LACAM - 25

Latest Advances in Computational and Applied Mathematics - 2025

December 8th to 11th, 2025

Information Brochure

School of Mathematics

Indian Institute of Science Education and Research
Thiruvananthapuram, Kerala, India. 695551

IISER THIRUVANANTHAPURAM | IWR Interdisciplinary Center for Scientific Computing | DAE | ANRF Anusandhan National Research Foundation | NBHM National Board for Higher Mathematics

ABOUT LACAM

It is with great pleasure that we extend a warm and heartfelt welcome to all our distinguished invited speakers, participants, scholars, and enthusiasts joining us for the “Latest Advances in Computational and Applied Mathematics 2025” (LACAM-25) international conference. LACAM-25 brings together a vibrant community of researchers and practitioners in Computational and Applied Mathematics, offering a dynamic platform to share ideas, explore cutting-edge developments, and engage in discussions that inspire progress and innovation in the field.

The LACAM conference series began its journey in 2016, with the inaugural edition held at Mahindra University, Hyderabad, India, marking the beginning of a thriving academic tradition. The second edition, LACAM-24, was hosted by the Indian Institute of Science Education and Research (IISER) Thiruvananthapuram from February 21 to 24, 2024, and we are delighted to welcome everyone back to IISER Thiruvananthapuram for the third edition, LACAM-25, to be held from December 8 to 11, 2025. This year’s conference is jointly organized by the University of Heidelberg, Germany, and IISER Thiruvananthapuram, India, reflecting the spirit of international collaboration that LACAM continues to foster.

We are excited to host an engaging and diverse scientific program featuring 23 plenary talks, 10 invited talks, over 138 contributed talks, and 15 poster presentations, covering a wide spectrum of topics in Computational and Applied Mathematics. With around 210 participants, including speakers and delegates from around the world, LACAM-25 promises to be an inspiring convergence of ideas and perspectives. The program has been thoughtfully curated to capture the richness and diversity of ongoing research, ensuring that there is something of interest for everyonefrom seasoned experts to emerging scholars. We hope that your participation in LACAM-25 not only broadens your academic horizons but also sparks new collaborations and lasting friendships within our global community.

We express our sincere gratitude for the generous support received from the Heidelberg Center for the Sciences and Arts (HCSA) and the Interdisciplinary Center for Scientific Computing (IWR) at the University of Heidelberg, Germany, the Anusandhan National Research Foundation (ANRF), the National Board for Higher Mathematics (NBHM), Department of Atomic Energy (DAE), India, and IISER Thiruvananthapuram, India.

On behalf of the organizing committee, we wish you all a rewarding, enjoyable, and intellectually stimulating experience at LACAM-25!

LACAM -25

Peter Bastian
Nagaiah Chamakuri
Asha K Dond
Suboor Bakht
LACAM-25 Organizers

https://conference.iisertvm.ac.in/lacam-25/

LACAM-25

"Latest Advances in Computational and Applied Mathematics–2025 (LACAM-25) " will be hosted from December 8–11, 2025, by the School of Mathematics, IISER Thiruvananthapuram, and the Interdisciplinary Center for Scientific Computing (IWR), University of Heidelberg, Germany.

The focused topics of this year are:

- Numerical analysis of partial differential equations (PDEs)
- Finite Element and Discontinuous Galerkin methods (FEM/DG)
- Development of efficient and robust algorithms for solving PDEs
- PDE-constrained optimization
- High-performance and hardware-aware computing
- Open-source software in scientific computing
- Real-world applications of PDEs in natural and engineering sciences

IISER THIRUVANANTHAPURAM

IWR Interdisciplinary Center for Scientific Computing

राष्ट्र की सेवा में परमाणु प ऊ वि DAE ATOMS IN THE SERVICE OF THE NATION

ANRF Anusandhan National Research Foundation

NBHM National Board for Higher Mathematics

IISER TVM

Founded in 2008 under the auspices of the Ministry of Human Resource Development (MHRD), the Indian Institute of Science Education and Research (IISER) Thiruvananthapuram has established itself as a pinnacle of science education and research with a global perspective. This autonomous institution is committed to advancing pure and interdisciplinary research, offering a nurturing ground for the holistic development of the next generation of scientists. With an emphasis on fostering scientific curiosity and inquiry, IISER Thiruvananthapuram provides unparalleled opportunities for students to delve into the intricacies of natural and mathematical sciences through its state-of-the-art infrastructure and cutting-edge research facilities.

Set against the backdrop of the serene Western Ghats, the institutes 200-acre campus is a testament to the harmony between nature and scientific endeavor. The lush, green surroundings not only offer a tranquil environment conducive to study and research but also inspire the young minds housed within to live, learn, and grow in a setting that stimulates creativity and innovation. As one of Indias elite research institutions, IISER Thiruvananthapuram continues to be a beacon of knowledge, pushing the boundaries of scientific discovery and education.

Currently, the main academic complex comprises the Physical Sciences, Chemical Sciences, Mathematical Sciences and Biological Sciences buildings along with Lecture Hall complex, Animal House and Central Instrumentation Facility (CIF) buildings. The institute fosters a strong research culture through its interdisciplinary programs, high-end computing labs, and regular seminars featuring leading national and international scholars.

HEIDELBERG UNIVERSITY

Founded in 1386, Heidelberg University – also known as Ruperto Carola – is Germanys oldest university and one of Europes leading research institutions. Established by Ruprecht I, Elector Palatine, with papal approval, the university began under the leadership of Marsilius of Inghen, a scholar from the University of Paris. Over the centuries, Heidelberg has shaped European intellectual life, emerging as a hub for humanism and reformation thought, particularly after Martin Luthers defense of his Ninety-Five Theses in 1518. The Heidelberg Catechism (1563) remains one of its enduring contributions to theological scholarship.

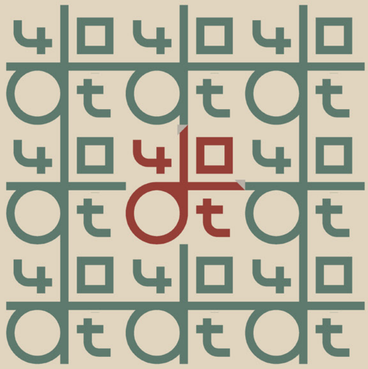
Through the 19th century, Heidelberg flourished as a center of academic freedom, liberal values, and groundbreaking research, attracting scholars and students from around the world. Renowned scientists such as Robert Bunsen, Hermann Helmholtz, Gustav Kirchhoff, and Max Weber contributed to its global reputation. Despite the challenges posed by the world wars and political upheavals of the 20th century, the university rebuilt its academic excellence and international appeal in the post-war era.

Today, Heidelberg University continues to thrive as a Comprehensive Research University with a strong interdisciplinary focus. It has been recognized as a University of Excellence under Germanys national Excellence Strategy, supporting cutting-edge initiatives such as STRUCTURES and 3D Matter Made to Order. With its long-standing tradition of innovation and commitment to societal progress, Heidelberg remains a beacon of academic excellence and global collaboration living up to its vision: “The Future since 1386.”

LACAM Logo Brief

Main Logo

LACAM-20XX



Logo Brief

The conceptualisation of the logo for LACAM is deeply rooted in the fundamental principles of computational and applied mathematics, with particular emphasis on the partial differential function. Leveraging the intricacies of the partial differentiation framework, we meticulously crafted a distinct logo component characterised by mirror symmetry. This symmetry not only serves as an aesthetic element but also functions as a versatile tessellation tile, capable of extending seamlessly across the two-dimensional plane via translation. The deliberate use of this mathematical framework underscores our commitment to precision and innovation. Moreover, the logo serves as a visual representation of the dynamic advancements taking place within the realm of Computational and Applied Mathematics. Its incorporation of a carefully selected two-colour palette further enhances its visual impact and reinforces the brand identity. By harmonising mathematical rigour with creative design, the LACAM logo encapsulates the essence of our organisation's mission and vision, symbolising our dedication to pushing the boundaries of mathematical inquiry and application.

Concept and Construction

$$\frac{\partial f}{\partial x}$$

Partial derivative

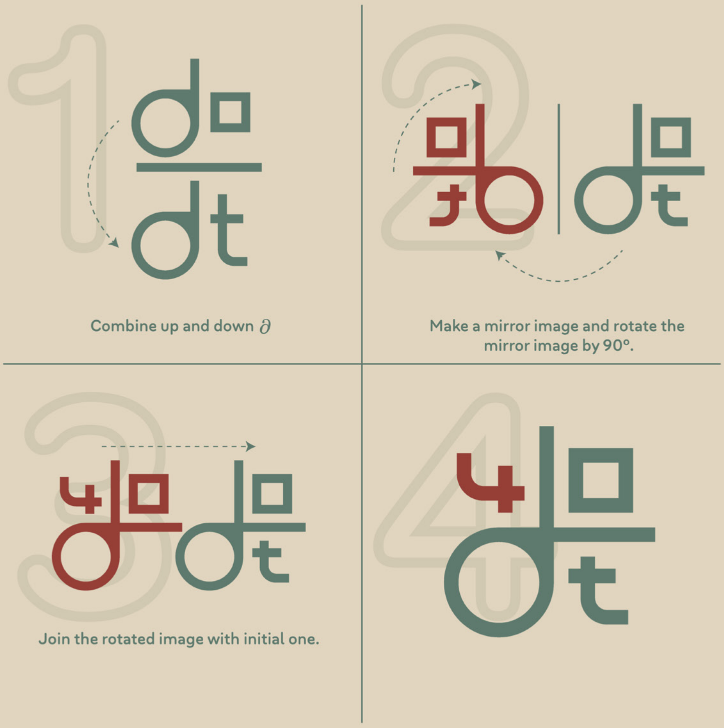
$+$

Reflection Symmetry

$+$

Tiling

||



Logo Design: **Shyam M**
(Batch '19, IISER Thiruvananthapuram)
| @shyam_m_sm

Organizers

Peter Bastian (IWR Uni Heildelberg, Germany)
Nagaiah Chamakuri (IISER Thiruvananthapuram, Kerala, India)
Asha K Dond (IISER Thiruvananthapuram, Kerala, India)
Suboor Bakht (HCSA Heildelberg, Germany)

Local Organizing Committee

- Utpal Manna
- Rajan M.P.
- Nagaiah Chamakuri
- Sheetal Dharmatti
- Asha K Dond
- Dhanya Rajendran
- Arun K.R.
- Sudarshan K.

Student Organizing Committee

- Ankur Upadhyay
- Gopika P B
- Himani Roul
- Jain M Francis
- Nishant Ranwan
- Shyam M
- Subhodip Ghosh
- Subham Nayak
- Tooba M Shaikh
- Arya E K
- Ajlan K
- Anbarasi
- Naveensurya V
- Sridhar Kumar
- Deepak Kumar Yadav

GENERAL INSTRUCTIONS

- All talks will be held in offline mode at **Kaumudi, PC Ray & GN Ramchandran (GNR) and S Ramanujan & C V Raman** lecture halls located at Lecture Hall Complex.

Kaumudi

PC Ray &
GN Ramchandran

S Ramanujan &
C V Raman

Conference Lounge

- Lunch and dinner will be served for participants at the **Visitors Forest Retreat (VFR)/CDH - III**. Breakfast will be served in **CDH - I** for Students. Tea/coffee will be served at the **Conference Lounge** in the Lecture Hall Complex during tea breaks.

Lecture Hall Complex

CDH - I

VFR

- Login credentials will be provided to each offline participant to connect to the campus WiFi during their stay during the conference days.
- Every participant will be provided with a conference badge. Kindly wear it at all times for convenience's sake.
- Refer to the campus map for seamless navigation to all the aforementioned venues.

CAMPUS MAP

1. Campus Entrance
2. **Visitors' Forest Retreat (VFR)**
3. Students' Library
4. SBI ATM
5. Restaurant
6. Bus Stop
7. **Central Dining Hall - I**
8. Student Lounge and Cafe
9. Physical Sciences Block
10. Chemical Sciences Block
11. Biological Sciences Block
12. **Students' Hostel area**
13. Medical Center
14. Shopping Center / **CDH-3**
15. Animal House Block
16. **Lecture Hall Complex/ Conference** Venue
17. Mathematical Sciences Block

Schedule

Monday – December 8, 2025

Time	LHC 103: Kaumudi	LHC 105: G N R	LHC 106: P C Ray	LHC 107: S Ramanujan
08:30–09:10	*Registration (LHC Lounge)*			
09:00–09:30	Inauguration			
09:30–10:05	**Vincent Heuveline**: *Challenges in mathematical modeling and numerical methods in cancer research*			
10:10–10:45	**A.K.Pani**: *On Backward Time-Fractional Diffusion Problems: A Unified Approach*			
10:50-11:10	*Coffee/Tea (LHC Lounge)*			
11:10–12:40	HPC/Scientific Machine Learning - 1 • **Ratikanta Behera** • Pratik Nayak • Sarthak Sharma • Monika Rani	A Posteriori Error Analysis and Adaptive FEM - 1 • **Kamana Porwal** • Tooba M. Shaikh • Arnab Pal • Arijit Pal	Recent Advances in Numerical Methods for Newtonian and Viscoelastic Fluid Models - 1 • **Saumya Bajpai** • Deepjyoti Goswami • Kallol Ray • Debendra Kumar Swain	From Algorithms to Applications: Numerical Methods for PDEs - 1 • **G. Murali Mohan Reddy** • Ashifa Khan • Avinash K • Shishu Pal Singh
12:40–13:50	*Lunch (VFR/CDH III)*			
13:50–14:25	**Olaf Ippisch**: *Efficient, Hybrid-Parallel Linear Algebra for Sparse Matrices*			
14:30–15:05	**Prabhu Ramachandran**: *Adaptive Resolution for SPH with Reproducible Open Source Software*			
15:10–15:20	*Group Photo (TBA)*			
15:20–15:40	*Coffee/Tea (LHC Lounge)*			
15:40–16:15	**Alexander Heinlein**: *Neural Network-Based Models for Physical Systems: Analysis, Domain Decomposition, and Preconditioning*			
16:20–16:55	**Sivaram Ambikasaran**: *Smoothed Analysis of Kernel Matrix Ranks: Understanding Rank Growth of Kernel Matrices for Randomized Particle Distributions*			
17:00–18:40	HPC/Scientific Machine Learning - 2 • Ziya Uddin • Subhashri A R • Vijay Kag • Nida Izhar Mallick • Muhammad Roshan	A Posteriori Error Analysis and Adaptive FEM - 2 • Mansi Yadav • Subham Nayak • Nakidi Shravani • Vikas Kumar	Recent Advances in Numerical Methods for Newtonian and Viscoelastic Fluid Models - 2 • Pooja Biswas • Sweta Chakraborty • Jeremy Rymbai • Hemalatha Veedhuluri • Himanshu Upreti	From Algorithms to Applications: Numerical Methods for PDEs - 2 • Vikash Sharma • Sahu Nagesh Sumanshankar • Jyoti Yadav • Rupal Aggarwal • Harshita
19:30	*Dinner (VFR/CDH III)*			

