we establish criteria for permanence and the existence of globally attractive periodic solutions, highlighting how seasonal forcing can lead to ecological collapse by crossing extinction thresholds. We further analyze a reaction-diffusion system under both autonomous and non-autonomous frameworks to investigate the spatial distribution of species. For non-autonomous cases with time-varying cross-diffusion and periodic reaction rates, we derive Turing instability conditions using comparison principles, expressed through inequalities involving time-varying parameters and their derivatives. The autonomous case recovers classical Turing conditions, validating our generalized approach. Numerical simulations quantify how fear intensity and refuge availability modulate pattern formation, while seasonality induces complex dynamics such as periodic oscillations, chaotic regimes, and bursting behaviors. This study highlights the profound impact of seasonal variations on ecological stability and pattern formation, offering valuable tools for understanding non-autonomous systems in ecological modelling.

Keywords: Prey-predator model, Seasonality, Chaos, Turing patterns

SPATIOTEMPORAL ANALYSIS OF PREY-PREDATOR MODEL WITH FEAR EFFECT AND NON-CONSTANT HANDLING TIME

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In this study, we investigate the prey-predator population dynamics by considering two important factors influencing foraging: (1) fear affecting prey and (2) handling time affecting predators. Fear of predators leads to reduced foraging and mate searching, which significantly impacts prey populations. Handling time of predators is often assumed constant in preypredator population models for simplicity; however, it varies due to various biotic and abiotic conditions. Considering these factors, we formulated a two-dimensional model encompassing spatiotemporal dynamics with a rational handling time function in the Holling type II functional response. Bifurcations such as Hopf, transcritical, and codimension-two Bautin bifurcations were observed in the temporal model. Bistability behaviour was observed on analysis with cost of fear and maximal handling time. Sensitivity analysis was performed to understand the role of reaction parameters in prey-predator coexistence. The spatiotemporal dynamics highlight the importance of cross-diffusion in pattern formation via Turing instability. Higher maximal handling times support coexistence by allowing prey to occupy high-density regions, whereas excessively high maximal handling times promote predator extinction.

Keywords: Non-constant handling time, fear, Turing

Zika Endemic Control Strategies with Multiple Transmission Routes and Resource Constraints

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The Zika virus presents a significant threat to global health, spreading through various transmission routes, including mosquito-to-human, human-to-mosquito, and human-to-human interactions. To address the psychological factors influencing the spread of Zika infection with limitations of medical resources during an outbreak. We developed a mathematical model that incorporates saturated incidence, multiple transmission pathways, and constraints on available medical resources for the Zika virus. We establish the positivity and boundedness of the model and explore the equilibrium states along with their stability using the threshold quantity reproduction number. Additionally, numerical simulations were conducted to illustrate the impact of the various transmission routes, the inhibitory effects of interventions, and the constraints on medical resources on the spread of the disease. Furthermore, local and global sensitivity analyses were performed to identify the key parameters that influence the reproduction number. The results from numerical simulations and sensitivity analyses indicate that transmission rates are critically sensitive parameters. These insights will enable public health authorities to effectively manage limited medical resources in combating Zika outbreaks.

Keywords: Zika infection; Mathematical modeling; limited medical resources; psychological impact

Numerical Simulation of Solitons and Peakons in Shallow Water Wave Models Using Improvised Collocation Method(online)

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Nonlinear partial differential equations (PDEs) play a significant role in understanding how waves propagate, steepen, and interact in many areas of science and engineering—from shallow water flows and plasma dynamics to nonlinear optics and elastic materials. Within this broad family, the Camassa–Holm (CH), Degasperis–Procesi (DP), and Fornberg–Whitham (FW) equations, along with their modified forms, stand out as powerful models. They are known for producing fascinating wave structures such as solitons, peakons, and shock-like profiles, all of which mirror real-world wave behavior. Beyond their physical relevance, these equations are mathematically rich, offering properties like integrability and diverse solution patterns that make them central to modern wave theory.
In this work, we focus on both the classical and modified versions of the CH, DP, and FW equations, applying a modified cubic B-spline collocation method. This approach takes advantage of the smoothness and local support of splines, while the modifications we introduce significantly improve accuracy and stability when simulating nonlinear dispersive waves. Through a series of numerical experiments, we show that the method delivers precise and efficient results, even in challenging scenarios with sharp gradients. Overall, our study demonstrates that the modified cubic B-spline collocation technique provides a robust and versatile computational framework. It captures the subtle dynamics of solitons and peakons with high fidelity, making it a valuable tool for exploring the complex world of nonlinear dispersive PDEs.

On the Approximate Controllability of Ψ-Hilfer Fractional Control Systems

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This paper investigates the approximate controllability of semilinear control systems involving Ψ Hilfer fractional derivatives. We introduce a novel sequential method based on a non-standard formulation of the mild solution. By constructing a Cauchy sequence of control functions in the underlying Hilbert space, we demonstrate its convergence to a limiting control. This control steers the system's solution arbitrarily close to a target state. The main proof leverages the completeness of Hilbert space and assumes the nonlinearity satisfies a Lipschitz condition.

Keywords: Ψ-Hilfer fractional operator, Controllability, Lipschitz condition, Cauchy sequence.

Mathematical modelling of viral infection, with particular application to H3N2 Influenza and optimal control strategy.

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Viral infections like H3N2 represents significant threat to global public health, necessitating the development of robust strategies for their containment. This study presents a compartmental deterministic model to analyze the transmission dynamics of a viral infection with help of differential equations and to identify an optimal, cost-effective intervention strategy. The model, based on a compartmental framework is formulated and analyzed and then basic reproduction number is obtained using next generation matrix method. Stability analysis of disease free and endemic equilibrium is obtained and sensitivity analysis of basic reproduction number conducted to identify key parameters. Subsequently, we introduce time-dependent control functions, representing interventions into the system. Using optimal control theory and Pontryagin's maximum principle, we seek to minimize the number of infected individuals and the cost associated with the interventions over a finite time horizon. Numerical simulations are performed to illustrate the effectiveness of the optimal strategy compared to scenarios with no control. This work underscores the power of mathematical modeling as a crucial tool for public health policymakers to design and implement efficient, resource-allocated strategies to effectively manage infectious disease outbreaks.

Keywords: Mathematical Modelling, Influenza virus, H3N2, Transmission Dynamics,Control Strategies, Optimal Control.

References
[1] Chaiwat Wilasang et al.(2022). Competitive evolution of H1N1 and H3N2 influenza viruses in the United States: A mathematical modeling study. Journal of Theoretical Biology, Elsevier Ltd.
[2] Amit Singh Thakur, Govind Prasad Sahu (2025). Modeling the COVID-19 Dynamics with Omicron Variant, Non-pharmaceutical Interventions, and Environmental Contamination. Differential Equations and Dynamical Systems, Springer.
[3] V. P. BAJIYA ET AL.(2022). Deciphering the transmission dynamics of COVID-19 in India: optimal control and cost effective analysis. Journal of Biological Dynamics, Taylor and Francis.

Modeling and Control of Vertical and Horizontal HBV Transmission with Saturated Incidence

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Hepatitis B, caused by the hepatitis B virus (HBV), is a serious global health issue that results in approximately 1.1 million deaths annually. Vertical transmission with HBeAgpositive mothers has transmission rates ranging from 70% to 90%. A saturated incidence rate offers a more accurate depiction of transmission dynamics by reflecting behavioral changes and reduced contact rates at higher infection levels. We proposed a mathematical model incorporating vertical transmission and a saturated incidence rate to describe HBV dynamics. The positivity and boundedness of the model are established. We compute the reproduction number R0 using the next-generation matrix. We examine the local and global stability of the HBV-free equilibrium point using the basic reproduction number. Local and global sensitivity analyses are performed to identify the key parameters influencing R0. Numerical simulations show that prevention of vertical transmission, along with reduced transmission rate and timely movement of individuals from the infected to the hospitalized class, is effective in reducing the spread of HBV. The model will help to develop effective intervention policies to control HBV in impacted communities.

Keywords: HBV, Vertical transmission, Saturation incidence, Stability analysis, PRCC.

Cubic-B Spline Collocation Method for the Prediction of Chemotherapy Response

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The response of cancerous tumors to chemotherapy is notoriously difficult to predict because of the complex interaction between cellular proliferation and the action of therapeutic drugs across both temporal and spatial domains. Mathematical modeling provides a powerful tool to explore such processes, offering a structured way to replicate tumor dynamics under treatment and to assess possible therapeutic outcomes. In this study, we focus on a Reaction–Diffusion framework to capture the evolution of malignant tumors subjected to chemotherapy. For the temporal discretization, the Crank–Nicolson method is employed, while spatial derivatives are approximated with a modified cubic B-spline collocation scheme. The nonlinear terms of the governing equations are managed through Rubin–Graves linearization, which simplifies the system while retaining diagonal dominance and appropriately enforcing boundary conditions. Stability of the numerical formulation is verified using von Neumann (Spectral Fourier) analysis. A series of numerical tests under different treatment scenarios demonstrates that the method delivers highly accurate solutions, closely aligned with existing benchmark results. The scheme is efficient, straightforward to implement, and provides a promising computational tool for simulating tumor–therapy interactions in biomedical research.

Impact of Fear and Prey-Dependent Predator Migration on Predator–Prey Dynamics in a Two-Patch Model

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This study explores the dynamics of a modified Leslie-Gower predatorprey model assumed in a two different patchy environment ($patch\, i,\ i\ =\ 1,\ 2$). Let $x_i(t),\ i\ =\ 1,\ 2$ be the density of prey in ith patch at time t such that $x(t)\ = x_1(t)\ +\ x_2(t)$. Similarly, $y(t)\ =\ y_1(t)\ +\ y_2(t)$ be the density of predator in ith patch (i = 1, 2) at time t. The proposed model incorporating a significant modification: the prey's reproduction rate is diminished due to the fear effect, where the presence of predator induces stress in a prey, resulting in a lower birth rates. On the other hand, the predator feeds on the prey according to a Holling-II functional response. The system is represented mathematically by a set of four ordinary differential equations, which describes the population densities of prey and predator within each patch. Predator movement between patches is assumed to follow constant migration rates, whereas the movement of prey population is considered predator density-dependent. The model assumes that the movement of prey and predator occurs on a much faster timescale compared to their growth and interactions. This timescales allows for the use of two time-scale method. Consequently, the fourequation system (complete model) is simplified into an aggregated method (reduced model) that describe the overall densities of prey and predator. The study identifies all feasible steady states of the aggregated system and examines their stability under certain predefined conditions. To explore the system's dynamic behavior, local bifurcation such as saddle-node bifurcation is investigated using Sotomayor's theorem. The occurrence of limit cycle is confirmed through Hopf bifurcation and Hopf-Hopf bifurcation (double Hopf) around the interior steady states. In addition, a two- parameter bifurcation analysis is also conducted, covering generalized Hopf bifurcation (GH) and Bogdanov-Takens bifurcation (BT). To validate the analytic results, numerical simulations are performed using a particular data set.

Keywords: Modified Leslie-Gower predator-prey model, fear effect, equilibrium points, local stability, Hopf bifurcation, numerical simulations.

References

[1] A. J. Lotka, ”Elements of physical biology”, Williams and Wilkins, 1925.
[2] B. V. Volterra, ”Fluctutation in the abundance of a species considered mathematically ”,Nature 118:558-600, 1926.
[3] Rani, R., Gakkhar, S., & Moussaoui, A. (2019). Dynamics of a fishery system in a patchy environment with nonlinear harvesting. Mathematical Methods in the Applied Sciences, 42(18), 7192-7209.
[4] Mchich, R., Auger, P.,& Poggiale, J. C. (2007). Effect of predator density dependent dispersal of prey on stability of a predator–prey system. Mathematical Biosciences, 206(2), 343-356.
[5] El Abdllaoui, A., Auger, P., Kooi, B. W., De la Parra, R. B., & Mchich, R. (2007). Effects of density-dependent migrations on stability of a two-patch predator–prey model. Mathematical Biosciences, 210(1), 335-354.
[6] Al-Momen, S., & Naji, R. K. (2022). The dynamics of modified Leslie-Gower predator-prey model under the influence of nonlinear harvesting and fear effect. Iraqi J. Sci, 63, 259-282.
[7] Wang, X., Tan, Y., Cai, Y., & Wang, W. (2020). Impact of the fear effect on the stability and bifurcation of a Leslie–Gower predator–prey model. International Journal of Bifurcation and Chaos, 30(14), 2050210.
[8] Aziz-Alaoui, M. A., & Okiye, M. D. (2003). Boundedness and global stability for a predator-prey model with modified Leslie-Gower and Holling-type II schemes. Applied Mathematics Letters, 16(7), 1069-1075.

Complex dynamics of a three species prey-predator-scavenger model with additional food, harvesting and the effect of double fear on prey species

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In this article, a three species prey-predator-scavenger system has been studied. The consequences of quadratic harvesting assumptions for predator and scavenger populations are examined by this study. Basic assumption of this three species system is that scavenger species depend on both living prey species as well as dead bodies of predators. This induces the fear effect on prey species and dynamics of the same are captured. Effects of intra-specific and interspecific competition have been observed by incorporating Crowley-Martin functional response. Dynamics of predator species are studied in presence of supply of additional food from an external source. In order to validate the the given system, the analytical conditions for positivity and boundedness are derived. The conditions of permanence and their feasibility has been invested in order to ensure the long-term coexistence of all the species. The steady states o the system are obtained and feasibility of all of them is confirmed. Stability of the steady states have been performed to understand the dynamics of the system. The local bifurcations such as transcritical and hopf bifurcation are studied and verified using Sotomayor's Theorem and Liu's Criteiron respectively with respect to suitable parameters analytically as well as numerically. One parametric bifurcation plots have been drawn for the respected parameters using MATCONT. Conditions for uniform persistence are obtained to analyze the long-term survival. Optimal harvesting policy is being studied using Pontryagin's Maximum Principle for finite time. Numerically the relationships between efforts, time and cost have been solved using Forward-Backward sweep method by using MATLAB. Rich dynamics of the system like periodic solutions, period doubling and chaos have been simulated using MATLAB.

References

[1] Layek, G. C. (2015). An introduction to dynamical systems and chaos (Vol. 1). West Bengal, India: Springer India.

[2] Mondal, B., Thirthar, A. A., Sk, N., Alqudah, M. A., Abdeljawad, T. (2024). Complex dynamics in a two species system with Crowley–Martin response function: Role of cooperation, additional food and seasonal perturbations. Mathematics and Computers in Simulation, 221, 415-434.