Tuesday – December 9, 2025

Time	LHC 103: Kaumudi	LHC 105: G N R	LHC 106: P C Ray	LHC 107: S Ramanujan
08:45–09:00	*Registration (LHC Lounge)*			
09:00–09:35	**Dmitri Kuzmin**: *Convex limiting and entropy fixes for finite element discretizations of nonlinear hyperbolic problems*			
09:40–10:15	**Srinivasan Natesan**: *Robust Numerical Methods for Singularly Perturbed Biharmonic Problems: Weak Galerkin FEM and Physics-Informed Neural Networks*			
10:20–10:55	**Martin Falcke**: *The role of sub-dyadic structure for whole cell behavior – multiscale modelling for cardiology*			
11:00-11:20	*Coffee/Tea (LHC Lounge)*			
11:20–12:50	HPC/Scientific Machine Learning - 3 • Mayank Kumar Bijay • Anju • Meenu • Atul Kaushik	Numerical Methods for Hyperbolic Conservation Laws - 1 • Sanjibanee Sudha • Subhodip Ghosh • Balwinder Singh • Samala Rathan	Recent Advances in Numerical Methods for Newtonian and Viscoelastic Fluid Models - 3 • Tapan Kumar Muduli • Nishant Ranwan • Udeshna Bhattacharya • Rajesh Chary Kandukoori	From Algorithms to Applications: Numerical Methods for PDEs - 3 • Vishal Tiwari • Deeksha Singh • Avijit Sarkar • Ravi Shankar Prasad
12:40–14:00	*Lunch (VFR/CDH III)*			
14:00–14:35	**Thomas Wick**: *Multigoal-oriented error estimation and adaptivity for coupled problems*			
14:40–15:15	**Martin Weiser**: *Adaptive solvers for cardiac electrophysiology simulations*			
15:20–15:40	*Coffee/Tea (LHC Lounge)*			
15:40–16:15	**Praveen Chandrashekar**: *Continuous Galerkin method for compressible flows*			
16:20–16:55	**Thomas Richter**: *Numerics of fluid-rigid body interactions*			
17:00–18:30	From Theory to Computation: FEM and DG Methods for Multiphysics Problems - 1 • **Konduri Aditya** • Surabhi Rathore • Kedar Wagh • Gautam Singh	Numerical Methods for Hyperbolic Conservation Laws - 2 • **Aekta Aggarwal** • Rahul Barthwal • Sujoy Basak • Sudipta Sahu	Recent Developments on Virtual Element Methods - 1 • **Sarvesh Kumar** • Ankit Kumar • Nitesh Verma • Aswini.N.K	Optimal control of PDEs - 1 • **Gopikrishnan C** • Himani Roul • Ankur Upadhyay • Maria Robert
19:30	*Conference Dinner (CDH III)*			

Schedule

Wednesday – December 10, 2025

Time	LHC 103: Kaumudi	LHC 105: G N R	LHC 106: P C Ray	LHC 107: S Ramanujan	LHC 108: C V Raman
08:30–09:00	*Registration (LHC Lounge)*				
09:00–09:35	**Hartwig Anzt**: *Mixed Feeling about Mixed Precision: Can we adapt Numerical Algorithms to AI Hardware?*				
09:40–10:15	**G D V Gowda**: *A convergent MUSCL-Hancock Scheme for Non-Local Conservation Laws*				
10:20–10:55	**Joscha Gedicke**: *P_1 and SIP Discretizations for Elliptic Optimal Control with Pointwise State Constraints*				
11:00-11:20	*Coffee/Tea (LHC Lounge)*				
11:20–12:40	HPC/Scientific Machine Learning - 4 • Mohd Vaseem • Jain M Francis • Geetanjli • Mahipal Jetta	From Theory to Computation: FEM and DG Methods for Multiphysics Problems - 2 • Aniruddha Seal • Manika Bag • Suraj Kumar • Aditi Tomar	Recent Developments on Virtual Element Methods - 2 • Ankur • Priyal Garg • Ambit Kumar Pany • Shantanu	Optimal control of PDEs - 2 • Pratibha Shakya • Soundarya G • Hemaleka A • Bhargav Kumar K	From Algorithms to Applications: Numerical Methods for PDEs - 4 • Richa Singh • Mohammad Saif • Sumit Kumar • Himanshu Kumar Dwivedi
12:40–14:00	*Lunch (VFR/CDH III)*				
14:00–14:35	**Gernot Plank**: *Computational Models of Cardiac Function - Closing the Gaps between Virtual and Physical Reality*				
14:40–15:15	**Phani Motamarri**: *A subspace iteration eigensolver tolerant to approximate matrix-vector products: Applications to quantum modelling of materials in the exascale era*				
15:20–16:20	*Posters & Coffee/Tea (LHC Lounge)*				
16:20–16:55	**Moritz Hauck**: *Iterative solution of Timoshenko beam network models*				
17:00–18:40	HPC/Scientific Machine Learning - 5 • Raghvendra Pratap Singh • Pavan Patel • Subhajit Sanfui • Chetan Singh • Maneesh Kumar Singh	Numerical Methods for Hyperbolic Conservation Laws - 3 • Rakesh Kumar • Asha Kumari Meena • Deepak Bhoriya • Biswarup Biswas • Bhramarbar Behera	Numerical Frontiers in Fluid Dynamics and Flow Simulation - 1 • Rakib Mondal • Priyanshu Agrahari • Shweta • Vivek Lodwal • **Ritesh Kumar Dubey**	Recent Advances in PDEs, Modelling, and Applied Analysis - 1 • Nitin Kumar • Radadiya Hardikkumar Sureshbhai • Kannan R • Buddhadev Pal • Nivedita	
19:30	*Dinner (VFR/CDH III)*				

Thursday – December 11, 2025

Time	LHC 103: Kaumudi	LHC 105: G N R	LHC 106: P C Ray	LHC 107: S Ramanujan
08:30–09:00	*Registration (LHC Lounge)*			
09:00–09:35	**Sandra May**: *The DoD Stabilization to solve the small cell problem*			
09:40–10:15	**Thirupathi Gudi**: *C0-IP methods for optimal control problems governed by the PDEs in nondivergence form: Formulations and Approximations.*			
10:20-10:40	*Coffee/Tea (LHC Lounge)*			
10:40–12:40	Numerical Frontiers in Fluid Dynamics and Flow Simulation - 2 • Dipti Ranjan Parida • Devika Jayan • Sukdeb Manna • Sukhendu Das Adhikary • Manisha Jangir • Akhilesh Yadav	Recent Advances in Numerical Methods for Newtonian and Viscoelastic Fluid Models - 4 • Ruthra J S • Om Prakash Meena • Antara Wajpe • Angel Priya E • Sheetal • Subrahamanyam Upadhyay	From Theory to Computation: FEM and DG Methods for Multiphysics Problems - 3 • Rishi Das • Kanchan Dwivedi • Nikhil Kodali • Gopika P B • Anoja Vijay • Gourab Panigrahi	Recent Advances in PDEs, Modelling, and Applied Analysis - 2 • Panchal Vijaykumar Amrutlal • Utsavkumar Dhansukhbhai Patel • Monalisa Anand • Rakesh Kumar Meena • Vivek Subhedar Pathak • Anupam Priyadarshi
12:40–13:50	*Lunch (VFR/CDH III)*			
13:50–14:50	Numerical Frontiers in Fluid Dynamics and Flow Simulation - 3 • Pratham Singh • Prashant Kumar Vishwakarma • Aiswarya R Iyer	A Posteriori Error Analysis and Adaptive FEM - 3 • Evana Islam Sarkar • Priyanka • Nitin	Recent Advances in PDEs, Modelling, and Applied Analysis - 3 • V Umapathi • Kanailal Mahato • Jyotiranjan Nayak	Recent Advances in PDEs, Modelling, and Applied Analysis - 4 • Aditya Bhattacharya • Pardeep Kumar • Sameer Nitin Khandagale
14:50–15:25	**Christian Engwer**: *Efficient simulation and discretization methods for brain source analysis*			
15:30–16:05	**Volker John**: *Some experiences in using ML techniques for the numerical solution of PDEs*			
16:10–16:20	Closing Remarks			
16:20	*High Tea (LHC Lounge)*			

Plenary Talks

Alexander Heinlein

TU Delft, Netherlands

Title: Neural Network-Based Models for Physical Systems: Analysis, Domain Decomposition, and Preconditioning

Abstract

Neural network-based surrogate models for physical systems are often promoted for their seemingly low computational costs compared to classical numerical simulations. While inference time is indeed very low, the significant costs of training data generation, hyper-parameter tuning, and model training are often overlooked. Although physics-informed loss functions can reduce or even eliminate the need for training data, optimizing hyper-parameters and network parameters remains challenging in terms of both robustness and efficiencydifficulties that are often even more pronounced in physics-informed training. Moreover, the training process itself is frequently observed to lack robustness. Overall, training neural network-based surrogate models remains a demanding task.

In this talk, we focus on physics-informed neural networks (PINNs) and deep operator networks (DeepONets), while noting that many of the concepts discussed also apply to other neural network- and operator-based approaches. First, we analyze the error contributions of the branch and trunk networks in DeepONets and their evolution during training. To this end, we rely on discretization and employ singular value decomposition to study these errors. We then present domain decomposition approaches for localizing neural networks and operators. This strategy helps mitigate spectral bias, i.e., the slow convergence of local and high-frequency components. In addition, domain decomposition enables effective preconditioning of randomized neural networks, substantially improving convergence for linear(ized) problems. Related benefits can also be achieved when these techniques are combined with natural gradient descent optimization.

To illustrate these phenomena, we consider a range of model problems, including the Burgers and AllenCahn equations, as well as multiscale and wave problems.

Amiya K Pani

IIT Bombay and BITS-Pilani-Goa

Title: On Backward Time-Fractional Diffusion Problems: A Unified Approach

Abstract

Inverse fractional diffusion problems, particularly, backward problems have received considerable attention in recent years, the resulting literature is diverse and sometimes fragmented due to the variety of models and numerical techniques employed. In this talk, it is intended to present a unified analysis of the quasi-boundary value method for solving backward problems associated with a broad class of time-fractional diffusion models. The regularized problem can be discretized using diverse spatial and temporal strategies; as a representative example, we analyze a piecewise linear finite element method in space and provide a hint for rigorous error analysis at least for the semidiscrete scheme and propose practical guidelines for selecting discretization and regularization parameters relative to the noise level. The unified character of our analysis ensures its applicability to various fractional models, spatial discretizations, etc.

Plenary Talks

Christian Engwer

Uni Münster, Germany

Title: Efficient simulation and discretization methods for brain source analysis

Abstract

Brain source analysis is an important tool in brain research. It is used for example during operation planing for epilepsy patients. Given EEG (electroencephalography) and MEG (magnetoencephalography) measurements the goal is to reconstruct the brain activity, i.e. the electric potential in the brain. This poses an inverse problem, but its accuracy strongly depends on the quality of the forward simulation, in particular the head model. We discuss how modern numerical methods can be used to increase simulation efficiency, improve robustness of the forward problem and simplify the overall workflow. Techniques in use range from discontinuous Galerkin (dG) discretizations, cut-cell methods, over local subtraction source models to block Krylov solvers

Plenary Talks

Dmitri Kuzmin

Title: Convex limiting and entropy fixes for finite element discretizations of nonlinear hyperbolic problems

Abstract

This talk is a review of modern algebraic flux correction tools for incorporating appropriate inequality constraints into finite element schemes for nonlinear hyperbolic conservation laws. In particular, we present monolithic convex limiting (MCL) techniques for generic scalar equations, for the compressible Euler equations, and for incompressible flows of fiber suspensions. The validity of discrete maximum principles is enforced using representation of spatial semi-discretizations in terms of admissible intermediate states. If necessary, additional limiting is performed to achieve entropy stability. In our MCL schemes for systems, problem-dependent bounds are imposed on scalar functions of conserved variables to ensure physical and numerical admissibility of approximate solutions. We prove the claimed properties of our flux-corrected schemes and discuss relevant implementation details. The main focus of the talk is on continuous Galerkin methods and piecewise-linear approximations, but convex limiting is also an option for discontinuous Galerkin and finite volume approaches. Extensions to high-order (Bernstein or spectral) finite elements and general Runge-Kutta methods demonstrate the wide applicability of the MCL methodology.

Plenary Talks

G.D.Veerappa Gowda

TIFR CAM, Bengaluru and Mahindra University, Hyderabad.

Title: A convergent MUSCL-Hancock Scheme for Non-Local Conservation Laws

Abstract

A MUSCL-Hancock (MH) second-order scheme for the discretization of a general class of non-local conservation laws is developed and its convergence analysis is presented. The MH scheme is a single-stage fully discrete second-order method which is well known for its simplicity and computational efficiency in the context of conservation laws. The core difficulty in designing such a scheme for non-local problems originates from the convolution operator embedded in the flux functions. This is handled through a novel strategy that ensures second-order accuracy and facilitates a rigorous theoretical analysis. Several essential estimates including L, bounded variation (BV) and L^1-Lipschitz continuity in time are derived. Applying these results within the framework of Kolmogorovs compactness theorem, we prove the convergence of a subsequence of approximate solutions to a weak solution. In general, establishing a discrete entropy inequality for second-order schemes remains elusive, making the proof of entropy convergence difficult. In this case, we resort to an approach where a mesh-dependent modification to the slope limiter is introduced, and through a series of appropriately formulated results, we establish convergence to the entropy solution. Numerical experiments are provided to validate the theoretical results and to demonstrate the improved accuracy of the proposed scheme over its first-order counterpart.
This is a joint work with Nikhil Manoj and Sudarshan Kumar K.

Gernot Plank

Medical University of Graz, Austria

Title: Computational Models of Cardiac Function - Closing the Gaps between Virtual and Physical Reality

Abstract

A fundamental concern hampering a broader adoption of computational models of cardiac function in industrial and clinical applications is the lack of evidence of a close correspondence between the physiology of a virtual heart and physical reality. Creating such evidence remains challenging as biophysically detailed virtual hearts are characterized by high dimensional parameter vectors that must be identified from limited low dimensional, noisy and uncertain observations.

In this talk, I report on methodological advances addressing these issues. Specifically, I will present methods for i) the automated generation of anatomically and structurally accurate models of whole heart and torso from medical images, with suitable reference frames to support automation of parameter sweeps; ii) full physics real-time enabled whole heart electrophysiology simulations and associated electrograms and ECGs as well as electro-mechanical modelling; iii) suitable model calibration techniques for whole heart electro-mechanical models; iv) calibration techniques for cardiac device therapies replicating device measurement applicable for optimizing device designs in industry and for personalized therapy planning in the clinic; and v) a computational approach for guiding ventricular tachycardia ablation therapies based on electrogram and ECG matching.

Hartwig Anzt

TU Munich, Germany

Title: Mixed Feeling about Mixed Precision: Can we adapt Numerical Algorithms to AI Hardware?

Abstract

The rise of AI has driven the development of special-purpose hardware and floating point formats that are suitable for executing AI applications. Generally speaking, the trend is towards less complex (shorter) floating point formats, simple operations like matrix multiplication, and over-provisioning processors for floating point performance. Most scientific applications, on the other hand, rely on long (high precision) floating point formats and linear algebra operations whose performance is often bound rather by the communication and memory speed. This motivates the investigation of sophisticated techniques to avoid, reduce, and/or hide data transfers in-between processors and between processors and main memory. One promising strategy is to decouple the memory precision from the arithmetic precision and compress the data before invoking communication operations. While this generally comes with a loss of information, the strategy can be reasonable when operating with approximate objects like preconditioners used in iterative methods. We will present a memory accessor separating the arithmetic precision from the memory precision and mixed precision algorithms based on the strategy of employing lower precision formats for communication and memory access without impacting the final accuracy.

Plenary Talks

Heuveline Vincent

Uni Heidelberg, Germany

Title: Challenges in mathematical modeling and numerical methods in cancer research

Abstract

Cancer presents a complex, multi-scale system characterized by intricate interactions between tumor cells, the immune system, and the microenvironment. This presentation will survey the primary obstacles in mathematical oncology, focusing on two core areas: (1) Modeling Challenges: including multi-scale integration (from molecular to tissue level), heterogeneity, and model selection amidst biological uncertainty. (2) Numerical Challenges: such as the computational cost of simulating complex systems, stability issues in solving coupled systems of equations, and model calibration. We will illustrate these challenges with examples from tumor growth, emphasizing the critical role of applied mathematics in developing the next generation of tools for cancer research.