[3] Lin, S., Li, Q., Zhu, Q., Chen, F. (2022). Stability property of the predator-free equilibrium of a predator-prey-scavenger model with fear effect and quadratic harvesting. Commun. Math. Biol. Neurosci., 2022, Article-ID.

[4] Rani, R., Gakkhar, S. (2019). The impact of provision of additional food to predator in predator–prey model with combined harvesting in the presence of toxicity. Journal of Applied Mathematics and Computing, 60, 673-701.

[5] Fleming, W. H., Rishel, R. W. (2012). Deterministic and stochastic optimal control (Vol. 1). Springer Science Business Media.

Dynamical Behaviour of a two species prey-predator model with density dependent migration between hunting and resting zone

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This paper investigates the dynamics of a prey-predator system structured into two distinctzones: a hunting zone, inhabited by both prey and a portion of the predator population, and a resting zone exclusively for the remaining predators. The model incorporates a prey-density dependent migration of predators with Holling-II functional response for the prey-predator interaction, a modified Leslie-Gower scheme for predator growth. The model is formulated as a three-dimensional slow-fast system, reflecting the rapid time scale of predator migration compared to the slower dynamics of population growth and interaction. To analyze the system's long-term behavior, the method of aggregation is applied to analytically reduce the full 3D model to a simplified 2D aggregated system. The fundamental properties of this aggregated system, including the positivity and boundedness of solutions, are rigorously established. A comprehensive bifurcation analysis is then performed to understand how the system's qualitative behavior changes with variations in key parameters. The analysis reveals several codimension-one bifurcations, including a transcritical bifurcation near the prey-free equilibrium, and saddle-node and Hopf bifurcations at the co-existence equilibrium. These bifurcations identify critical thresholds for population collapse and the emergence of periodic solutions. Furthermore, a two-parameter analysis uncovers rich and complex behaviors, including several codimension-two bifurcations, namely Bogdanov-Takens, Generalized Hopf, and Cusp bifurcations. All analytical findings are validated with extensive numerical simulations performed using MATLAB and MatCont, demonstrating that the interplay between spatial movement and population dynamics can generate remarkably complex ecological behaviors.

References

[1] Manoharan, R., Rani, R., & Moussaoui, A. (2025). Dynamics of a Predator-Prey System With Fear Effect and Prey-Dependent Predator Migrations in a Two-Patch System. Mathematical Methods in the Applied Sciences.
[2] Mchich, R., Bergam, A., & Raissi, N. (2005). Effects of density dependent migrations on the dynamics of a predator prey model. Acta biotheoretica, 53(4), 331-340.
[3] El Abdllaoui, A., Auger, P., Kooi, B. W., De la Parra, R. B., & Mchich, R. (2007). Effects of density-dependent migrations on stability of a two-patch predator–prey model. Mathematical Biosciences, 210(1), 335-354.
[4] Sen, D., Ghorai, S., Banerjee, M., & Morozov, A. (2022). Bifurcation analysis of the predator–prey model with the Allee effect in the predator. Journal of mathematical biology, 84(1), 7.
[5] Pal, S., Pal, N., Samanta, S., & Chattopadhyay, J. (2019). Fear effect in prey and hunting cooperation among predators in a Leslie-Gower model. Mathematical Biosciences and Engineering, 16(5), 5146.
[6] Sen, D., Petrovskii, S., Ghorai, S., & Banerjee, M. (2020). Rich bifurcation structure of prey–predator model induced by the Allee effect in the growth of generalist predator. International Journal of Bifurcation and Chaos, 30(06), 2050084.

Exploring the Role of Fuzzy Uncertainty in Calcium Signaling Model of Astrocytes

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Numerous physiological and physical processes in astrocyte cells depends on free calcium concentration level. Free cytosolic calcium ions are referred as a second messenger. Ca^{2+} plays pivotal role in various signaling process in nervous system. Astrocytes is one of the most important nerve cells found in brain which support neurons and participate in signaling process too. In astrocytes there are two major compartments Endoplasmic Reticulum (ER) and Mitochondria. ER and Mitochondria plays very important role in maintaining the cytosolic calcium concentration $[Ca^{2+}]$ in astrocytes. In this work a mathematical model is developed in the form of fuzzy system of differential equation to study the interaction among cytosol, ER and mitochondria via free calcium ions. The stability analysis is performed for non-linear fuzzy system. Obtained results are drawn in python. The obtained equilibrium points and stability give new idea to understand the calcium signaling process in astrocytes under uncertainty conditions.

Keywords: Calcium concentration, Astrocytes, Endoplasmic Reticulum, Mitochondria, Fuzzy system, Stability, Bifurcation.

A New View of Cell Talk: Using Fractional Calculus to Model Astrocyte

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Calcium is the essential part of signaling process in nervous system. Astrocytes are one of the important nerve cells found in brain which support neurons and participate in signaling process. Astrocytes have two primary regions mitochondria and endoplasmic reticulum (ER). ER and mitochondria play very important role in maintaining the cytosolic calcium concentration $[Ca^{2+}]$ in astrocytes. In this work a mathematical model is developed in the form of fractional system of differential equation to study the interaction among cytosol, ER and mitochondria via free calcium ion. The stability analysis is performed for non linear fractional order system. Obtained result are draw in python. The obtained equilibrium point and stability analysis gives new idea to understand the calcium signaling process in astrocytes.

Keywords: Calcium ions, Endoplasmic Reticulum, Mitochondria, Astrocyte, Fractional Calculus

Calibrating and Monitoring of Soil Nutrients Transferring through Xylem

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Efficient monitoring of plant nutrient uptake is vital in modern precision agriculture to ensure optimal growth, yield, and resource utilization. Conventional soil testing methods reveal only nutrient availability but not actual plant absorption. This project integrates real-time IoT soil NPK and moisture sensing with spectroscopic analysis of plant tissues to assess nutrient uptake and biochemical composition. Specifically, we explored nitrogen uptake correlation with leaf extract optical absorbance and further extended analysis to characterize chili varieties through Raman and UV-Vis spectroscopy of their peels and seeds.

The methodology consisted of two phases. The first involved measuring soil nutrient content using RS485-based NPK and capacitive soil moisture sensors, with data transmitted via an ESP32 IoT system and visualized on the ThingSpeak platform. The second phase analysed both young and old chili leaves of different varieties; leaves were crushed, extracted in ethanol, and subjected to UV-Vis spectroscopy for nitrate- and phenolic-related absorbance. Raman spectroscopy was also employed to profile pigments and secondary metabolites in chili peels and seeds, comparing biochemical fingerprints across Byadgi, Ramnad Mundu, and Guntur cultivars.

Leaf extract absorbance spectra showed characteristic peaks at 230 nm and ~280 nm indicative of nitrate and phenolic compounds, with young leaves exhibiting stronger intensities, reflecting active nutrient flow and metabolic activity. PCA of Raman and absorbance spectral data successfully differentiated chili varieties and tissue types, revealing distinct biochemical signatures linked to pigment and antioxidant content. This multivariate spectral approach validated the relationship between soil nutrient levels, plant uptake, and varietal biochemical diversity.

In conclusion, merging IoT-enabled soil monitoring with detailed spectroscopic profiling of plant tissues offers a comprehensive, non-destructive method to estimate nutrient uptake and assess crop quality. The study highlights the efficacy of optical methods integrated with multivariate analysis for precise nutrient and varietal classification in chili cultivation. Key tools include the ESP32 microcontroller, RS485 NPK sensor, Ocean Insight HR4Pro spectrometer, and advanced data analysis employing PCA for spectral differentiation.

Stochastic Analysis of an SIRI Model

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In this study, we propose a stochastic epidemic model based on a pre-existing deterministic SIRI model. We employ a continuous-time Markov chain and stochastic differential equations to investigate the role of stochasticity in disease dynamics within an infected population, and compare the disease dynamics of deterministic and stochastic models. We calculate the stochastic threshold ρ and show that for $\rho \leq 1$, the probability of disease extinction is almost surely near the disease-free equilibrium. For the special case when $\rho > 1$, we estimate the probabilities of disease extinction and outbreak analytically using a Galton-Watson branching process. Also, we estimate disease extinction probabilities numerically using 20,000 sample paths and validated the branching process approximation. Within the stochastic framework, we derive implicit equations for the mean first passage time. In addition, we formulate the stochastic differential equations using the covariance matrix estimation and perform numerical simulations using the Euler-Maruyama method. In particular, our results indicate high probability of disease extinction during the early stages of epidemics. However, stochastic simulations reveal that multiple sample paths can reemerge after extinction, illustrating the reinfection dynamics present in the model.

Keywords: SIRI Model, Markov Chain, Branching Process, Mean First Passage Time, Stochastic Differential Equation

First Order Integro-Dynamic Equations on Time Scales with Extended Δ-Carath´eodory Functions

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In this paper, we consider a first-order integro-dynamic equation on time scales where the right-hand side is a discontinuous extended Δ-Carath´eodory function. We extend previous results on existence and uniqueness of solutions by applying an Osgood-type condition to discontinuous dynamic equations, adapting existing results using the Henstock–Kurzweil Δ-integral for the integro-dynamic case. Furthermore, we present results on continuous dependence and convergence of solutions using the concept of Henstock–Kurzweil Δ-equi-integrability.

Keywords: Henstock–Kurzweil Δ-integral; time scale dynamic equations; Carath´eodory-type conditions; existence and uniqueness; continuous dependence; integro-dynamic equations. MSC (2020): Primary 34A40; Secondary 26E70, 34A12, 34K30, 45D05.

Properties of the Generalized Marcum functions of the first and second kinds

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The generalized Marcum function of the first kind is a key tool in radar signal processing and the analysis of multichannel communication systems. Its counterpart, the generalized Marcum function of the second kind, serves as a survival analogue and has recently gained attention. This work presents a concise overview of the analytical properties of both functions, including their monotonicity, bounds, convexity, and closed-form representations, along with an interesting relation between the two.

TUR´AN TYPE INEQUALITIES FOR FERRERS FUNCTIONS OF THE FIRST KIND

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We present our investigation on the monotonicity properties of the ratio of Ferrers functions of the first kind and we use these properties to derive sharp functional bounds for this ratio, which are shown to be optimal and asymptotically accurate for large values of the parameters. By using these bounds, we establish the convexity of the Ferrers function of the first kind and we obtain some Tur´an type inequalities with respect to both of the parameters, which are sharp at the endpoints of the argument. Finally, we propose some open problems concerning the log-convexity and log-concavity of Ferrers functions of the first kind.

A NOTE ON JT RINGS(online)

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The class of JT rings in which each element can be expressed as the sum of two tripotent elements and an element of the Jacobson radical is introduced and methodically examined in this paper. We give clear definitions, important characteristics, and structural findings about JT rings, such as closure under direct products and homomorphic images. We relate these results to the behavior of the Jacobson radical and nilpotent elements, and our analysis includes algebraic conditions characterizing JT rings through Peirce decomposition and Morita contexts.

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Dynamics of Bacterial Infections under Dual Treatment: Modelling and Effectiveness Analysis.

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Bacteria are single-celled, ubiquitous microorganisms found everywhere on Earth. Some bacteria are beneficial for us; they help in the digestion and absorption of nutrients, whereas some are bad for the human body, causing infections. Bacterial infections are diseases that result from the growth of pathogenic bacteria in host tissues, leading to clinical manifestations in various organ systems, such as the skin, lungs, and bloodstream. To heal such bacterial infections, some people opt for homoeopathic treatment, while others opt for allopathic treatment. In our article, we focus on the dynamics of bacterial infection transmission using the $SEIT_1T_2R$ model. In the proposed model, we consider two types of treatment: one is through modern medicine (allopathy) and the other is an alternative to modern medicine (homoeopathy) to treat bacterial infection. The positivity and boundedness of the model are discussed. We establish an endemic and disease-free equilibrium point. The next-generation matrix approach is used to compute the fundamental reproduction number R_0. The DFE and endemic equilibria are locally stable when $R_0 < 1$ and $R_0 > 1$, respectively. When $R_0 > 1$, the endemic equilibrium point is globally stable. In addition, sensitivity indices have been used to investigate the parameter behaviour of bacterial infection. Furthermore, we introduce u_1 and u_2 as two parameters to discuss the effectiveness of the treatment using the optimal control technique. The effect of u_1 and u_2 on the population of compartments T_1, T_2 and R in different scenarios has been thoroughly illustrated in numerical simulation. Based on the numerical simulations and graphical representations performed, we conclude that our results are consistent with our analytical findings.

Keywords: Epidemiological model, Bacterial infection, Stability analysis, Optimal, Treatment strategies

Qualitative and Numerical Analysis of SEIR S_vI_v Model of Lumpy Skin Disease

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Lumpy Skin Disease (LSD) is a highly transmissible viral infection in cattle, leading to significant economic losses through reduced milk yield, hide quality, trade restrictions, and increased mortality in severe cases. Its rising prevalence, especially in livestock-dependent regions, highlights the urgent need for effective tools to understand and control its spread. This study introduces a mathematical model of LSD, establishes the existence and uniqueness of its solution, and derives the basic reproduction number R_0 to capture the threshold dynamics governing disease transmission. Furthermore, the positivity and boundedness of the solutions are proved to ensure the biological feasibility of the model. To illustrate the theoretical findings, numerical simulations are carried out using Adams Bashforth method, highlighting the impact of key parameters on disease dynamics.

Keywords: Lumpy skin disease; Host-vector model; Basic reproduction number; Adams Bashforth numerical scheme

Dynamical Analysis and Optimal Control of fractional Monkeypox transmission model

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Abstract: In this study, monkeypox transmission model of fractional-order is developed using the Caputo fractional derivative to incorporate memory effects and long-range temporal dependencies. The qualitative behaviour of the system is rigorously analysed, where positivity and boundedness of solutions are established to biological feasibility. The basic reproduction number R_0 is computed using the next-generation matrix approach and serves as the threshold parameter governing disease extinction or persistence. The disease-free equilibrium is shown to be locally asymptotically stable whenever $R_0 < 1$, while a unique endemic equilibrium emerges and is locally asymptotically stable for $R_0 > 1$. To minimize disease burden and associated intervention costs, an optimal control framework is formulated involving time-dependent vaccination of susceptible individuals, isolation strategies, and treatment efforts for infected individuals. The necessary optimality conditions are derived via Pontryagin’s maximum principle. Furthermore, numerical simulations performed using the Adams–Bashforth–Moulton method, demonstrate the consistency of the analytical results and highlight the effectiveness of the proposed control strategies in mitigating Monkeypox transmission.