Joscha Gedicke

Uni Bonn

Title: P_1 and SIP Discretizations for Elliptic Optimal Control with Pointwise State Constraints

Abstract

We develop and analyze finite element discretizations for elliptic distributed optimal control problems with pointwise state constraints on general polygonal/polyhedral domains. Two P_1 conforming methods and a symmetric interior penalty formulation are considered, leading to discrete quadratic programs with simple box constraints that can be efficiently solved using a primal-dual active set strategy. Theoretical results are established and supported by numerical experiments.

Martin Falcke

MDC, Berlin, Germany

Title: The role of sub-dyadic structure for whole cell behavior–multiscale modelling for cardiology

Abstract

Wilhelm Neubert, Nagaiah Chamakuri, Martin Falcke

Cardiovascular disease is often related to defects in molecular and sub-cellular components in cardiac myocytes, specifically in the dyadic cleft, which include changes in cleft geometry and channel placement. Modeling of these pathological changes requires both spatially resolved cleft as well as the whole cell level descriptions. We use a multi-scale model to create dyadic structure-function relationships in order to explore the impact of molecular changes on whole cell electrophysiology and Ca^{2+} cycling. The presentation will briefly describe the numerical challenges coming with such a model and will focus on applications. To investigate the relevance of structures on a length scale of about 10 nm inside dyadic clefts for whole cell behavior, we created a population of models with varying dyadic cleft properties including RyR and LCC clustering, stochastic opening and closing rates as well as changes in LCC and RyR Ca^{2+} currents. We investigated commonly used biomarkers describing action potential, Ca^{2+} transient and Ca^{2+} spark dynamics. Structural changes inside dyadic clefts affect global Ca^{2+}transients in the range of 10-20%. By constructing response surfaces for crucial biomarkers we were able to quantify sensitivity and parameter uncertainty in order to derive functional implications of molecular level properties. The second application investigates the placement of Na^{+}/Ca^{2+}–exchangers (NCX). They transport Ca^{2+} and Na^{+} through the plasma membrane of cardiomyocytes. NCX dysregulation has been related to diastolic dysfunction, and NCX has been inhibition identified as a potential therapeutic approach. However, measured consequences of NCX inhibition could not be reproduced by modelling based on current structural ideas. Therefore, we follow the hypothesis of NCX placement inside dyadic clefts and report its consequences for Ca^{2+} handling.

Martin Weiser

Zuse Institute Berlin, Germany

Title: Adaptive solvers for cardiac electrophysiology simulations

Abstract

Cardiac electrophysiology is described by PDEs of reaction-diffusion type with elliptic constraints, ranging from homogenized monodomain and bidomain models to extracellular-membrane-intracellular (EMI) models resolving the cardiac myocytes geometrically. Organ-scale simulations and in particular large EMI simulations incur a high computational cost, since faithful excitation propagation requires fine meshes and small time steps. The locality of solution features calls for adaptive methods, but traditional mesh adaptivity, despite being effective in reducing the problem size, fails to provide speedup.

We present a novel low-overhead approach to adaptivity that works completely on the algebraic level and exploits shrinking correction support in spectral deferred correction (SDC) time stepping methods. We discuss its basic structure, its combination with balancing domain decomposition with constraints (BDDC) preconditioners, and its extension to second order finite element discretization using hierarchical elements and a hybrid multigrid-BDDC preconditioner.

We also discuss lossy data compression for reducing the amount of data to be communicated between compute nodes in BDDC preconditioners, and its impact on convergence and solver efficiency.

Numerical experiments with electrophysiology models illustrate the properties of the proposed methods

Plenary Talks

Moritz Hauck

Karlsruhe Institute of Technology (KIT), Germany

Title: Iterative solution of Timoshenko beam network models

Abstract

This talk deals with the numerical solution of Timoshenko beam network models, i.e., Timoshenko beam equations at each edge of the network, coupled at the nodes of the network by rigid joint conditions. A prominent application of such models is the simulation of fiber-based materials such as paper or cardboard. Through hybridization, we can reformulate the problem equivalently as a symmetric positive definite system of linear equations posed at the nodes of the network. This is possible because the nodes to which the beam equations are coupled are zero-dimensional objects. To discretize the beam network model, we apply a hybridizable discontinuous Galerkin method that can achieve arbitrary orders of convergence under mesh refinement without increasing the size of the global system matrix. As a preconditioner for the typically very poorly conditioned global system matrix, we employ a two-level overlapping additive Schwarz method. We prove uniform convergence of the corresponding preconditioned conjugate gradient method under appropriate connectivity assumptions on the network. Extensions to a more algebraic approach and to a multilevel method are also presented. Numerical experiments demonstrate the practical performance of the method.

Plenary Talks

Natesan Srinivasan

IIT Guwahati

Title: Robust Numerical Methods for Singularly Perturbed Biharmonic Problems: Weak Galerkin FEM and Physics-Informed Neural Networks

Abstract

In this work, we study the numerical solution of singularly perturbed biharmonic problems on the unit square with clamped boundary conditions. A layer-adapted Shishkin mesh is employed to efficiently resolve boundary layers. Within this framework, we develop two weak Galerkin finite element methods (WG-FEM): a standard formulation and a mixed formulation. For both approaches, rigorous error analyses are carried out. In particular, anisotropic error estimates are derived in the equivalent H^2-norm, and parameter-uniform convergence of the methods is established. For the mixed WG-FEM, we further obtain parameter-uniform error bounds in both the energy and balanced norms. Numerical experiments confirm the theoretical results and demonstrate the efficiency of these WG-FEM schemes on layer-adapted meshes. In parallel, we implement two physics-informed neural network frameworks, Finite-basis PINN (FB-PINN) and Parameter asymptotic PINN (PA-PINN), as alternative solvers for the same model problem, and systematically investigate their performance through numerical studies. The comparative assessment highlights both the strengths of traditional discretization methods and the potential of machine learning-based approaches. Overall, this work provides robust and complementary computational strategies for addressing the challenges posed by singularly perturbed fourth-order problems with boundary layers.

Olaf Ippisch

TU Clausthal, Germany

Title: Efficient, Hybrid-Parallel Linear Algebra for Sparse Matrices

Abstract

Solving large sparse linear systems arising from PDE discretization efficiently on attainable hardware as well on supercomputers is a challenge requiring optimal use of resources including memory bandwidth and vectorization. Experiences obtained during the development of Lineal, a new C++ linear algebra library, are presented. The Algebraic Multi-Grid preconditioner of Lineal is based on DUNE ISTLs algorithm and supports matrix-free linear systems on the finest level with CSR matrices on coarser levels - a novel approach, to our knowledge. Lineal offers support for efficient mixed precision, SIMD operations, and tiling, and is almost fully multithreaded. Recently added MPI support enables hybrid-parallel computations on compute clusters while minimizing communication costs. Lineal has been used to simulate oxygen diffusion in soil samples, solving instances with more than 10 unknowns in under 4 minutes using 128 threads and less than 160 GB of RAM. Additional tests confirm Lineals strong performance compared to existing libraries and its scalability on larger compute clusters using hybrid parallelism.

Plenary Talks

Phani Motamarri

IISc Bengaluru

Title: A subspace iteration eigensolver tolerant to approximate matrix-vector multiplications: Applications to quantum modeling of materials in the exascale era

Abstract

Chebyshev Filtered Subspace Iteration (ChFSI) is a well-established method for computing a small subset of extreme eigenvalues in large sparse matrices. In this talk, we present a residual-based reformulation of ChFSI, termed R-ChFSI, designed to accommodate inexact matrixvector products while preserving robust convergence properties. The key idea is to reformulate the Chebyshev recurrence so that it operates on residuals rather than on eigenvector estimates. This residual-driven approach effectively suppresses errors arising from inexact matrixvector operations, thereby enhancing convergence for both standard and generalized eigenvalue problems. The inherent tolerance of R-ChFSI to inexact matrixvector products enables the use of low-precision arithmetic and approximate inverses for large-scale generalized eigenproblems. This makes the method particularly well-suited for large-scale quantum modeling of materials within density functional theory (DFT), where the governing equations require the solution of nonlinear generalized eigenproblems. We demonstrate the effectiveness of R-ChFSI in finite-element discretized DFT calculations, showing that FP32 and TF32 arithmetic can be employed for computation, while BF16 precision can be used for domain-decomposition communication, without compromising robustness. These capabilities make R-ChFSI a scalable and computationally efficient alternative for solving large-scale eigenproblems in modern high-performance computing environments powered by hardware accelerators.

Prabhu Ramachandran

IIT Bombay

Title: Adaptive Resolution for SPH with Reproducible Open Source Software

Abstract

The Smoothed Particle Hydrodynamics (SPH) method was first invented in the late 1970s to solve problems in astrophysical gas dynamics. It is a Lagrangian method that does not require the use of a mesh. The method has since been used to simulate a wide variety of other continuum mechanics problems. This includes fluid flow involving incompressible fluids, free-surfaces, multi-phase fluids, solid mechanics problems involving elastic dynamics, plastic deformation, fracture, as well as fluid structure interaction and many other complex problems.
Despite its grid-free nature, it is not easy to incorporate adaptive spatial resolution in an SPH solver. There have been many important works that have attempted to address this. Over the last few years our group has developed state-of-the-art techniques and parallel algorithms that allow us to efficiently and accurately performs adaptive spatial resolution automatically using the given geometry, pre-defined regions, or solution features. The initial development was for weakly-compressible fluids and we have recently developed methods to use adaptive spatial resolution for compressible fluid flows.
All of our work in the area of SPH is open source and reproducible. We develop and use the open-source, Python-based, PySPH framework for our work. For each manuscript we publish, we release our source code and also ensure that every figure (made using PySPH) is fully automated (using the automan package). This makes it easy to see how every result was obtained and also reproduce the same result. We have done this for over a dozen papers over the last 7 years and it has been invaluable to our research group.

In this talk, I will discuss the recent adaptive resolution techniques that we have developed for SPH and also delve into our automation tools in the hope that this may be useful to other computational scientists.

Praveen Chandrashekar

TIFR-CAM Bengaluru

Title: Continuous Galerkin method for compressible flows

Abstract

Continuous Galerkin methods use a continuous representation of the solution using piecewise polynomials. They can suffer from too much dispersion errors when applied to wave-type problems especially when the solution has steep gradients or is not very well resolved. Some form of stabilization is usually used to make these methods less prone to such errors. Here we explore ideas from summation-by-parts, split-form schemes and gradient jump penalty to construct useful schemes for the compressible Euler and Navier-Stokes equations. Split-form schemes in combination with summation-by-parts help to achieve consistent evolution of other quantities like kinetic energy, internal energy and entropy, and are thought to lead to better stability. Gradient jump penalty is another idea to add extra dissipation which is found to reduce dispersion errors. Here we will try these ideas in the context of compressible flows and try to identify useful schemes.

Sandra May

Title: **The DoD Stabilization to solve the small cell problem**

Abstract

The usage of cut cell meshes is a very suitable approach for dealing with complex geometries in flow simulations: the geometry is cut out of a structured background mesh, resulting in cut cells where the object intersects the mesh. When solving hyperbolic conservation laws, this poses the small cell problem: standard schemes using explicit time stepping are unstable if the time step size does not take the potentially arbitrarily small size of cut cells into account, which is not feasible in practice.
In this talk, we will first give an introduction to the small cell problem. Then we will introduce the Domain-of-Dependence (DoD) Stabilization, which has been developed to solve this problem for Discontinuous Galerkin methods. We will explain the method, summarize some of the latest developments, and provide corresponding numerical results.

Sivaram Ambikasaran

IIT Madras

Title: Smoothed Analysis of Kernel Matrix Ranks: Understanding Rank Growth of Kernel Matrices for Randomized Particle Distributions

Abstract

Kernel matrices are central to numerical computation, data science, and machine learning,but their dense and often high-dimensional nature poses major computational challenges. Hierarchical low-rank methods offer efficient representations, yet most theoretical analysis assume that source and target particles are arranged on quasi-uniform gridsan assumption rarely met in practice. In this talk, we present a smoothed analysis framework for studying the rank behavior of kernel matrices when particles are randomly distributed within neighboring domains. These results extend classical deterministic analysis to realistic, unstructured configurations, providing new insights into the robustness and efficiency of hierarchical matrix algorithms under arbitrary particle distributions. Numerical experiments in one-, two-, and three-dimensional settings confirm the theoretical predictions, offering a probabilistic foundation for fast kernel-based methods in scientific computing and machine learning.

Plenary Talks

Thirupathi Gudi

IISc Bengaluru

Title: C0-IP methods for optimal control problems governed by the PDEs in nondivergence form: Formulations and its convergence analysis.

Abstract

Numerical approximation of nondivergent form PDEs has received tremendous attention in recent years. The coefficients in the equation are generally not regular enough to formulate them in the standard weak formulation. Their well posedness is often established when the coefficients satisfy a Cordes condition. Many numerical methods are proposed and analyzed for these problems including DG and C^0-IP methods. In this talk, we will discuss optimal control aspects and their numerical approximation for such PDEs. The optimality system for such optimal control problems includes a fourth order adjoint PDE in nondivergent form, hence its numerical approximation and analysis becomes even more complicated. We employ the well known medius analysis to achieve optimal order error estimates under the realistic regularity and illustrate the results with some numerical experiments. This is based on the joint works with Arnab Pal and Pratibha Shakya.

Thomas Richter

Uni Magdeburg, Germany

Title: Numerics of fluid-rigid body interactions

Abstract

We describe the coupled dynamics of rigid bodies immersed in an incompressible fluid and the fundamental approaches to numerically approximate this system. In a first part we focus on the detailed description of the coupled problem and how to obtain accurate numerical approximations. Then, we study two specific applications.

First, we investigate the questions whether it is possible to propulse an immersed body purely by the internal motion of a mass. This question is not trivial, as an internal mass-oscillation will act as force with average zero. While the linear Stokes case yields a zero average velocity, the consideration of the full nonlinear system can cause a non-zero average velocity under certain conditions. The numerical simulation is difficult as the body will undergo oscillations with large amplitude, however with a mean that is very close to zero.

Second, we study the dynamics of very small bodies that are too small to be resolved efficiently. We will present a two-way coupled algorithm that combines the Navier-Stokes equations with a particle model and that uses neural networks to properly transfer the forces from the fluid to the bodies and back to the fluid.

Thomas Wick

Leibniz Universität Hannover, Germany

Title: Multigoal-oriented error estimation and adaptivity for coupled problems

Abstract

In this presentation, we formulate goal-oriented mesh adaptivity for multiple functionals of interest for nonlinear problems in which both the Partial Differential Equation (PDE) and the goal functionals may be nonlinear. Our method is based on a posteriori error estimates in which the adjoint problem is used and a partition-of-unity is employed for the error localization that allows us to formulate the error estimator in the weak form. We provide a careful derivation of the primal and adjoint parts of the error estimator. Another objective is concerned with balancing the nonlinear iteration error with the discretization error yielding adaptive stopping rules for Newton's method. Our techniques are substantiated with several numerical examples including scalar PDEs, coupled PDEs, up to space-time problems.

Plenary Talks

Volker John

WIAS, Berlin, Germany

Title: Some experiences in using ML techniques for the numerical solution of PDEs

Abstract

Exploring the benefits and limitations of using techniques from machine learning (ML) for the numerical solution of partial differential equations (PDEs) is a current topic of research. This talk reports on a few experiences with such approaches for: - determining slope limiters for steady-state convection-diffusion problems, - computing the solution of steady-state convection-diffusion problems with physics-informed neural networks (PINNs), - trying to enhance the accuracy of time-dependent incompressible flow simulations on coarse grids with neural networks and fine grid data.