Keywords: Monkeypox, fractional-order model, stability, optimal control, numerical simulation

A Comparative Study of Caputo and Caputo–Fabrizio Fractional Operators in Modeling Tomato Yellow Leaf Curl Disease

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Tomatoes are the second most consumed vegetable crop worldwide, and their production is severely threatened by Tomato Yellow Leaf Curl (TYLC) disease. To better understand the transmission dynamics of this virus, we propose fractional-order mathematical models formulated with the Caputo and Caputo–Fabrizio derivatives. These operators enable the incorporation of memory effects, allowing a more realistic description of the interaction between tomato plants and vector populations. The study establishes the existence and uniqueness of solutions, alongside a qualitative analysis of the system dynamics. Numerical simulations are carried out to illustrate the influence of fractional order and model parameters on disease progression. A comparative discussion between the Caputo and Caputo–Fabrizio frameworks highlights the role of singular and non-singular kernels in shaping system behavior. This work provides new mathematical insights into agricultural disease modeling and demonstrates the relevance of fractional calculus in studying plant–virus interactions.

Keywords:, Caputo derivative, mathematical model, tomato yellow leaf curl disease, numerical simulation.

References

[1] M. Caputo and M. Fabrizio, Progress in Fractional Differentiation & Applications 1, 1 (2015).

Fractal–Fractional Modeling of Chaotic Inputs in Neuronal Systems: The R¨ossler–FitzHugh–Nagumo Framework

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Thiswork examines the dynamics of a fractal–fractionalR¨ossler system and its influence as a chaotic drive on the FitzHugh–Nagumo (FHN) neuron model. By introducing the fractional order (μ) and fractal dimension (ν), the framework incorporates memory effects and structural heterogeneity, giving rise to diverse dynamical behaviors. Numerical analysis shows that the R¨ossler system follows a period-doubling path to chaos, with the onset and complexity of bifurcations strongly shaped by the fractional and fractal parameters. When this chaotic signal drives the FHN neuron, the firing activity evolves from regular spiking to bursting and ultimately to chaotic firing. The results indicate that stronger memory effects (larger μ) stabilize neuronal excitability by reducing irregular oscillations, while enhanced fractal features (smaller ν) promote irregular and chaotic activity. These findings provide biologically meaningful insights into irregular brain rhythms and pathological oscillations, while also suggesting engineering applications such as chaos-based communication and secure signal transmission. Overall, the proposed framework establishes a versatile link between chaotic dynamics and neuronal models through fractal–fractional operators.

Keywords: Fractal–fractional calculus; R¨ossler system; FitzHugh–Nagumo neuron; chaotic dynamics; bifurcation analysis; neuronal excitability

Exploring Chaotic Calcium Oscillations: A Neural Network-Based Approach Using Ordinary Differential Equations

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Calcium oscillations are crucial signaling mechanisms that regulate a wide range of cellular processes such as fertilization, neurotransmitter release, secretion, gene expression, and programmed cell death (apoptosis). These oscillatory calcium signals have been extensively observed in various cell types, including cardiac cells, oocytes, and hepatocytes, and they exhibit different temporal patterns ranging from regular periodic oscillations to more complex and chaotic behaviors. Several mathematical models have been developed over the years to describe and simulate calcium dynamics. Among them, the model proposed by Kummer et al. has been widely studied for its ability to replicate the calcium oscillatory behavior in hepatocytes by capturing the underlying biochemical interactions through a system of ordinary differential equations (ODEs) [1]. While many traditional methods have been used to analyze such models, recent advancements in machine learning offer promising alternatives for solving and studying complex biological systems.

In this work, we revisit the classical Kummer model and propose a novel approach using artificial neural networks (ANNs) to solve its system of ODEs. Unlike traditional numerical solvers, the ANN-based framework provides a data-driven, flexible method for approximating solutions to nonlinear dynamical systems. This approach is applied here for the first time to a calcium oscillation model, enabling us to explore its complex dynamic behavior, including potential chaotic patterns. The results obtained from the ANN model are validated by comparing them with conventional numerical results. The good agreement between the two methods confirms the robustness of the ANN approach and its potential as an efficient tool for modeling and analyzing nonlinear biological dynamics.

Keywords: Calcium Oscillations, Artificial Neural Network, ODE, Calcium Signaling

References

[1] Kummer, U., Olsen, L. F., Dixon, C. J., Green, A. K., Bornberg-Bauer, E., & Baier, G. (2000). Switching from simple to complex oscillations in calcium signaling. Biophysical journal, 79(3), 1188-1195.

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Some ecological paradoxes in a couple of dimensionally homogenous fractional order tri-trophic systems

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The Hastings-Powell (HP) framework is one of the most significant models in ecology. An intriguing extension is the omnivore model, which exhibits notably distinct dynamics. While the Hastings-Powell model has been extensively studied under various scenarios, including harvesting, intraspecific competition, time delay, and diffusion, to explore potential ecological outcomes, research on corresponding fractional-order systems remains limited, particularly of omnivorous systems. In this work, we propose a dimensionally homogeneous Caputo fractional-order HP model and its omnivore extension with proportional harvesting. Species enrichment often yields paradoxical outcomes (non-equilibrium) in the HP model. However, our analysis reveals that ecosystems could be healthier in terms of mean population density. In the Hastings-Powell omnivore model, increasing nutrient supply to the prey benefits both the prey and IGPredator but harms the IGPrey stock at the stable state. However, the situation completely flips just after destabilization and proves to be beneficial for sufficient nutrient supply. We also uncover the paradox of searching efficiency: a counter-intuitive outcome occurs as for an increased attack rate of the mid-predator reduces its stock at stable state in both models. Within the coexistence region of the Hastings-Powell omnivore model, we observe two types of switching: harvesting induces stability switching, while increased omnivore effect leads to instability switching. For top-predator harvesting, hydra effects are also uncovered. Hopf-bifurcation phenomenon, catastrophic species collapse, and saddle-node bifurcation are identified, along with the presence of two limit cycles for different initial conditions. We also propose a couple of open questions by the end of the conclusion section.

Keywords: Caputo derivative; Omnivore; Switching dynamics; Catastrophic population collapse.

Nonlinear Analysis of Predator–Prey System with Climate-Sensitive Parameters

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Predator–prey interactions are highly sensitive to environmental conditions, and climate change can significantly alter species growth and interaction rates. In this study, we develop a predator–prey model where key parameters depend on temperature, capturing the effects of climate variability on ecological dynamics. Using analytical stability analysis, bifurcation analysis, and numerical simulations, we examine how changes in temperature influence long-term population behavior. The results show that under moderate climate variation, the system exhibits stable oscillatory coexistence. However, beyond a critical threshold in temperature-dependent growth and predation rates, the system transitions to extinction of the predator species. This reveals climate-driven tipping points in ecosystem stability, emphasizing the vulnerability of ecological communities under warming conditions.

Keywords: Climate change, Bifurcation analysis, Predator–Prey model, Temperature-dependent parameters

Symmetry Breaking and Multistability in a Patchy Predator-Prey Model with Dispersal Delay

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This study investigates the emergence and stability of symmetric and asymmetric steady states in a two-patch predator–prey model incorporating dispersal delay. In contrast to isolated systems that typically possess a single stable interior equilibrium, the inclusion of dispersal leads to the appearance of additional asymmetric equilibria. These newly identified equilibria, which have not been reported previously, can exhibit both stable and unstable behaviors, resulting in multistability within the system. Our analysis reveals that the interplay between dispersal intensity and time delay governs symmetry breaking and generates novel dynamical behaviors such as coexistence of multiple attractors and stability switching between equilibria. The results highlight how inter-patch interactions fundamentally modify the system's qualitative dynamics, offering new insights into spatial heterogeneity in ecological systems.

Keywords: predator–prey model; dispersal; asymmetric equilibrium; multistability; stability switching

Stability and Catastrophic changes in delayed Predator-Prey system with Beddington–DeAngelis functional response

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We investigate a delayed prey–predator system incorporating the Beddington– DeAngelis functional response and intra-specific competition among predators. By introducing a maturation delay as the bifurcation parameter and incorporating delay-dependent parameters, we examine the existence and evolution of multiple equilibria with respect to the delay. The stability analysis reveals switching behaviour between equilibria, indicating that time delay plays a crucial role in controlling bistability and inducing distinct bistable modes in the system. Numerical simulations further demonstrate the emergence of three distinct equilibria: a focus, a saddle point, and a node. In one case, the third equilibrium remains stable while the first equilibrium initially undergoes a stability change and, upon approaching the saddle point, experiences a catastrophic transition that drives the system toward the third equilibrium. In another case, the third equilibrium loses stability as the delay increases, leading to a qualitative shift in the system's dynamics.

Mathematical modelling of prey switching in ecological system in Amami Oshima Island

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Many endangered species are native to Amami Oshima Island in Japan. In order to combat the venomous native Habu pit viper, alien predatory small Indian mongooses were introduced. Mongooses began preying on readily available native species instead of snakes, upsetting the ecological balance. The underlying dynamics of this prey-switching behavior and its impact are mathematically represented in this paper. The mathematical model is fitted using the mongoose population data. Based on earlier
biological research conducted on Amami Island, a number of parameters are employed, and a predatorprey model involving mongoose, habu, and other species has been developed. The results of this study indicate that the introduction of non-native predatory species into an ecosystem can disrupt its equilibrium and cause chaos.

Keywords: Prey Switching, Ratio Dependence, Differential Preference, Differential Vulnerability

Analysis of dynamical behavior of a discrete time predator-prey model incorporated with time delay

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Discrete-time dynamical systems tend to show interesting and complex behavior and are more realistic with regard to biological system. In this paper, we discretize the continuous-time predator-prey model using the Euler discretization scheme and examine how the stability of the system changes with changing parameter values. Time delay has also been incorporated to help achieve the objective of understanding the real world problem with more accuracy. Thus, we analyze how changing discrete-time delays can introduce chaotic behavior in the system. Numerical stimulations are performed to get a better understanding of the behavior of the system. Further, we also compare the results for the same model with its continuous counterpart.

Keywords: Euler discretization, Bifurcation Theory, Neimark-Sacker Bifurcation, Chaos

A Mathematical Model for Diabetes Progression Influenced by Obesity: Analysis, Control, and Economic Evaluation

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Diabetes is a chronic, non-communicable disease that remains a major global health challenge. In this study, we propose a compartmental model to describe the dynamics of diabetes, incorporating both pharmacological and non-pharmacological interventions. A mass-action term captures the transition from the diabetic class to non-pharmacological treatment. To numerically solve the model, we implement a Nonstandard Finite Difference (NSFD) scheme, which preserves essential properties such as positivity and boundedness of solutions. The consistency, convergence, and error of the NSFD scheme are verified. Numerical results demonstrate that, unlike classical methods such as RK4 and Forward Euler which diverge for larger step sizes the NSFD method remains stable and accurate. Model parameters are estimated by fitting the model to annual diabetes prevalence data from the United States (2000–2022). A global sensitivity analysis using Partial Rank Correlation Coefficients (PRCC) identifies key parameters influencing disease dynamics. The model is further extended by incorporating three time-dependent control strategies, and a cost-effectiveness analysis is conducted to determine the most efficient intervention. These findings offer valuable insights for enhancing diabetes management and support informed decision-making in public health planning.

Keywords: Diabetes, Obesity, Optimal control, Cost-effectiveness analysis, Parameter estimation, Stability analysis, Numerical comparision

Transfer Learning Based Wavelet-CNN Model for Diabetic Retinopathy Classification Using EyePACS Dataset

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Diabetic Retinopathy (DR) is a major contributor to vision loss in diabetic patients worldwide. This study introduces a novel hybrid framework that synergistically combines Discrete Wavelet Transform (DWT) with transfer learning for robust classification of DR severity from EyePACS fundus images. The DWT decomposes the green channel into four sub-bands (LL, LH, HL, HH), effectively capturing multi-scale spatial–frequency features, while pretrained CNNs extract rich semantic representations. A two-branch Wavelet–Transfer Learning (WTL) model fuses these complementary feature sets to classify images into five DR grades. Experimental evaluation on a subset of EyePACS demonstrates that WTL improved accuracy, outperforming conventional CNN baselines. The integration of wavelet coefficients with deep transfer features ensures robust performance under limited data and variable illumination, underscoring its potential for automated, reliable DR screening in clinical practice.

Keywords: Diabetic Retinopathy, Discrete Wavelet Transform, Convolutional Neural Networks, EyePACS dataset.

Numerical Simulation of Fuzzy Burgers' Equation for Traffic Flow Using Realistic Initial Conditions

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This work proposes a fuzzy extension of the viscous Burgers' equation for modeling traffic flow under uncertainty. Imprecision in initial states and parameters is represented using triangular fuzzy numbers, which are solved via the α-cut method, yielding intervalvalued PDEs. The stability of the system involving imprecision is established. Representative real-life initial conditions, including step function, sinusoidal, and localized bump, are used to model congestion and stop-and-go dynamics. Conservative finite-difference schemes with adaptive CFL-based time-stepping ensure stability and fast convergence. The numerical results highlight the evolution of fuzzy solution envelopes and the role of uncertainty in traffic behavior, demonstrating the efficiency of the proposed method for realistic traffic analysis.

Keywords: Fuzzy Burgers' Equation, Traffic Flow Modeling, Stability Analysis, Numerical Simulation, Realistic Traffic Scenarios.

Modeling strain-controlled domain wall motion in tetragonal magnetostrictive materials with nonlinear dissipative effects

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In this work, we investigate magnetostrictive effects in a transversely isotropic tetragonal crystal, where the fourth-order magnetostriction tensor-characterized by seven independent yet undetermined coefficients-governs the micromagnetic behavior. These coefficients are evaluated through suitable physical and mathematical assumptions, leading to a systematic derivation of the magnetoelastic field from the magnetoelastic energy density. The study further examines the interplay of magnetoelastic coupling, spin-transfer torque, and nonlinear damping (viscous and dry friction) on domain-wall dynamics within a magnetostrictive layer bonded to a piezoelectric actuator in a bilayer piezoelectric-magnetostrictive composite structure. We employ the one-dimensional extended Landau-Lifshitz-Gilbert equation and the classical traveling-wave ansatz to analyze how magnetostriction, damping, and electric current influence domain-wall motion across steady and precessional regimes. The findings reveal how these parameters modulate domain-wall width, velocity, mobility, threshold behavior, and Walker breakdown limits.