Aekta Aggarwal

IIM Indore

Title: Non-Local Conservation Laws Modelling Traffic Flow and Crowd Dynamics

Abstract

Nonlocal conservation laws are gaining interest due to their wide range of applications in modeling real world phenomena such as crowd dynamics and traffic flow. In this talk, the well-posedness of the initial value problems for certain class of nonlocal conservation laws, scalar as well as system, will be discussed and monotone finite volume approximations for such PDEs will be proposed. Strong compactness of the proposed numerical schemes will be presented and their convergence to the entropy solution will be proven. Some numerical results illustrating the established theory will also be presented.

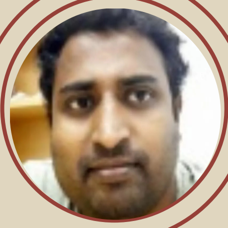
Gopikrishnan C R

IIT Palakkad

Title: Semi and fully discrete analysis of extended FisherKolmogorov equation with nonstandard FEMs for space discretization

Abstract

This presentation discusses lowest-order nonstandard finite element methods for space discretization and backward Euler scheme for time discretization of the extended FisherKolmogorov equation with clamped boundary conditions. Spatial discretisation employs popular piecewise quadratic schemes based on triangles, namely, the Morley, the discontinuous Galerkin, and the C^0 interior penalty schemes. Based on the smoother JI_M defined for a piecewise smooth input function by a (generalized) Morley interpolation I_M followed by a companion operator J from [Carstensen, Nataraj: Lowest-order equivalent nonstandard finite element methods for biharmonic plates: ESAIM Math. Model. Numer. Anal. (2021)], a smoother based Ritz projection operator is defined. {A set of abstract hypotheses establish the approximation properties of the Ritz projection operator.} The approach allows for an elegant semidiscrete and fully discrete error analysis with minimal regularity assumption on the exact solution. Error estimates for both the semidiscrete and fully discrete schemes are presented. The numerical results validate the theoretical estimates and demonstrate the capability of the discontinuous Galerkin method to approximate the solution, even for non-smooth initial condition.
*Joint work with Avijit Das (NIT Silchar), Neela Nataraj (IIT Bombay)



Gujji Murali Mohan Reddy

BITS-Pilani-Hyderabad

Title: Elliptic reconstruction and a posteriori error estimates for parabolic partial differential equations with small random input data

Abstract

In this talk, we present residual-based a posteriori error estimates for parabolic PDEs with small random randomness in Robin boundary conditions. A perturbation approach reduces the stochastic problem to deterministic counterparts, discretized by the finite element method with backward Euler time-stepping. Elliptic reconstruction ensures optimal spatial accuracy, and numerical experiments confirm the efficiency of the proposed estimators. The results extend classical deterministic analysis to parabolic problems with small randomness in Robin boundary conditions.

Kamana Porwal

IIT Delhi

Title: Adaptive quadratic finite element method for a unilateral contact problem

Abstract

In this talk, I will discuss energy norm a posteriori error estimates of a quadratic finite element method for the frictionless unilateral contact problem. The reliability and the efficiency of the proposed a posteriori error estimator will be discussed. A suitable decomposition of the discrete spaces play crucial role in deriving a posteriori error estimates. Numerical results will be presented to illustrate the performance of the proposed error estimator.

Invited Talks

Konduri Aditya

IISc Bengaluru

Title: Scalable asynchrony-tolerant numerical fluxes for DG solvers

Abstract

The discontinuous Galerkin (DG) method has been widely considered in recent years to develop scalable flow solvers for its ability to handle discontinuities, such as shocks and detonations, with greater accuracy and high arithmetic intensity. However, its scalability is severely affected by communication bottlenecks that arise from data movement and synchronization at extreme scales. Recently, an asynchronous discontinuous Galerkin (ADG) method was proposed to reduce communication overhead by either relaxing synchronization or avoiding communication between processing elements (PEs). The numerical properties of the ADG method were verified by solving simple one-dimensional partial differential equations (PDEs) in recent literature. In this study, the application of the ADG method is extended to complex chemically reacting flows, particularly to evaluate its efficacy in capturing flame fronts and detonations. New asynchrony-tolerant weighted essentially non-oscillatory (AT-WENO) limiters are derived to accurately capture flow discontinuities with communication delays at the PE boundaries. The ADG method is first implemented in a simulated environment where the statistics of communication delays are controlled. Its numerical accuracy is verified on the spontaneous ignition of a fuel-lean mixture in a one-dimensional domain with detailed chemistry. The progression of the flame front is accurately represented by the ADG method, and the numerical errors incurred at the PE boundaries turn out to be insignificant. The efficacy of the AT-WENO limiters in capturing discontinuities is demonstrated by the propagation of a detonation wave. A parallel code is then used to demonstrate the numerical efficacy and scalability of the ADG method by propagating a premixed flame and significant speedups are observed relative to the standard DG method. The newly proposed AT-WENO limiters and demonstration of scalability of the ADG method in this study serve as a basis for the development of highly scalable DG-based solvers for massively parallel combustion simulations on future exascale supercomputers.

Authors: Konduri Aditya, Aswin Kumar A., Shubham K. Goswami

Ratikanta Behera

IISc Bengaluru

Title: Neural Network Models for the Dynamic Moore-Penrose Inverse of Tensors

Abstract

In the era of BIG data, we need to process multiway (tensor-shaped) data. These data are mainly in three or higher-order dimensions, whose orders of magnitude can reach billions. Vast volumes of multidimensional data are a significantchallenge for processing and analysis; the matrix representation of data analysis is insufficient to represent all the information content of multiway data in different fields. This talk discusses a neural network model for computing the time-varying Moore-Penrose inverse of tensors within the **M**-product framework. Conventional methodologies for computing the Moore-Penrose inverse of tensors are computationally expensive and are inadequately suited for real-time applications involving complex multidimensional data. To address these challenges, the talk will focus on adapting zeroing neural network models to tensor structures via the **M**-product. Then we discuss a rigorous theoretical analysis and extensive experimental verification that establish global convergence guarantees for the proposed models. The application of the neural network model is demonstrated through applications in color image deblurring.

Ritesh Kumar Dubey

SRM-IST Chennai

Title: **Data Driven WENO schemes for hyperbolic conservation laws**

Abstract

In this work, we investigate high-order Weighted Essentially Non-Oscillatory (WENO) schemes for hyperbolic partial differential equations, with a particular emphasis on scalar conservation laws. We first revisit the classical WENO-JS and WENO-Z formulations, which serve as the foundation of our study. Building on these established methods, we develop a new hybrid scheme that integrates data-driven techniques to enhance the computation of nonlinear weights and improve the overall accuracy of the numerical approximation. The proposed framework details the collection and processing of training data, as well as the design of the hybrid data-driven strategy. To evaluate the effectiveness of the new method, we conduct a comprehensive set of numerical experiments across diverse benchmark problems. The results demonstrate that the hybrid approach achieves superior accuracy and high resolution compared to traditional WENO schemes.

Invited Talks

Sarvesh Kumar

IIST Thiruvananthapuram

Title: **Three and four fields mixed formulations for poroelasticity**

Abstract

In this talk, we propose two different formulations for the approximation of the linear poroelasticity equation. The first is a three-field formulation, in which the steady-state system is expressed in terms of displacement, pressure, and volumetric stress. We will discuss and analyze both continuous and virtual element discretizations for this formulation.

The second is a four-field formulation, where the primary variables are the solid displacement, fluid pressure, fluid flux, and total pressure. For this formulation, we employ a discontinuous finite-volume method to approximate the solid displacement and use mixed methods to approximate the fluid flux and the two pressures.

Invited Talks

Saumya Bajpai

IIT Goa

Title: **Local Discontinuous Galerkin Method for Kelvin-Voigt Viscoelastic Fluid Flow Model**

Abstract

In this study, we propose and examine a local discontinuous Galerkin finite element approach for solving the Kelvin-Voigt viscoelastic fluid flow equations, incorporating a forcing term within the $\mathbf{L}^2(\Omega)$ space for $t > 0$. The method employs an upwind scheme to efficiently manage the nonlinear convective term. We establish new *a priori* bounds for the semidiscrete local discontinuous Galerkin approximations. Furthermore, we derive optimal *a priori* error estimates for the semidiscrete discontinuous Galerkin velocity approximation in $\mathbf{L}^2$-norm and the pressure approximation in L^2-norm for $t > 0$. Assuming the smallness of the data, we also prove uniform error estimates in time. Additionally, we consider the first- and second-order backward difference schemes for full discretization and derive the corresponding fully discrete error estimates. Finally, numerical experiments are presented to support the theoretical findings.

Contributed Talks

IMEX-Alikhanov-FEM for time-fractional PDEs/PIDEs

Aditi Tomar

IIT Gandhinagar

Abstract

We investigate the stability and error analysis of a non-uniform implicit-explicit Alikhanov FEM for a class of time-fractional linear partial differential and integro-differential equations. These equations involve a non-self-adjoint elliptic operator with variable coefficients in both space and time. For initial data in $H_0^1(\Omega) \cap H^2(\Omega)$, we establish a second-order error estimate in the H^2-norm, up to a logarithmic factor.

Determining Effectiveness of Treatment Measures in Controlling Dengue Outbreaks Using Optimal Control

Aditya Bhattacharya

Amity University, Kolkata

Abstract

This study formulates a dengue virus (DENV) transmission model with multiple incubation delays and analyzes its dynamics mathematically. Local stability is shown to depend on the basic reproduction number R0, and sensitivity analysis identifies key transmission drivers. An optimal control framework, solved numerically via the delayed ForwardBackward Sweep Method (FBSM), evaluates treatment-based interventions. Computational results indicate that clinical and supportive measures significantly reduce transmission intensity and prevent progression to severe infection, demonstrating the mathematical models effectiveness in guiding dengue outbreak control strategies.

Asymptotic Dispersion Behaviour of Contaminants in Heterogeneous Groundwater Systems under Directional Inlet Regime

Aiswarya R Iyer

CHRIST (Deemed to be University)

Abstract

The study investigates asymptotic dispersion of heavy metals, biodegradable, and radioactive contaminants in heterogeneous groundwater, incorporating asymptotic dispersion coefficients. Contaminant transport, modeled by Advection Dispersion Equation (ADE), is governed by advection, dispersion, diffusion, and sorption. The ADE discretized uniformly, applying the Peaceman - Rachford Alternating Direction Implicit (PR-ADI) scheme and solved via the Thomas Algorithm. The stability is assessed through modified von Neumann analysis. Sorption effects, flow heterogeneity, and porosity are evaluated, highlighting directional inlet influences. The findings enhance understanding of asymptotic dispersion under non-linear sorption and aim at supporting Sustainable Development Goal 6clean water and sanitationby assessing contaminant migration.

Contributed Talks

Almost Ricci Solitons on Weakly Ricci Symmetric Perfect Fluid Spacetime.

Akhilesh Yadav

Banaras Hindu University

Abstract

Ricci solitons are the fixed points of the Hamilton's Ricci flow $(g(t))/t = -2S(g(t))$, viewed as a dynamical system on the space of Riemannian metrics modulo diffeomorphisms and scaling. The aim of present paper is to study geometrical aspects of perfect fluid space-time admitting almost Ricci soliton. We find the soliton constant and cosmological constant in terms of scalar curvature and potential vector field in perfect fluid spacetime obeying Einstein's field equation. Also, we add some results in a perfect fluid spacetime satisfying Einstein's field equation whose metric represents an almost Ricci soliton when basic vector field and potential vector field both are torseforming vector field.

Second order backward difference scheme combined with finite element method for a 2D Sobolev equation with Burgers' type non-linearity

Ambit Kumar Pany

Institute of Mathematics and Applications

Abstract

A second-order backward difference scheme combined with a conforming finite element method (FEM) is applied to a two-dimensional Sobolev equation with Burgers type non-linearity with a nonhomogeneous forcing function . Some new a priori estimates are derived for the semidiscrete solution, which helps to prove the convergence result. Then, based on the Stolz-Cesaro theorem, a priori bounds for the second-order backward difference scheme are derived, which are valid uniformly in time and uniformly in the dispersion coefficient . For the discrete problem at each time step, it is shown using one variant of Brouwer's fixed point theorem that, there exists a discrete solution and uniqueness follows in a standard way. Moreover, existence of a discrete global attractor is established. Optimal error estimates are obtained, whose bounds may depend exponentially on time. Subsequently, error bounds are established, which are valid uniformly in time under uniqueness conditions. Additionally, it is shown that as , the completely discrete solution of the 2D Sobolev equation converges to the corresponding discrete solution of the Burgers' equation. Further, results on extrapolated Backward difference scheme are briefly discussed. Finally, some computational experiments are conducted, whose results confirm our theoretical findings.

MHD DarcyForchheimer Flow with Chemical Reaction along a Stretching Sheet.

Angel Priya E

SRM Institute of Science and Technology

Abstract

This study investigates the impact of magnetohydrodynamic flow of an incompressible fluid with a flat plate, taking into account chemical processes and the DarcyForchheimer extension. We numerically solve the governing partial differential equations (PDEs) by applying similarity transformations to convert them into a system of nonlinear ordinary differential equations (ODEs). The resulting system is then solved using the Python function *scipy.integrate.solve_bvp*, which employs a finite difference method. The results demonstrate how the Forchheimer parameter influences the velocity profile and how the chemical reaction impacts the concentration profile. This study elucidates the dynamics of fluid movement through porous materials, which is crucial for applications in energy systems, chemical manufacturing, and biomedical engineering.

C0 interior penalty method for time-fractional Cahn-Hilliard equation

Aniruddha Seal

IISc, Bengaluru

Abstract

We present a C0 interior penalty approach for solving the two-dimensional time-fractional Cahn-Hilliard equation. The fractional time derivative is approximated using the L1 scheme on a uniform grid, and spatial discretization is carried out within the C0 interior penalty framework. We establish the stability results and the optimal L2-error bounds, providing a rigorous theoretical foundation for the scheme. Numerical results with discontinuous initial data confirm the methods accuracy and its ability to effectively capture phase separation dynamics in time-fractional systems.

Hybrid Physics-Informed Neural Networks with Adaptive Flux Correction for Hyperbolic PDEs

Anju

VNIT Nagpur

Abstract

Hyperbolic partial differential equations (PDEs) often develop discontinuities, such as shocks and contact surfaces, which pose significant challenges for Physics-Informed Neural Networks (PINNs). While traditional PINNs struggle to capture these sharp features due to the smoothness of neural approximators, this work proposes a novel hybrid PINN framework that integrates adaptive flux correction mechanisms inspired by classical numerical methods. By leveraging neural networks for global solution approximation and embedding shock-capturing flux limiters into the residual loss, our method effectively bridges data-driven and numerical physics-based strategies. The resulting architecture is robust to discontinuities, requires fewer training points in shock regions, and yields physically consistent results for hyperbolic conservation laws.

Contributed Talks

Convergence analysis of the mixed virtual element methods for the Sobolev equation with convection

Ankit Kumar

BITS Pilani, Pilani Campus

Abstract

In this study, we explore the potential application of the mixed virtual element method for the Sobolev equation with convection. For spatial discretization, the virtual element method in mixed form is used, and the backward Euler method is employed to obtain the temporal discretization of the formulation. We introduced an appropriate intermediate projection operator to effectively handle the variable coefficients in the formulation. An in-depth analysis is carried out for both the semi-discrete and fully discrete schemes, and optimal a priori error estimates are derived in the L2-norm and the energy norm. Theoretical findings are supported by several numerical experiments.

Non-smooth Time-Space Control-Constrained Optimal Control Problem in a Cardiac Electrophysiology Model

Ankur Upadhyay

IISER Thiruvananthapuram

Abstract

This work explores an optimal control problem governed by the monodomain model equations, subject to pointwise-in-time control constraints of the form $\|I_e\|_{L^1(\Omega)} \leq R$, $\forall t \in (0,T)$. This constraint restricts the total control applied at each time instant and naturally promotes spatial sparsity in the control only when active. However, the non-smooth nature of the L^1-norm introduces analytical challenges, particularly in proving the existence of optimal solutions and in analyzing the differentiability of the control-to-state mapping. A key difficulty lies in selecting a control space that ensures both existence and regularity. The space $L^2(Q)$ does not have sufficient regularity for the differentiability of the control to state map. On the other hand, $L^\infty(Q)$ is not reflexive and thus the usual techniques to prove the existence of an optimal solution fails. To overcome this difficulties, we choose $L^s(Q)$, $s > \frac{5}{2}$ as our control space where we prove the existence of our solution and differentiability of the control to state operator and later we show that the solution belongs to $L^\infty(Q)$. We then derive first and second-order optimality conditions. We implement projected nonlinear gradient algorithm to solve the discretized optimization problem. Numerical experiments show that as the control bound R decreases, the sparsity region increases and the solution is more sparse. These results validate the theoretical prediction that L^1-type constraints effectively promote sparsity in optimal control settings.

* Joint work with Miss Himani Roul, Dr. Nagaiah Chamakuri.

Contributed Talks

A Virtual Element Framework for Modified PoissonNernstPlanckNavierStokes of Room-Temperature Ionic Liquids

Ankur

SISSA, Trieste, Italy

Abstract

The Poisson–Nernst–Planck–Navier–Stokes (PNP–NS) system models the transport of charged species in a fluid under electric fields, coupled with fluid flow dynamics. While the classical PNP–NS framework provides a foundational model, it has limitations in capturing complex electrokinetic phenomena and remains a topic of active research. To address these challenges, several modified formulations have been proposed in recent years. We briefly review some of these approaches and their limitations, then focus on a specific model based on the Landau–Ginzburg-type continuum theory for room-temperature ionic liquids (RTILs), which leads to a modified fourth-order PNP–NS system. The well-posedness of the model is first established at the continuous level. A semi-discrete numerical scheme is then introduced based on a conforming Virtual Element Method (VEM) discretization. The proposed scheme employs an H^2-conforming virtual element space for the Poisson equation, an H^1-conforming space for the Nernst–Planck (NP) system, and divergence-free conforming spaces for the Navier–Stokes (NS) equations. For time discretization, a fully implicit backward Euler scheme is adopted to ensure robustness and stability. Well-posedness and a priori error analysis are provided at both the semi-discrete and fully discrete levels.

Finite Element Method for two-phase flow using Volume of Fluid method with stabilization techniques

Anoja Vijay

Digital University Kerala

Abstract

This study presents a finite element method for two-phase flow using Volume of Fluid (VoF) with SUPG stabilization to minimize convection-induced instabilities. The Navier-Stokes and VoF equations are discretized using implicit Euler and Crank-Nicolson schemes. The numerical schemes are tested using the classical dam break problem, results show that the Crank-Nicolson scheme outperforms implicit Euler in mass conservation and is more consistent with experimental data. Flux-Corrected Transport (FCT) is also implemented as an alternative stabilization method. A comparative analysis between SUPG and FCT evaluates their performance and effectiveness in capturing free-surface dynamics.

Fluid Flow Analysis in Curved Pipes using Homotopy Analysis Method

Antara Wajpe

National Institute of Technology Warangal

Abstract

This paper presents a semi-analytical study of viscous, incompressible flow in a slightly curved pipe. The nonlinear equations in toroidal coordinates are solved using the Homotopy Analysis Method (HAM), rarely applied in this framework. Stream function and axial velocity are obtained up to the eighteenth-order approximation to assess convergence. The effect of Deans number on axial velocity, stream function, volumetric flow rate, and streamlines is analyzed graphically. Results show excellent agreement with literature, validating the efficiency of HAM and highlighting its potential for more complex curved pipe flow problems.

From Stability to Chaos: Fractional-Order Modeling of Intra-Guild Predation with Long-Term Ecological Memory

Anupam Priyadarshi

Department of Mathematics, Banaras Hindu University Varanasi

Abstract

Modeling complex species interactions in ecological communities requires frameworks that capture not only present dynamics but also the influence of past states. Traditional integer-order differential equations, while widely applied, often neglect these memory effects. In this seminar, we present a fractional-order intra-guild predation (IGP) model comprising a basal prey, an intermediate predator, and a top predator, where Caputo fractional derivatives are employed to incorporate long-term ecological memory. The model integrates LeslieGower and Holling type-II functional responses to represent biologically realistic predation processes. Through bifurcation and iso-spike analyses, we uncover a rich spectrum of dynamical behaviors in the fractional-order systemranging from stable equilibria to chaotic oscillationsstrongly influenced by the strength of memory. Lower fractional orders, corresponding to stronger memory effects, tend to stabilize population dynamics, whereas higher orders sustain complex and irregular oscillations. These results highlight that fractional-order modeling not only enhances ecological realism but also provides a powerful framework for investigating ecosystem stability, resilience, and the intricate interplay between memory and nonlinearity in ecological systems.

A Posteriori Error Analysis of the Weak Galerkin FEM for Singularly Perturbed 2D ReactionDiffusion Problems

Arijit pal

IIT Guwahati

Abstract

This research investigates a residual-based a posteriori error estimator within the weak Galerkin FEM (WGFEM) framework, focusing on singularly perturbed reactiondiffusion problems in the energy norm. The proposed estimator is shown to be both reliable and efficient in theory, and numerical experiments on the unit square and unit circular domains demonstrate its effectiveness.

Convergence and Quasi-Optimality of an AFEM via Inf-Sup Stability for a Dirichlet Boundary Control Problem.

Arnab Pal

Indian Institute of Science

Abstract

Let Ω be a bounded polyhedral domain in $\mathbb{R}^d$, $d \geq 2$. We consider the Dirichlet boundary control problem: find $(u, q) \in H^1(\Omega) \times H^1(\Omega)$ such that

$$J(\bar{u}, \bar{q})\& = \min_{(u,q)\in H^1(\Omega)\times H^1(\Omega)} J(u, q)\& = \min_{(u,q)\in H^1(\Omega)\times H^1(\Omega)} \frac{1}{2}\|u - u_d\|^2 + \frac{\alpha}{2}\|\nabla q\|^2$$

subject to the PDE

$$\begin{cases} \mathcal{L}u := -\nabla \cdot (A\nabla u) + b \cdot \nabla u + cu = f & \text{in } \Omega, \\ u = q & \text{on } \partial\Omega, \end{cases}$$

We present an energy-space-based formulation for this problem and develop a conforming finite element method for its numerical approximation. We derive both a priori and a posteriori error estimates and establish a key quasi-orthogonality property. Using the framework of the axioms of adaptivity, we prove the quasi-optimal convergence of the AFEM in terms of the error estimator. Numerical experiments are provided to illustrate and validate the theoretical results.

Contributed Talks

Robust Numerical Schemes for Two-Fluid Ten-Moment Plasma Flow Equations

Asha Kumari Meena

Central University of Rajasthan

Abstract

Two-Fluid Ten-Moment plasma ow equations are a Two-Fluid (ions and electrons)-based description of the plasma in which uid is modeled by Ten-Moment Gaussian closure equations. This results in a tensorial description of the pressure and hence allows anisotropic eects in the plasma, which are important in several applications. In addition, this model also allows non-quasineutral eects. In this work, we design a robust nite volume numerical schemes for this model. This includes a positivity preserving HLLC solver for three-dimensional Ten-Moment equations and a positivity preserving reconstruction process. In addition, to overcome time restriction imposed by sti source terms, an implicit source discretization is designed, which results in an inversion of a local linear system (in each cell) at each time step. Numerical results are presented to demonstrate robustness and accuracy of the proposed schemes.

Exponentially fitted mesh spline approach for the numerical study of mathematical model arising from a model of neuronal variability.

Ashifa Khan

JAMIA MILLIA ISLAMIA

Abstract

In this paper, we consider a computational approach based on an exponentially fitted mesh cubic spline in compression for the numerical treatment of mathematical model arising from a model of neuronal variability. The mathematical modeling of the determination of the expected time for the generation of action potential in nerve cells by random synaptic inputs into dendrites includes a general boundary value problem for a singularly perturbed differential-difference equation with small shifts. For the numerical scheme subsequently constructed, a parameter uniform error estimate is established. To show how effective the scheme described in the paper is and how the size of the delay argument and the coefficient of the delay term affect the layer behavior of the solution, a number of test examples are analyzed whose results are found to be consistent with the theory.

DGVEM for Parabolic Problems

Aswini.N.K

Indian Institute of Space Science and Technology, Thiruvananthapuram.

Abstract

We investigate the application of discontinuous virtual element methods for the numerical approximation of parabolic problems. For spatial discretization, we employ a virtual element space consisting of discontinuous functions, while the Euler backward scheme is used for time derivative. We analyze both semi-discrete and fully discrete schemes and establish optimal error estimates using appropriate projections. Several numerical experiments are conducted to validate the theoretical convergence rates and demonstrate the computational advantages of the proposed scheme over other existing numerical techniques.

Neural Network-Based Analysis of MHD Jeffery-Hamel Flow for Couple Stress Fluids in Stretching/Shrinking Channels

Atul Kaushik

National Institute of Technology Warangal

Abstract

The Jeffery-Hamel flow, a classic benchmark in fluid dynamics, describes the motion of an incompressible viscous fluid within convergent or divergent channels. While extensively studied for Newtonian fluids, the dynamics of such flows in channels with stretching or shrinking walls, especially for couple-stress fluids, remains largely unexplored. In this study, we pioneer using Artificial Neural Networks (ANNs) to solve a fifth-order nonlinear differential equation arising from the two-dimensional Jeffery-Hamel flow of couple-stress fluids within deformable channels, addressing a complex, nonlinear fluid dynamics problem. By capturing microstructural effects and the unique rheology of Couple stress fluids, our approach enables high-accuracy solutions for complex flow behaviour influenced by wall deformation. We focus exclusively on fluid flow behaviour, analysing the influence of some of the key parameters such as Reynolds number (Re), magnetic parameter (M), channel angle (), stretching parameter (c), and couple stress parameter (S) on velocity distribution and flow structure.

On prey-predator dynamics with hunting cooperation among predators and Allee effect in preys

Avijit Sarkar

University of Kalyani

Abstract

The object of the paper is to investigate the dynamics of a prey-predator model where the preys possess Allee effect and the predators exhibit hunting cooperation. How the carrying capacity controls the stability of the system has been established. It has been established that the trivial equilibrium point is unstable and exhibits saddle behavior. The conditions for the axial and interior equilibrium points to be stable or unstable have been calculated with respect to the related parameters. It is shown that the axial equilibrium shows transcritical bifurcation for change of the carrying capacity. Furthermore, for change of the hunting cooperation parameter one interior equilibrium point shows Hopf bifurcation. The analytical results have been delineated by graphical representations.

On the Convergence of the Modified Scale-3 Haar Wavelet Method for Solving Elliptic Partial Differential Equations

Avinash K

Manipal Institute of Technology, MAHE, Manipal

Abstract

This research introduces a modified Scale-3 Haar wavelet-based numerical scheme for solving elliptic partial differential equations (PDEs), specifically the Helmholtz equation. The method discretizes spatial derivatives using Scale-3 Haar wavelet expansions, integrating and extending them to 2D via the Kronecker product while incorporating boundary conditions. The study includes a theoretical convergence analysis, supported by numerical evaluations of L and L2 errors, and the computational convergence rate. Implemented in MATLAB, the Scale-3 Haar wavelet method is compared against existing Finite Difference Method (FDM), Finite Element Method (FEM), and Scale-2 Haar wavelet methods. Results indicate that while all methods effectively solve elliptic PDEs, the Scale-3 Haar wavelet approach delivers more accurate and efficient approximate solutions, highlighting its potential for complex engineering PDEs.

A compactly supported distribution function based contact discontinuity capturing Boltzmann scheme

Balwinder Singh

Indian Institute of Science, Bengaluru

Abstract

The suitable moments of the Maxwell velocity distribution function recover the conserved variable and flux vectors of the Euler equations. However, its infinite velocity-space support poses challenges for numerical analyses on kinetic numerical methods based on it. While the Maxwellian is a natural choice, it is not the only distribution preserving these key moments. This work presents the formulation and analysis of the contact discontinuity capturing Boltzmann scheme based on peculiar velocity, constructed using the hat function introduced by Perthame. Owing to its compact support in velocity space, the positivity analysis of the proposed Boltzmann scheme is considerably simplified.

Optimal control of renewal equation with generic cost functional

Bhargav Kumar K

Birla Institute of Technology and Science - Pilani, Hyderabad Campus

Abstract

An optimal control problem for the renewal equation with generic cost functional will be considered. With the help of the Ekeland variational principle, the existence of an optimal control will be established. An optimal feedback controller will be provided which is useful to calculate the control numerically.

Contributed Talks

Galerkin Finite Element Analysis of Singularly Perturbed Integro-Differential ConvectionDiffusion Problems with Time Delay

Bhramarbar Behera

National Institute Of Technology Silchar

Abstract

This paper introduces the numerical solution of solving an integro-differential singularly perturbed convectiondiffusion problem with delay in time . The spatial domain is discretized using the Galerkin finite element method (FEM), while the temporal discretization is performed with the Backward Euler scheme. Layer-adapted meshes, such as Shishkin meshes, are employed in space to capture sharp layers induced by the perturbation and delay effect. The fully discretized error in L^2 and H^1 norms are computed to assess the accuracy. Numerical experiments validate the effectiveness of the scheme and spatial delay effects.

Limiter based Entropy Stable WENO Schemes for Relativistic Hydrodynamic Equations

Biswarup Biswas

Mahindra University

Abstract

We propose an alternative approach to approximate entropy-stable solutions of the relativistic hydrodynamics (RHD) equations. An entropy correction is performed within the finite difference WENO scheme using a limiter-based strategy. The method is theoretically proven to satisfy a discrete entropy inequality. Computational results are presented for various one- and two-dimensional RHD test cases. The proposed scheme ensures robustness in the presence of strong shocks and discontinuities. It also achieves high-resolution accuracy while preserving the correct physical admissibility of solutions.

ALMOST RICCIBOURGUIGNON SOLITON ON WARPED PRODUCT SPACE

Buddhadev Pal

Banaras Hindu University

Abstract

The Ricci flow on a Riemannian manifold is an one parameter family of the metric which satisfies the following PDE equation, where is the Ricci curvature tensor and is the initial metric. The purpose of this article is to study the almost RicciBourguignon soliton on warped product space. Some results for solenoidal and concurrent vector fields are obtained on warped product space with almost RicciBourguignon soliton. We provide the relation between the warped manifold and its base manifold (fiber manifold) for an almost RicciBourguignon soliton. We also generalize the Bochner formula in warped product space.

Chew, Goldberger & Low equations: Eigensystem analysis and applications to one-dimensional test problems

Chetan Singh

Indian Institute Of Technology Delhi

Abstract

Chew, Goldberger & Low (CGL) equations describe one of the simplest plasma flow models that allow anisotropic pressure, i.e., pressure is modeled using a symmetric tensor described by two scalar pressure components, one parallel to the magnetic field, another perpendicular to the magnetic field. The system of equations is a non-conservative hyperbolic system. In this work, we analyze the eigensystem of the CGL equations. We present the eigenvalues and the complete set of right eigenvectors. We also prove the linear degeneracy of some of the characteristic fields. Using the eigensystem for CGL equations, we propose HLL and HLLI Riemann solvers for the CGL system. Furthermore, we present the AFD-WENO schemes up to the seventh order in one dimension and demonstrate the performance of the schemes on several one-dimensional test cases.