Nonlinear Magnetically-Coupled Shock Wave Propagation in a Non-Ideal Gas Using a Perturbative-Fresnel Transform Framework

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This paper presents a new analytical–numerical model for the propagation of nonlinear strong shock waves in a non-ideal magnetogasdynamics (MHD) medium. Extending the perturbation series technique of Van Dyke Guttmann and the non-ideal gas equation of state used by Tomar et al. (Acta Astronautica, 2019), a transverse magnetic field is introduced to study its influence on shock convergence, collapse time, and similarity exponents. The Fresnel transform domain is employed to analyse the wave front curvature and phase evolution of magnetically constrained shocks. The modified Rankine - Hugoniot conditions include both gas dynamic and magnetic pressure terms. The governing nonlinear partial differential equations are solved using symbolic computation in Mathematica up to third-order perturbations. Results reveal that increasing magnetic pressure enhances stability, delays collapse, and reduces density oscillations near the shock center. The proposed model provides new insight into magnetically assisted implosions, relevant for plasma confinement, astrophysical shocks, and laser-induced compression systems.

Keywords: Shock waves; Non- ideal gas; Magnetic effect; Fresnel transform

A Bibliometric Analysis and Comprehensive Review of Interactions of Air Pollution, Climate Change and Human Health

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Environmental issues of air pollution and climate change strongly impact human health through their interconnected nature. Understanding these interactions requires robust analytical frameworks capable of capturing their complex and nonlinear relationships. Mathematical modelling plays a crucial role in quantifying these relationships; however, existing studies remain fragmented across disciplines. This study employed a comprehensive literature review and bibliometric analysis to give a thorough assessment of worldwide research trends in this field and to give a summary of the most recent studies on the relationship between air pollution, climate change, and human health. Bibliometric tools such as VOSviewer and Biblioshiny were used to map research trends, collaborative networks, and thematic clusters. In this paper, we highlight key research gaps in the existing studies and propose valuable directions for future work.

Keywords: Air pollution, Climate change, Human health, Mathematical modelling, Bibliometric analysis

Bifurcation and Stability Analysis of Aerosol Eects on Plant Biomass and Population Dynamics

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This study examines the nonlinear impact of atmospheric aerosols on plant biomass growth and human population dynamics using a mathematical mod- eling framework. A system of nonlinear dierential equations is developed to capture the interactions among these components. Stability analysis and bi-furcation theory are applied to determine equilibrium behavior under varying parameter conditions. Results show that aerosol levels signicantly inuence both biomass production and population growth. The two-parameter bifur- cation diagram (As shown in Figure1.) delineates critical threshold curves in the parameter space, revealing how increasing deforestation rate and aerosol absorption in plant biomass drive a Hopf bifurcation, leading to a transition from stable equilibrium to oscillatory or unstable regimes. These ndings highlight how environmental disturbances can cascade through ecological sys-
tems, underscoring the need to control aerosol emissions and deforestation to sustain ecological balance. Numerical simulations are performed using MAT- LAB to validate the analytical results and illustrate the system's dynamic behavior.

Keywords:
Aerosol pollution, Non-Linear mathematical model, Plant biomass, Human population, Stability theory, Hopf bifurcation, Numerical simulation

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Numerical Computation of Glucose-Insulin Interaction involving imprecision and delay using cross product

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This study focus on numerical computation of glucose–insulin interaction model by introducing fuzzy parameters and fuzzy initial conditions in a delay differential framework. Biological systems like glucose–insulin regulation often involve uncertainties due to measurement errors and individual variations. To capture these imprecisions, the model is reformulated as a fuzzy delay differential equation (FDDE) using the cross product of fuzzy numbers. A numerical scheme is applied to obtain fuzzy trajectories, and its stability and convergence are examined. The simulation results show that the fuzzy model preserves the essential behavior of the original crisp system while providing uncertainty bounds that reflect real-world variability.

Keywords: Fuzzy delay differential equations, Glucose–insulin model, Fuzzy parameters, Cross product of fuzzy numbers, Numerical computation, Euler method, Uncertainty modeling, Biological system dynamics

ARX modelling of IOT enabled Automated Drip Irrigation System

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Water is the principal source for all living species like individuals, creatures, plants, and so on. The pointless and constant withdrawal of water from the terrain through pits or bore wells prompts the drop in the ground water level which then transforms the part of land into the areas of unirrigated land. Consequently, appropriate preparation of water utilization is required. There is a huge interest in new procedures of water saving in water system frameworks. The lack of water and deficiency of terrain water likewise brings about a decrement in the volume of water on the planet. In the dribble water system procedure, the water is given to the stem zone of crops utilizing trickle because of which a lot of water can be saved. As of now, the ranchers have been flooding the land physically in which the ranchers should water the terrains at each standard stretch. To try not to dry yields, water is given to the foundations of the plants. Because of this development rate turns out to be slow, the heaviness of natural products becomes lighter, and so on. The programmed dribble and ARX model water system framework can address this issue altogether. Sometimes many of the ranchers are not able to reach their fields for many reasons and they are not able provide the water in proper time to crops. IoT technology provides the option for ranchers to provide water to crops even in their absence.

Periodic solution of a stochastic epidemic model involving two separate epidemics and different epidemiological frameworks

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In epidemiology, the host population may be at risk for more than one infectious disease. Researchers have been recently interested in this area of study. In the article, we have explored an epidemic model that combines SIRS and SIR, two different transmission techniques. The considered deterministic model has been perturbed stochastically at transmission rates. For the resulting stochastic model, the analysis has been done. We study the periodic solution for the stochastic system. We use the Lyapunov function and Khasminskii theory to establish that the nonautonomous periodic form of the system with white noise has a positive periodic solution.

References

[1] Cantab, M. D., Hamer, W. H. (2006). The Milroy lectures on epidemic disease in England—The evidence of variability and persistence of type. The Lancet 167(4305): 569–574.

[2] Kermack, W. O., McKendrick, A. G. (1991). Contributions to the mathematical theory of epidemics-I, Bulletin of Mathematical Biology 53(1-2): 33-55.

[3] Gray, A., Greenhalgh, D., Hu, L., Mao, X., Pan, J. (2011). A Stochastic Differential Equation SIS Epidemic Model. SIAM Journal on Applied Mathematics 71(3): 876-902.

[4] Chang, Z., Lu, X., Meng, X. (2017). Analysis of a novel stochastic SIRS epidemic model with two different saturated incidence rates. Physica A: Statistical Mechanics and its Applications 472: 103-116.

[5] Meng, X. (2010). Stability of a novel stochastic epidemic model with double epidemic hypothesis. Applied Mathematics and Computation 217(2): 506-515.

[6] Feng, T., Meng, X., Zhang, T., Zhao, S. (2016) Dynamics of a novel nonlinear stochastic SIS epidemic model with double epidemic hypothesis. Journal of Mathematical Analysis and Applications 433(1): 227–242.