Discontinuous Galerkin two–grid method for the transient Boussinesq equations

Debendra Kumar Swain

IIT Goa

Abstract

In this paper, we propose a two-grid scheme for the discontinuous Galerkin formulation of the Boussinesq system of equations. The algorithm consists of two steps: in Step I, the nonlinear system is solved on a coarse mesh of size H; in Step II, the coarse solution is used to linearize the system on a finer mesh of size h. We establish optimal error estimates for velocity, temperature in energy-norm and pressure in L^2-norm. Extending the spatial scheme with backward Euler time discretization, we derive fully discrete error bounds. Numerical experiments confirm the efficiency and reliability of the method.

An Efficient Newton-ADI scheme for 2D Time-Fractional Reaction-Diffusion Equations with Weak Initial Singularity

Deeksha Singh

IIT Guwahati

Abstract

A two-dimensional nonlinear reactiondiffusion equation involving a time fractional derivative of order $\alpha \in (0,1)$ is considered. The typical solution to such problems usually has an initial singularity at $t = 0$. To capture the initial singularity, the Caputo time fractional derivative is approximated using the $L^21\sigma$ formula on the smoothly graded meshes. Spatial derivatives are approximated using standard central difference approximation. The computational cost is minimized by employing Newtons linearization method in conjunction with the alternating direction implicit method. A comprehensive theoretical analysis including stability, solvability, and convergence of the discussed scheme, has been rigorously examined and it is shown that the method is convergent with convergence order$M$min $3\alpha, r\alpha, 1+\alpha, 2+\alpha+2x+2y)$ where M is the temporal discretization parameter, x, y are the step sizes in the spatial direction and $M \in (0,1)$ is the fractional order. The effectiveness of the proposed numerical scheme is demonstrated through two examples, one with a smooth solution and the other with a nonsmooth solution.

Entropy Stable ADER-DG (Arbitrary high-order DERivative - Discontinuous Galerkin) scheme for Conservation Laws

Deepak Bhoriya

Department of Mathmatics, BITS Pilani, Pilani Campus, Rajasthan.

Abstract

We present high-order accurate entropy-stable ADER (Arbitrary high-order DERivative) predictor-corrector numerical schemes as an efficient numerical method for solving Hyperbolic Conservation laws. Traditional high-order methods such as WENO, TVD, and DG typically rely on multi-stage Runge-Kutta timestepping to maintain the temporal accuracy. However, these approaches become inefficient beyond the third order because of the Butcher barriers and the high memory traffic they impose on modern CPU and GPU hardware. ADER methods overcome these limitations using a predictorcorrector strategy that achieves arbitrarily high-order accuracy within a single-step update in both space and time, making them well-suited for parallel architectures. Moreover, for a general nonlinear hyperbolic system, the solutions may break down in a finite amount of time, leading to infinitely many weak solutions. While conservation laws are necessary, they do not guarantee physical admissibility. Entropy stability is essential to enforce the second law of thermodynamics and select the physically admissible weak solutions at shocks. In this work, we construct high-order accurate, robust, and efficient entropy stable ADER schemes by combining entropy-conservative fluxes with suitable dissipation and limiter corrections inside the ADER framework. The designed numerical schemes are entropy stable and show high-order convergence, sharp shock capturing and robustness over various multidimensional test problems.

Fully discrete error analysis of a two-grid discontinuous method for the Oldroyd model of order one

Deepjyoti Goswami

Tezpur University

Abstract

We analyse a two-grid algorithm based on discontinuous Galerkin approximation for the Oldroyd model of order one, represented by non-linear integro-parabolic differential equations. Our proposed scheme (SIPG), preserves the positivity of the kernel in both semi and fully discrete cases. We carry over the standard L^2 projection and estimates of the nonlinear term to broken spaces. Then a modified Stokes-Volterra projection and, an improved Sobolev estimate and a trace inequality allow us to derive optimal error estimates in L^2 for an appropriate choice of coarse and fine grid parameters.

Effect of Temperature Modulation on Salt-Finger Convection in Micropolar Liquids

Devika Jayan

CHRIST(Deemed to be University), Bangalore, 560029

Abstract

This paper investigates effect of temperature modulation on salt-finger convection in micropolar liquids layer confined between two parallel long plates separated by a thin gap. Using linear stability analysis and Venezian approach the critical thermal and solutal Rayleigh numbers are determined to understand convection onset. The influence of micropolar fluid parameterssuch as the coupling, micropolar heat conduction, couple stress, and inertiaaffect the system under temperature modulation. Result shows that temperature modulation can either stabilize or destabilize convection. The study also explores the relationship between the critical thermal and solutal Rayleigh number, related to heat and solute concentration, respectively.

Novel mathematical models capture energy transfer patterns in wave turbulence

Dipti Ranjan Parida

TIFR Centre For Applicable Mathematics, Bangalore

Abstract

Wave turbulence involves complex interactions among nonlinear waves, relevant in systems like ocean-atmospheric flows. Despite extensive study, how energy cascades in wave turbulent system remains unclear. We examine energy transfer pathways under varying conditions, focusing on transitions between strong and weak nonlinearity and changes in resonant configurations. Using 1D models across 40 flow regimes, we test whether downscale transfer depends solely on resonant interactions or also on quasi-/non-resonant ones. Strong turbulence shows efficient, local cascades with -5/3 like spectra, while weak turbulence has steeper spectra, intermittent bursts, and inefficient resonant transfers, often linked to short-lived, localized coherent structures.

Finite Element Analysis of the 3-D MHD System With p-Laplacian

Evana Islam Sarkar

IIT Bhubaneswar

Abstract

A finite element method is developed and analyzed for three dimensional incompressible magnetohydrodynamic (MHD) flows involving a nonlinear p-Laplace viscosity term. The method employs a fully discrete scheme based on the Euler semi-implicit time- stepping technique. We establish the stability of the scheme and address the challenge posed by the p-Laplace term, which prevents the direct application of the Lax-Milgram theorem. Instead, the existence of a discrete solution is proved using a fixed point argument. Furthermore, we show that, as both mesh size and time step tend to zero, the fully discrete solution converges to a weak solution of the continuous MHD problem. Unconditional error estimates for the velocity and magnetic induction are derived-meaning the time step size can be chosen independently of the spatial discretization-under suitable regularity assumptions on the exact solution.

Direct Discontinuous Galerkin Method for Singularly Perturbed Problems

Gautam Singh

National Institute of Technology Tiruchirappalli

Abstract

Singular perturbation problems (SPPs) arise in various fields of science and engineering, often characterized by the presence of a small parameter multiplying the highest derivative in a differential equation. These problems exhibit boundary or interior layers where the solution undergoes rapid variations over a small region. The main challenge is to capture these boundary layers while maintaining numerical stability and efficiency. In this work, we have applied the DDG method with suitable numerical flux to solve SPPs. A rigorous error analysis is conducted to establish the convergence properties of the method. Numerical experiments validate the effectiveness of the approach, demonstrating its accuracy and robustness.

Computation of waveguide eigenmodes by Physics-Informed Neural Networks

Geetanjli

IIT jodhpur Rajasthan

Abstract

Physics-Informed Neural Networks (PINNs) is one of the emerging efficient and robust numerical methods to solve PDEs. It embeds the underlying physical laws in learning. We present a PINN approach to solve the Helmholtz eigenvalue problem underlying waveguide modes, targeting geometries challenging for analytical and traditional numerical methods. This flexible model jointly learns mode profiles and propagation constants from the PDE with Dirichlet boundaries. Convergence and stability are improved through informed initialization of the propagation constant, smooth activations, and tuned learning rates, enabling label-free training. Across diverse geometries and boundary conditions, the model accurately recovers eigenvalues and fields. These results demonstrate potential of PINNs method to solve increasingly complex photonic structures.

Novel bidomain partitioned strategies for the simulation of ventricular fibrillation dynamics*

Gopika P B

IISER Thiruvananthapuram

Abstract

The bidomain model in cardiac electrophysiology is advancing due to clinical relevance and computational progress. It comprises an elliptic PDE coupled with a nonlinear parabolic PDE, where a system of ODEs defines the reaction term. We develop and compare fully coupled, decoupled, and a novel partitioned strategy for efficient simulation, focusing on ventricular fibrillation. The proposed partitioned strategy, enhanced with spectral deferred correction, balances accuracy and computational cost. We adapt a compile-time memory-efficient sparse matrix technique to address the high memory demand of ionic models. Numerical experiments with Luo-Rudy and Ten Tusscher models in 2D/3D, including bidomain-bath coupling, confirm improved performance without accuracy loss over standard decoupled strategies.

*This is a joint work with Dr. Nagaiah Chamakuri and Prof. Peter Bastian.

Matrix-free algorithms for fast electronic structure calculations on distributed architectures using finite-element discretization

Gourab Panigrahi

Indian Institute of Science

Abstract

The finite-element (FE) discretization of a partial differential equation usually involves construction of a FE discretized operator and computing its action on trial FE discretized fields for the solution of a linear system of equations or eigenvalue problems using iterative solvers. This is traditionally computed using global sparse-vector multiplication algorithms. However, recent hardware-aware algorithms for evaluating such higher-order FE discretized matrix-vector multiplications suggest that on-the-fly matrix-vector products without building and storing the cell-level dense matrices reduce both arithmetic complexity and memory footprint and are referred to as matrix-free approaches. These approaches exploit the tensor-structured nature of the FE polynomial basis for evaluating the underlying integrals, and the current state-of-the-art matrix-free implementations deal with the action of FE discretized matrix on a single vector. These are neither optimal nor readily applicable for matrix multi-vector products involving a large number of vectors. In this context, we developed hardware-aware computational algorithms and implementation procedures that can accelerate FE discretized eigenvalue problems and linear system of equations on extreme-scaling computing architectures. Particularly, we accelerated the finite-element discretized matrix-free multivector multiplications arising in various forms of discretized operators in partial differential equations. Subsequently, to showcase the effectiveness of the proposed method arising in a more realistic application domain, eigenvalue problems arising in the quantum modelling of materials (Kohn-Sham density functional theory) are taken as another application for the proposed implementation. To this end, a CPU based matrix-free algorithm is first proposed and then the methodology is being currently extended to GPUs addressing the limitations of our prior approach. The sophisticated operator arising in the field of quantum modeling of materials presents an interesting challenge for the proposed method and the obtained speedups enforce the efficacy of the same. Similar operators dealt in other fields of science and engineering can thus take advantage of the proposed matrix-free methods in accelerating time to solution on modern exascale architectures.

Contributed Talks

Self-similar solutions for magnetogasdynamic shock waves in rotating self-gravitating perfect gas using Lie group invariance method

Harshita

Motilal Nehru National Institute of Technology, Allahabad Prayagraj

Abstract

The aim of our study is to examine the cylindrical shock waves in a self-gravitating ideal gas within a rotating medium influenced by the magnetic field using the Lie group invariance method. We have found that similarity solutions exist in three cases: one involving a power-law shock path and two involving exponential-law shock paths. This study examines the effect of various physical parameter on the shock strength and associated flow variables. This study can have its possible applications in data analysis from exploding wire experiments, pinch effects and in astrophysical events such as galactic winds, supernova explosion, accretion disks.

Flow separation-induced stability and bioconvection dynamics in water-based AA7075 nanofluid with gyrotactic microorganisms

Hemalatha Veedhuluri

National Institute of Technology, Warangal

Abstract

This study presents a numerical investigation of AA7075-water nanofluid with gyrotactic microorganisms over an exponentially shrinking sheet. The governing equations are transformed into nonlinear coupled ODEs and solved using bvp4c routine. Stability analysis has been performed to examine the consistent solution. The study observes that multiple solutions arise only in opposing buoyancy. Flow separation is delayed, enhancing smooth flow. Reduced Eckert number improves heat transfer by 23.69%, while higher Schmidt number boosts Sherwood number by 39.69%. Bioconvection parameters increase microbial density by 38.46%. The findings highlight improved heat-mass transfer and stable bioconvective flows, relevant to microfluidic, biomedical, and thermal applications.

Optimal control analysis of a fractional-order tuberculosis model with age-structured population

Hemaleka A

PSG College of Technology, Coimbatore.

Abstract

In this study, we investigated the Caputo fractional-order epidemiological tuberculosis model,which incorporates long-term dependencies in the dynamics of the disease. The community is divided into three age-structured susceptible groups. The well-posedness of the proposed model is investigated. Furthermore, the optimal control is introduced with two intervention strategies: latent prophylaxis and post-treatment follow-up, which are computed using Pontryagins maximum principle. This demonstrates their efficacy in reducing infection and is validated through numerical simulations. The obtained results highlight the importance of curtailing the infectious population and enhancing recovery, which incorporates memory effects into epidemiological models for tuberculosis control.

Analysis of Sparse Control in Heart Tissue Dynamics Using Gradient-Driven Functionals

Himani Roul

IISER Thiruvananthapuram

Abstract

This work investigates a sparse optimal control problem for the monodomain model in cardiac electrophysiology, incorporating gradient-type terms into the formulation. The cost functional combines a quadratic tracking term, the L^2 norm of the gradient of the state variable, and an L^1 norm penalty to promote sparsity. The presence of the gradient term introduces a Laplacian contribution in the adjoint system, necessitating higher regularity of the state variable to ensure well-posedness. We establish the existence of the adjoint equations and derive first- and second-order necessary optimality conditions. Numerical experiments reveal that increasing the weight of the L^1 term enlarges the sparsity region, leading to vanishing optimal controls over larger portions of the domain. Moreover, the gradient term enhances the damping of the excitation wave, driving the system more effectively toward the desired state. The proposed control problem is solved with a semi-smooth Newton method, and the computational results confirm superlinear convergence, consistent with the theoretical analysis.

*This is a joint work with Mr. Ankur Upadhyay, Dr. Nagaiah Chamakuri, and Prof. Karl Kunisch.

A Novel Fast Second Order Approach with High-Order Compact Difference Scheme and its Analysis for the Tempered Fractional Burgers Equations

Himanshu Kumar Dwivedi

Indian Institute of Technology(BHU), Varanasi

Abstract

We develop a fast finite-difference scheme for the Caputo tempered fractional derivative and apply it to the tempered time-fractional Burgers equation (TFBE) with a tempering parameter λ and order $\alpha \in (0,1)$. The method a fast tempered ${}^{\lambda}\mathcal{FL}2{-}1_{\sigma}$ discretizationuses a sum-of-exponentials (SOE) history approximation and a linearized treatment of the nonlinear term to avoid iterative solves. We prove unconditional stability and accuracy $\mathcal{O}(\tau^2+h^2+\varepsilon)$, where τ and h are the time and space steps and ε is the SOE tolerance. In addition, we design a fourth-order compact spatial discretization that attains $\mathcal{O}(\tau^2+h^4+\varepsilon)$ under standard regularity. Numerical experiments corroborate the theory and show markedly reduced runtime and memory versus the standard tempered ${}^{\lambda}\mathcal{FL}2{-}1_{\sigma}$ scheme, with substantial CPU-time savings. The model targets wave propagation in porous media with power-law memory and exponential attenuation.

Thermal Analysis of Casson Hybrid Nanofluid Around a Circular Cylinder Using DTM

Himanshu Upreti

BML Munjal University

Abstract

This study develops a mathematical model for free convective flow of Casson hybrid nanofluid around a horizontal circular cylinder near the lower stagnation point. The governing equations account for magnetic field, porous medium, Ohmic heating, and thermal radiation effects. The nonlinear system is solved using the Differential Transformation Method, which avoids discretization, linearization, or perturbation. The influence of magnetic field, radiation, Casson parameter, and Grashof number on velocity and temperature distributions is examined. Results demonstrate that increasing the Grashof number reduces heat transfer, whereas magnetic and radiative effects strongly modify flow resistance, underscoring their importance in optimizing next-generation cooling technologies.

Capturing Shocks in Weakly Hyperbolic Systems Using Physics-Informed Neural Network Framework

Jain M Francis

National Institute of Technology Karnataka

Abstract

In this study, we present a new shock-capturing physics-informed neural network (S-PINN) specifically designed for addressing weakly hyperbolic systems. In such systems, classical solutions may fail to exist, and phenomena like shocks, contact discontinuities, delta shocks, and rarefaction waves can develop within a finite time, creating significant challenges for accurate numerical modeling. The proposed S-PINN incorporates the Rankine-Hugoniot (RH) conditions directly into the neural network architecture and uses a masking function to precisely capture discontinuities at high resolution. To benchmark its performance, we also implemented a multi-level Weighted Essentially Non-Oscillatory (WENO) scheme, referred to as WENO-M(5,3,2), which outperforms the traditional WENO approach. Through extensive numerical tests, we demonstrate that the S-PINN framework offers superior accuracy, effectively resolves discontinuities, and exhibits enhanced robustness compared to conventional numerical methods such as WENO.

Nanoparticle aggregation kinematics in hybrid nanofluid over a stretching surface

Jeremy Rymbai

North-Eastern Hill University (NEHU), Shillong, Meghalaya, India

Abstract

Nanoparticle aggregation in nanofluids is recognized as an important mechanism that enhances their thermal conductivity. This study examines the aggregation kinematics of hybrid nanofluid composing of single-walled carbon nanotubes (SWCNTs) and titanium dioxide (TiO2) nanoparticles dispersed in Ethylene Glycol (EG). The flow is analyzed over a stretching surface under the effect of an external applied magnetic field and buoyancy forces in a porous medium. The transformed governing equations are solved using the Galerkin-Finite Element Method (G-FEM) and the results are presented graphically. The outcomes of this study are relevant to various fields that involve applications of a stretching/shrinking surface.

An Efficient High-Order Scheme for Two-Dimensional Caputo Time-Fractional Convection-Diffusion-Reaction Equations with Weak Initial Singularity: Analysis and Computation

Jyoti Yadav

Visvesvaraya National Institute of Technology, Nagpur

Abstract

A high-order numerical method is proposed for solving a two-dimensional Caputo time-fractional convectiondiffusionreaction (TFCDR) equation with an initial weak singularity. The temporal Caputo derivative is approximated using an $L1$ scheme on a graded mesh and spatial discretization employs a compact alternating direction implicit (ADI) scheme. Unconditional stability and L^2-norm convergence are established. The method attains fourth-order spatial accuracy and an optimal temporal rate of $\min\{2-\alpha, r\alpha, 2\alpha+1\}$, where $\alpha \in (0,1)$ is the order of fractional derivative and r is the grading parameter. Numerical experiments validate the theoretical results and demonstrate the high accuracy and efficiency of the proposed scheme.

A Comparative Analysis of Quadrilateral and Triangular Finite Elements in SIMP-Based Topology Optimization.

Jyotiranjan Nayak

SRM University, AP.

Abstract

This work presents a topology optimization framework based on the Solid Isotropic Material with Penalization (SIMP) method, implemented on unstructured triangulated meshes using both linear (P_1) and quadratic (P_2) triangular finite elements. Numerical experiments are conducted on benchmark problems to evaluate the effectiveness and robustness of the approach. Results demonstrate that, unlike conventional SIMP implementations with structured quadrilateral (Q_1) elements which tend to alter shape and topology with changes in domain dimensions, the proposed method using unstructured P_1 and P_2 triangular elements exhibits shape-preserving behavior. Moreover, under equivalent mesh resolutions and volume constraints, designs generated with $P1$ elements consistently achieve lower compliance compared to those obtained with $P2$ elements, highlighting significant performance variations in stiffness across element types within the unstructured SIMP framework.

$H(\text{div})$-Conforming DG Method for the Coupled Convective BrinkmanForchheimer and Double-Diffusion Equations

Kallol Ray

Indian Institute of Technology Guwahati

Abstract

This work addresses a steady-state nonlinear system that couples the convective Brinkman-Forchheimer model with double-diffusion equations. The existence and uniqueness of weak solutions to these governing equations are established using the Galerkin framework. An $H(\text{div})$-conforming DG discretization is subsequently devised, and the well-posedness of the discrete DG solutions is rigorously verified. Optimal a priori error estimates are derived for all discrete solutions. Numerical experiments are presented to corroborate the theoretical findings and to demonstrate the performance of the proposed method.

Composition of pseudo-differential operators via coupled fractional Fourier transform

Kanailal Mahato

Banaras Hindu University

Abstract

In this talk, we obtained some important results of the coupled fractional Fourier transform and its kernel. We defined pseudo-differential operators related to coupled fractional Fourier transform on Schwartz spaces and it is shown that their composition is again a pseudo-differential operator. Furthermore, we have successfully applied some of the results of the coupled fractional Fourier transform to investigate the solution of n^{th} order linear non-homogeneous partial differential equation and wave equation. Lastly, we present some examples involving graphs and tables to illustrate the validity of our theoretical findings.

Large time asymptotics for the viscous Burgers equation under impulsive forcing

Kanchan Dwivedi

National Institute of Technology Warangal

Abstract

We considered an initial value problem to the viscous Burgers equation under the influence of an external forcing of distribution type. The existence and uniqueness of weak solutions for it are investigated. To do this, we linearize the viscous Burgers equation and show the existence and uniqueness of common boundary function for the associated initial-boundary problems. Jump discontinuity of the spatial derivative of the solution makes a key role in determining large time asymptotics to the solutions. The explicit representation of the common boundary function and its asymptotic behavior are discussed for a specific case of the jump discontinuity. Here, the common boundary is obtained in terms of Associated Legendre functions of the first and second kind. For the general case, asymptotic behavior of the common boundary of the associated initial-boundary problems is used to determine the large time asymptotics for the Cauchy problem to the viscous Burgers equation.

The Distance to Bounded Realness

Kannan R

Indian Institute Of Technology Guwahati.

Abstract

Purely imaginary eigenvalues break the symmetry of a Hamiltonian matrix's spectrum about the imaginary axis, which leads to numerical challenges in optimal control. The distance to bounded realness measures how far a Hamiltonian matrix H is from the nearest Hamiltonian matrix $H+\Delta H$, where an arbitrarily small Hamiltonian perturbation removes all purely imaginary eigenvalues. Here, ΔH is real if H is real. While previous studies have produced upper bounds, we present both lower and upper bounds that are tight and often equal in numerical experiments and provide a sufficient condition that ensures equality.

A kinetic energy preserving discontinuous Galerkin scheme based on discrete kinetic model

Kedar Wagh

Indian Institute of Science, Bangalore

Abstract

Discrete kinetic energy preservation (KEP) is a desirable property for the higher-order accurate numerical schemes used in under-resolved simulations of the compressible flows. In this work, we present a novel KEP numerical flux for the compressible Euler equations derived from a discrete-velocity kinetic model of the Boltzmann equation. This numerical flux is integrated into the modern flux differencing based nodal discontinuous Galerkin framework to construct a high-order accurate KEP scheme. We demonstrate the accuracy, robustness, and kinetic energy preserving properties of the proposed scheme through a series of benchmark test problems.

On A Fractional Telegraph-Diffusion Model for Image Denoising

Mahipal Jetta

Mahindra University

Abstract

In this work, we develop a finite difference scheme for the Generalized Time-Fractional Telegraph Equation (GTFTE), where the time derivative is defined using Generalized Fractional Derivatives (GFD). The GFD incorporates scale and weight functions, and reduces to the classical Caputo and Riemann–Liouville derivatives for specific parameter choices. To demonstrate the effectiveness of the proposed scheme, we extend the GTFTE framework to image denoising applications. Unlike traditional integer-order diffusion models, which often fail to preserve fine structural details, our approach leverages the flexibility of fractional dynamics to adaptively suppress diverse types of noise. In particular, we address additive Gaussian noise, multiplicative gamma noise, and Cauchy noise. Extensive experiments on both synthetic and real datasets demonstrate that the proposed method consistently outperforms several state-of-the-art denoising algorithms. Quantitative evaluation using peak signal-to-noise ratio (PSNR), mean structural similarity index (MSSIM), and mean absolute error (MAE) confirms both the accuracy and robustness of the proposed fractional PDE-based framework, while visual comparisons highlight its ability to preserve fine image structures.

A New Paradigm for Data Assimilation: The Global Girsanov Nudged Particle Filter

Maneesh Kumar Singh

Imperial College London

Abstract

We discuss a new nudged particle filtering algorithm designed to improve data assimilation for stochastic models. A key challenge we address is maintaining an optimal effective sample size (ESS), which we achieve by introducing an optimisation framework that couples control variables across all particles. Our three-stage formulation is particularly innovative as it separates the nonlinearity of the ESS term from the forward problem, which allows for independent parallel computation for each particle. We showcase the algorithm's effectiveness on the stochastic Kuramoto-Sivashinsky equation. In a comparison with the temper-jitter particle filter, our method, though exhibiting a larger spread, demonstrates a distinct advantage in its ability to respond more quickly and robustly to extreme events.

Well-posedness of three-dimensional Damped Cahn-Hilliard-Navier-Stokes Equations

Manika Bag

IISER TVM

Abstract

In this talk we present a coupled system of convective BrinkmanForchheimer equations and the CahnHilliard equation, considering a regular potential and non-degenerate mobility. We first establish the existence of a LerayHopf weak solution for the coupled system when the absorption exponent $r \geq 1$. Additionally, we prove that every weak solution satisfies the energy equality for $r \geq 3$. This further leads to the uniqueness of weak solutions in three-dimensional bounded domains, subject to certain restrictions on the *viscosity* (ν) and the *Forchheimer coefficient* (β) in the critical case $r = 3$. Moreover, we provide an alternative simplified proof for the uniqueness of weak solutions for $r \geq 3$ that holds without imposing any restrictions on ν or β. Similar results are also obtained for the case of degenerate mobility and singular potential.

Magneto-Convection in Anisotropic Non-Darcy Porous Media with Non-uniform Boundary Heating and Internal Heat Generation

Manisha Jangir

National Institute of Technology, Warangal

Abstract

We investigate the intricate interplay between magnetic fields, anisotropy, and internal heat sources in buoyancy-driven convection within a porous cavity, a configuration pertinent to next-generation thermal management systems. The cavity features sinusoidal heating along its top and bottom boundaries, with thermally insulated vertical walls. Using the DarcyBrinkman extended model, discretized via the finite volume method and solved with the SIMPLE algorithm, we examine the effects of key dimensionless parameters: high permeability ratio, thermal conductivity ratio ($0.1 \leq k_c \leq 10$), Hartmann number ($0 \leq Ha \leq 100$), internal heat generation/absorption (-5Q5), and cavity orientation angle. The results reveal striking multicellular convection structures, with anisotropic permeability tilt producing wave-like thermal plumes near heated walls. These insights offer design strategies for enhancing solar collectors, improving passive room ventilation, and optimizing cooling in high-power electronics.

Pointwise adaptive weak Galerkin methods for the obstacle problem

Mansi Yadav

INDIAN INSTITUTE OF TECHNOLOGY DELHI

Abstract

This work investigates a posteriori error analysis in the supremum norm for the weak Galerkin method and the modified weak Galerkin method applied to the elliptic obstacle problem. We examine the efficiency and reliability of the proposed a posteriori error estimators. The approach involves constructing barrier-type functions obtained by modifying the corrector function and the conforming component of the discrete solution, and subsequently applying estimates of the Greens function for the unconstrained Poisson problem. Finally, numerical results are presented to confirm the theoretical analysis.

A Lagrange multiplier approach to optimal control of the monodomain model

Maria Robert

National Institute of Technology, Calicut

Abstract

In this work, we address an optimal control problem governed by the monodomain equations with both control and state constraints. The monodomain model describes the propagation of the electrophysiological wave through cardiac tissue. We propose an algorithm based on the augmented Lagrange method to solve the state-constrained optimal control problem. Moreover, we establish the convergence of the sequence of controls generated by the algorithm to a local solution of the problem. Numerical experiments are presented to validate the theoretical findings and demonstrate the methods efficiency.

Neural Networks Predicting Submesoscale Tracer Dispersion

Mayank Kumar Bijay

TIFR-ICTS

Abstract

Oceanic tracers such as dissolved oxygen and carbon are important from a climate and ecological perspective. Tracers are obtained computationally by integrating PDEs along with the flows in ocean models, which are slow. We examine the use of neural network for direct tracer prediction. We generate meso and submesoscale flows and advect passive tracers with such flows. We develop a novel model, that we call LoConv, that outperforms popular architectures such as GAN to predict tracer from flow. The LoConv model with physics-influenced training produced the best fine-scale tracer predictions and are 20 times faster than numerical methods.

Neural Network Stabilization of Chaotic Cancer Dynamics Derived from Perturbation-Reduced Models

Meenu

Department of Mathematics, Vinoba Bhave University, Hazaribag, Jharkhand

Abstract

Cancer dynamics are highly nonlinear and often display chaotic behavior due to complex interactions among malignant cells, host cells, immune responses, and drugs. We develop a chaotic cancer model using coupled partial differential equations to represent spatiotemporal tumorimmunedrug dynamics. Singular perturbation techniques reduce the PDEs to ordinary differential equations, preserving key nonlinear features. The reduced system exhibits chaotic oscillations, reflecting unpredictable tumorimmune interactions. To suppress chaos, a neural-network-based controller is designed, adaptively tuning feedback gains and addressing uncertainties. Simulations confirm its ability to stabilize dynamics, enhance drug efficacy, and protect host cells, offering a novel intelligent control framework.

A Fixed-Point Iterative Method for Solving Fractional Order Boundary Value Problems

Mohammad Saif

Jamia Millia Islamia, New Delhi

Abstract

During this presentation, we defined convergence behaviour of iterative scheme for Contractive-like mapping. Further we apply this method to find approximate solution of nonlinear boundary value problems. Also few numerical examples are exhibiting for the validity, high effectiveness of the utilized iterative method.

Wavelet-Based PINN for Micropolar MEPCM Flow over Paraboloidal Surface

Mohd Vaseem

BML Munjal University Gurugram, Haryana

Abstract

A wavelet-based Physics-Informed Neural Network (PINN) is employed to provide an accurate and efficient framework for modeling complex thermal-fluid interactions. The non-dimensional formulation is directly learned within the PINN, ensuring improved accuracy and convergence. This approach is applied to quadratic convective micropolar microencapsulated phase change materials (MEPCM) flow over a paraboloidal surface, considering nonlinear radiation and viscous dissipation effects. The method effectively captures microrotation behavior and phase change heat storage, showing that MEPCM-based micropolar fluids significantly enhance energy transport. The findings highlight their strong potential for advanced heat exchangers, solar thermal collectors, and other renewable energy applications.