Validation of Q-learning Algorithm on a Polymerization Batch Reactor: Reinforcement Learning Approach

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This article experimentally validates the Q-learning algorithm on an unsteady state pilot plant polymerization Batch Reactor (BR) using the Jetson Orin Board. Conventional control methods often struggle to adapt to the dynamic changes that occur in BR operations in industrial settings. In such conditions, the proposed article suggests using a controller based on the Deep Deterministic Policy Gradient (DDPG) algorithm to address the complex problems encountered by BRs. This model implements the controller in the mixing phase, enabling it to directly regulate the coolant flow rate. This model uses a dynamic temperature profile to achieve the desired temperature, specifically for an exothermic acrylamide polymerization reaction. This approach, which leverages reinforcement learning (RL), offers the potential for autonomous learning and flexibility without the need for extensive manual parameter tuning. RL is ideal for BR systems' inherent nonlinearities. The proposed model optimizes energy usage, output quality, and efficiency during validation compared to the existing approaches. This endeavour could revolutionize industrial BR operations by following industry trends toward automation and optimization using artificial intelligence and machine learning. The regulator's rapid execution and authentication may encourage more widespread incorporation of RL approaches into industrial processes, improving efficacy and lowering costs in many industries.

Keywords: Q-learning, batch reactor, deep deterministic policy gradient, reinforcement learning, energy usage

A Mathematical Model for Penetration of Zona Pellucida

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Mammalian fertilization consists of spermatozoon motion towards an oocyte, followed by penetration of zona pellucida, the outer layer of an oocyte. Experimental explorations reveal that glycan and enzyme kinetics as well as advection are important for this process despite their roles not being well understood. Mathematical models bridge the gap between theory and experimentation. I will present a advection-reaction-diffusion model that yields in-silico insight into underlying competing physiological factors, as demonstrated by the numerical results. This model displays desirable properties such as positivity and boundedness while accommodating a myriad of reaction mechanisms for the underlying chemicals. An important observation from the model is that with an experimentally justified assumption (zona pellucida does not diffuse), even in the absence of advection, sperm can penetrate zona pellucida due to reaction and diffusion. This research provides the crucial link to a fuller understanding of fertilization, opening the door to future investigation. Time permitting, we will explore generalizations of this model that are currently under consideration.

Boundary detection and segmentation of benign brain tumour using anisotropic diffusion(online)

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Benign brain tumour is an early stage of cancer in the tumour development life cycle. Its detection is challenging due to its low variability compared to surrounding non-cancerous cells. The segmentation of tumour regions becomes more complex due to the inherent noise in MRI images. Image enhancement and smoothing techniques are therefore used to reduce noise effects. However, detecting benign brain tumours remains difficult since their intensity is similar to normal tissue. These challenges are addressed using the proposed method, which detects low-intensity variational regions such as benign brain tumours while suppressing noise. A novel anisotropic diffusion equation is employed with a new conductance function formulated using the tansig function. This enables detection of tumour boundaries and denoising without losing fine details. The proposed diffusion coefficient allows optimal smoothing in regions with small gradients, while diffusion decreases as gradient magnitude increases. As a result, the diffusion flow rapidly approaches zero in areas of high intensity variation, preserving fine edges and structural content. Active contour models are employed for segmenting the tumour region from the boundary detected through anisotropic diffusion. Both regionbased and edge-based contour models are applied alternately to achieve accurate delineation of tumour boundaries. Experimental results on the BRATS dataset demonstrate that applying the Perona–Malik diffusion equation provides a dual advantage: effectively detecting tumour cells with low-intensity variation while suppressing noise without compromising essential structural information. Performance analysis on the BRATS 2020 dataset, evaluated using Hausdorff distance, Jaccard similarity index, and Dice coefficient, confirms the superiority of the proposed method over fractional-based and non-fractional-based methods.

Keywords: Active contour, Anisotropic diffusion, BRATS dataset,
Dice coefficient, Hausdorff distance, Jaccard similarity index, Perona–Malik,
Tansig function.

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Meshfree method for solving two-dimensional semilinear wave equation with a singular sourceterm(online)

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This study investigates the quenching behavior of numerical solutions for a twodimensional semilinear wave equation with nonlinear source term. Spatial approximations are carried out using the localized Radial Basis Function-generated Finite Difference (RBF-FD) method, while time discretization is handled via a finite difference approach. A discrete energy analysis is conducted to evaluate the local stability of the proposed numerical technique. Furthermore, the energy functional of the classical solution is defined and numerically calculated to confirm the accuracy of the numerical method. The findings demonstrate finite-time quenching, and the influence of various parameters is explored through detailed numerical experiments.

Shape Preserving Exponential Spline Fractal Interpolation Function

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This paper presents the construction of a shape-preserving exponential spline fractal interpolation function (ESFIF) for the first time in the literature and examines shape preserving properties such as positivity, monotonicity, and convexity in detail.

Keywords: Fractals, Iterated Function System, Fractal Interpolation Functions, Exponential Spline Interpolation, Positivity, Monotonicity, Convexity.

OPTIMAL QUANTIZATION ON SPHERICAL CURVES: UNIFORM DISTRIBUTIONS ON ARCS, CIRCLES, AND EQUILATERAL TRIANGLES

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2010 Mathematics Subject Classification. 60E05, 94A34, 53C22, 65D30.

Abstract. This paper develops a systematic theory of optimal quantization on spherical surfaces with respect to the squared geodesic distance. For uniform probability distributions supported on onedimensional spherical subsets—namely great circular arcs, great and small circles, and the boundary of a spherical equilateral triangle—we determine the exact spherical optimal sets of n-means and the corresponding nth quantization errors for all integers $n \geq 1$. For the great circular arc and circular cases, the optimal sets consist of equally spaced points along the support, yielding explicit closed-form errors $V_n = \ell^2/(12n^2)$ and $V_n = \pi^2 cos^2 \lambda/(3n^2)$, respectively. Extending the analysis to polygonal boundaries, we establish complete solutions for uniform measures on the boundary of an equilateral spherical triangle: the one-, two-, and three-means configurations are determined exactly, and for arbitrary $n \geq 3$ the optimal set consists of midpoints of equal subarcs on each side. The resulting quantization error satisfies

$V_n(P) = S_0^2/36(r/(q + 1)^2 + (3 - r)/q^2$, $n = 3q + r$, $r \in \{0, 1, 2\}$,

and the quantization dimension and coefficient are shown to be $D_2(P) = 1$ and

$\lim_{n\to\infty} n^2 V_n(P) = L^2/12 = (3/4)/S_0^2$.

These results provide the first complete classification of optimal quantization on spherical curves, connecting geometric symmetry, Voronoi structure, and asymptotic quantization theory on curved manifolds.

Key words and phrases. Quantization for probability measures, spherical geometry, geodesic distance, optimal n-means, Voronoi partition, great and small circles, quantization error.

OPTIMAL SETS AND QUANTIZATION ERRORS UNDER GEOMETRIC CONSTRAINTS FOR DISCRE DISTRIBUTIONS

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This paper presents a detailed study of constrained quantization for both finite and infinite discrete probability distributions supported on subsets of the real line. Under specific geometric constraints- namely, a semicircular arc and the union of two sides of an equilateral triangle- we compute constrained optimal sets of n-points and the corresponding nth constrained quantization errors. For finite discrete distributions, we consider both uniform and nonuniform cases with support on $\{-3,-2, \ldots, 3\}$. For infinite discrete distributions, two cases are analyzed: one supported on $\{1/n\colon n \in N\}$ and the other on the set of natural numbers N. Explicit constructions and numerical computations of optimal quantizers and errors are provided. Furthermore, for the infinite discrete distribution supported on N, we develop a general framework for constrained quantization under the linear constraint $y = mx + c$ and prove that the constrained quantization dimension in this setting is zero. Our results highlight how geometric constraints influence the structure and existence of optimal quantizers and pave the way for further investigations into constrained quantization theory.