Influence of Incubation Delays on Covid-19 Transmission in Diabetic and Non-Diabetic Populations

Monalisa Anand

UPES Dehradun

Abstract

The study of dynamics of diabetic population infected by COVID-19 is of pressing concern as people with diabetes are considered to be at higher risk of severe illness from COVID-19. A three-compartment mathematical model to describe the interactions of diabetic population and non-diabetic population both infected by COVID-19 with a susceptible population is considered. Time delays in incubation periods of COVID-19 in diabetic and non-diabetic populations are introduced. Besides the basic properties of such a dynamical system, both local and global stability of endemic equilibrium, are studied. The lengths of time delays are estimated for which the stability of the system is preserved locally, while sufficient conditions on system parameters are obtained for global stability. Numerical examples are provided to establish the theory, and simulations are provided to visualise the examples. It is noted that an increase in length of time delay in either of infected populations leads to oscillations in susceptible population but has no impact on infected populations.

A Robust Deep Learning Framework Using ANN and PINN for Solving a class of Singularly Perturbed Fredholm Integro-Differential Equations

Monika Rani

National Institute of Technology Kurukshetra

Abstract

This study introduces a deep learning-based framework for solving singularly perturbed Fredholm integro-differential equations (SPFIDEs) formulated as initial value problems (IVPs). The proposed approach utilizes artificial neural networks (ANNs) when the exact solution is available, and physics-informed neural networks (PINNs) when the exact solution is unknown. In first case, the ANN is trained using the ADAM optimizer to minimize the mean squared error (MSE) loss function, computed over training data derived from the exact solution. In second case, the PINN architecture incorporates the governing differential equation, initial conditions, and integral terms directly into the loss function, ensuring that the network adheres to the underlying physics of the problem. The integral terms are efficiently computed using Gaussian quadrature, enhancing numerical accuracy. Unlike traditional numerical methods that depend on grid discretization, the neural network-based approach offers greater flexibility and improved accuracy. Comprehensive evaluations demonstrate significant error reduction, stable loss convergence, and enhanced computational efficiency, establishing this deep learning framework as a reliable and versatile alternative to traditional numerical methods for solving SPFIDEs.

A machine learning approach for dynamic prediction of a physiological flow through an annulus between two peristaltic tubes: Applications in biomedicine

Muhammad Roshan

SRM IST Kattankulathur Chennai

Abstract

This work focuses on the development of an artificial intelligence (AI) model designed to dynamically predict the flow behavior when a physiological fluid gets propelled inside an annular gap between two peristaltic tubes deforming with a phase difference and different amplitudes, where the outer peristaltic tube can permeate the fluid across its wall. The governing equations for the considered problem are simplified under the assumptions of a creeping flow and long-wavelength approximations. A semi-analytical expression for the axial velocity is obtained using the homotopy perturbation method. Variations in prominent flow variables are displayed in graphical illustrations prepared in the computational software. A noticeable result is drawn from the present study is that phase difference and amplitude ratio are responsible for enhancement in axial velocity of the moving fluid. It is also found that the rise in the strength of the applied magnetic field enhances the transverse fluctuations of peristaltically propagating waves. An AI-driven neural network model accurately predicts wall shear stress (97% accuracy in testing, 100% in validation). The research findings highlight potential improvements in endoscopic treatment strategies and contribute to the broader field of biomedical engineering.

A posteriori error estimates for the two-step backward difference formula: application to parabolic partial differential equations subject to a Robin boundary condition with small randomness

Nakidi Shravani

BITS Pilani, Hyderabad Campus

Abstract

This study presents residual-based a posteriori error estimates for a parabolic PDE with small uncertainty in the Robin boundary condition. We employ a perturbation technique to express the exact random solution as a power series in relation to the uncertainty parameter, necessitating the solution of corresponding deterministic problems. Each deterministic problem is then discretized using the finite element method in spatial direction combined with the two-step backward difference time-stepping method. To achieve optimal bounds in the temporal direction, we use a three-point quadratic time reconstruction. Numerical investigations are performed that support the theoretical findings

---

A simple and efficient iterative scheme for image restoration

Nida Izhar Mallick

Jamia Millia Islamia

Abstract

Our work presents a new iterative scheme and establishes its convergence results to approximate the fixed points of nonexpansive mapping. In particular, we demonstrate effectiveness of our proposed iterative scheme in the image restoration process by formulating the problem as a split feasibility problem (SFP). A comparative analysis reveals that our scheme not only converges faster than some classical iterative processes but also achieves good restoration quality, thereby bridging the gap between abstract convergence results and real-world computational performance. The integration of fixed point methods with modern image restoration highlights the novelty of our approach and underscores its potential as a powerful tool for advancing variational and projection-based techniques in imaging sciences.

Residual-based Chebyshev filtered subspace iteration for sparse Hermitian eigenvalue problems tolerant to inexact matrix-vector products

Nikhil Kodali

Indian Institute of Science, Bengalaru

Abstract

We present a novel eigensolver R-ChFSI, a residual-based reformulation of Chebyshev-filtered subspace iteration (ChFSI) that operates on residuals rather than on eigenvector estimates and is designed to tolerate inexact matrixvector products while retaining robust convergence for both standard and generalized Hermitian eigenproblems. By reformulating the Chebyshev recurrence to operate on residuals, R-ChFSI suppresses errors introduced by inexact matrix-vector products, enabling the use of approximate inverses for generalized problems and the use of lower-precision (e.g., FP32/TF32) matrix-vector products on modern accelerators without sacrificing final accuracy. We demonstrate R-ChFSI on eigenproblems arising from KohnSham DFT calculations using the DFT-FE code, and on benchmarks with millions of degrees of freedom and thousands of eigenpairs: R-ChFSI attains final residual norms of order 10źš10ź even with reduced-precision arithmetic, acheiving speedups of upto 4x over the full precision method, and when employing approximate inverses in generalized eigenvalue problems, it achieves up to ten orders of magnitude improvement in residual tolerances compared to standard ChFSI. These results show that R-ChFSI is a scalable, computationally efficient, and error-tolerant alternative for large-scale eigenvalue computations.
References [1] Sambit Das, Phani Motamarri, Vishal Subramanian, David M. Rogers, Vikram Gavini, DFT-FE 1.0: A massively parallel hybrid CPU-GPU density functional theory code using finite-element discretization Computer Physics Communications, Volume 280, November 2022, 108473. [2] N. Kodali, K. Ramakrishnan, P. Motamarri, Residual-based Chebyshev filtered subspace iteration for sparse Hermitian eigenvalue problems tolerant to inexact matrix-vector products arXiv:2503.22652 (2025). [3] Y. Zhou, Y. Saad, M. L. Tiago, J. R. Chelikowsky, Chebyshev-filtered subspace iteration method free of sparse diagonalization for solving the KohnSham equation Journal of Computational Physics, Volume 274, 1 October 2014, Pages 770-782.

The finite element analysis of a fluid–structure interaction problem in fixed domains

Nishant Ranwan

IISER Thiruvananthapuram

Abstract

This talk presents the study on the finite element approximation of a nonlinear fluid–structure interaction (FSI) problem. The FSI problem is governed by the unsteady incompressible Navier–Stokes equations and the equations of linear elasticity. We consider that both the fluid and solid subdomains are stationary. In the spatial discretization of the Navier–Stokes equations, we incorporate the grad-div stabilization term. The grad-div stabilization penalizes the loss of mass conservation during the discretization, and also stabilizes the effect of small viscosity. In the time continuous case, the existence of a finite element solution will be proved, and the a priori estimates, the strong a priori estimates will be derived. We will present the finite element error analysis and derive the

error estimates. The grad-div stabilization together with the special form of the convective term, the divergence form, shows that the error bounds do not depend on the Reynolds number.
This is a joint work with Dr. Nagaiah Chamakuri and Prof. Volker John.

A Virtual Element Method for the BiotBrinkman Equations Using Nitsches Technique

Nitesh Verma

Universidad del Bio-Bio, Concepcion, Chile

Abstract

In this paper, we formulate, analyze, and implement a novel four-field discrete formulation of the Biot-Brinkman problem using Nitsche's technique within the framework of virtual element methods. By employing a properly weighted norm, we derive a robust analysis for this model problem and establish a priori error estimates for the discrete scheme. Moreover, a set of numerical tests demonstrates the robustness of the method and verifies the theoretical convergence results.

A high order numerical method for solving parabolic degenerate convection-diffusion singularly perturbed problem on the Bakhvalov-type meshes

Nitin

IIT BHU (Varanasi)

Abstract

In this paper, a finite difference scheme is used for solving time-dependent parabolic degenerate convection-diffusion SPP that exhibits a boundary layer on the left side of the domain. The discretization of this paper is done in two steps. In the first step, we semi-discretize the given problem using an implicit backward Euler and Crank-Nicolson finite-difference scheme in the temporal direction, and then an auxiliary problem is used to prove its uniform convergence. In the second step, a suitable combination of a central-midpoint upwind scheme is used to discretize the semi-discrete problem in the spatial direction on the Bakhvalov-type mesh. A well-known local truncation error and barrier function approach is used for the error estimates. Some numerical results are also presented to validate the theoretical part of this paper.

Bifurcation Curve Detection with Deflation for Multi-parametric PDEs

Nitin Kumar

Scuola Internazionale Superiore di Studi Avanzati (SISSA), Trieste, Italy

Abstract

This work presents a comprehensive framework for capturing bifurcating phenomena and detecting bifurcation curves in nonlinear multi-parametric partial differential equations, where the system exhibits multiple coexisting solutions for given values of the parameters. Traditional continuation methods for one-dimensional parametrizations employ the previously computed solution as the initial guess for the next parameter value. These are usually very inefficient, since small step sizes increase computational cost, while larger steps could jeopardize the method convergence jumping to a different solution branch or missing the bifurcation point. To address these challenges, we propose a novel framework that combines: (i) arclength continuation, adaptively selecting new parameter values in higher dimension, and (ii) the deflation technique, discovering multiple branches to construct complete bifurcation diagrams. In particular, the arclength continuation method is designed to handle multi-parametric scenarios, where the parameter vector $\lambda \in \mathbb{R}^p$ traces a curve $g(\lambda)$ within a p-dimensional parameter space. In addition, we introduce a zigzag path-following strategy to robustly track the bifurcation curves and surfaces, respectively, for two- and three-dimensional parametric spaces. Finally, we demonstrate its performance on two benchmark problems: the Bratu equation and the AllenCahn equation.

Existence and uniqueness of identification problem for different kinds of abstract differential equations using perturbation of linear operators

Nivedita

Indian Institute of Technology Mandi

Abstract

Identifying causes from their effects is essential for solving inverse problems, which have several practical applications. In direct problems, solutions are found using supplementary conditions, while in inverse problems, both the equation and solution are unknown, requiring additional conditions beyond those needed for direct problems. We primarily employ perturbation theory of linear operators and semigroup theory to solve the identification problem. We address the identification problem by considering singular and non-singular cases separately. In the non-singular case, we use the perturbation method to determine the existence and uniqueness of the solution. For the singular case, we obtain approximate solution.

Contributed Talks

Magnetic and Joule Heating Effects on Mixed Convection Flow Across a Vertical Cone

Om Prakash Meena

Jawaharlal Nehru University (JNU) New Delhi

Abstract

A numerical and theoretical analysis of the viscous fluid across a vertical cone in the presence of joule heating and magnetic impacts is organized in this segment of the work; this study involves numerous applications in the sciences, engineering, and industrials. The flow model is designed in the form of mathematical equations and for shaking of numerical solution simplicity a non-dimensionalization process is performed and the earned non-similarity equations are solved numerically via the bivariate Chebyshev spectral collocation quasi-linearization method. A schematic illustration of the obtained results at various streamwise locations of the flow profiles for variations of the governing parameters are exhibited in the results and discussions section; and we observed that the velocity can be controlled by the magnetic impact. Moreover, skin friction, mass and heat transfer rate are also illustrated in tabular form. To authenticate the accuracy of the present computations a comparison with prior computation is organized; the residual analysis study is also depicted which determines the convergence of the formulated numerical simulation.

Bi-Objective Optimization in Non-Markovian Finite-Capacity Retrial Queue Models with N-Policy

Panchal Vijaykumar Amrutlal

Sardar Vallabhbhai National Institute of Technology Surat Gujarat India

Abstract

The present study investigates cost-optimization and performance analysis of a finite-capacity non-Markovian retrial queue under N-policy. By taking the remaining repair time as a supplementary variable, the steady state queue size distribution of the number of failed machines in the system is established. The probability distributions are derived using LaplaceStieltjes transform, recursive, and supplementary variable methods. The model is applied to a conveyor belt motor repair station, vital in manufacturing and logistics. Various performance measures are evaluated to study the efficiency of system and the Genetic algorithm have been used for optimization of cost function and waiting time together.

Contributed Talks

Chaos-Control of Nanoparticles Transport in Tumors

Pardeep Kumar

Indraprastha College for Women, University of Delhi

Abstract

We present a reactionadvectiondiffusion framework for modelling coupled tumour glycolytic metabolism, magnetic nanoparticle (MNP) transport, and drug delivery in the tumour microenvironment. The model integrates Warburg-effect-based kinetics, heterogeneous diffusion, fractional-order spacetime operators, coupled cellularvascular transport and magnetic guidance. Further, we have applied nonlinear optimal control strategies (particle swarm, genetic algorithms), incorporating stochastic perturbations for robustness. Spatio-temporal chaos analysis identifies unstable tumourdrug regimes, while magnetic fielddrug coupling enables controllable advection. Patient-specific simulations using clinical imaging support predictive, personalized therapy, offering a mathematically rigorous, clinically translatable platform for precision-guided cancer treatment design.

Data-Driven Recovery of Longitudinal Dispersion Parameters via Inverse Physics-Informed Neural Networks

Pavan Patel and Saroj. R. Yadav

SVNIT SURAT

Abstract

This paper is devoted to the combination of scientific machine learning and fluid dynamics. In this paper we present a novel approach for the data-driven recovery of the longitudinal dispersion parameter, a crucial variable in transport phenomena. Our method leverages an inverse Physics-Informed Neural Networks (I-PINNs), a deep learning architecture that embeds the governing equation into its loss function. By integrating physical laws directly into the neural network's training, we achieve a robust and accurate dispersion parameter estimation, demonstrating inverse PINNs' power for solving real-world inverse problems in fluid dynamics.

Virtual Element Method for the Oldroyd Model of order one.

Pooja Biswas

Tezpur University

Abstract

In this work, we analyze the divergence free conforming virtual element method for the equations of motion that arise in the 2D Oldroyd model of order one. We derive new a priori and regularity results for the discrete solution and establish optimal error estimates in $L^\infty(L^2)$ norm for both velocity and pressure approximations. We next apply the backward Euler method to the semi discrete formulation and establish optimal fully discrete error estimates. Finally, we conduct numerical experiments to support our theoretical results and analyze the findings.

A bi-slope linear distribution function-based Boltzmann scheme for fluid flows

Prashant Kumar Vishwakarma

indian institute of science bangalore

Abstract

This work involves the development of a high-fidelity numerical method for compressible flows that ensures conservation, positivity, and entropy stability. The Euler equations, derived from the Boltzmann equation with a Maxwellian distribution, face challenges due to the Maxwellians infinite support on velocity space and resulting diffusion in kinetic flux vector splitting schemes. Recognising that the Maxwellian is not unique, a compactly supported bi-slope linear(tent) distribution function is proposed. The resulting molecular velocity-based upwind kinetic scheme is positive, entropy-stable, and validated on benchmark one and two-dimensional Euler cases. The present scheme is extended to third-order accuracy for the numerical simulations of the Navier-Stokes equations.

Coherent Structure Dynamics of Heat Transfer in Wakes of an Inclined Elliptical Cylinder: A Novel Lagrangian Framework

Pratham Singh

Indian Institute of Technology Guwahati

Abstract

This work introduces a novel Lagrangian framework to analyze forced convective heat transfer in the unsteady wake of a heated elliptical cylinder inclined at angles ranging from $= 0$ to 90, in 15 increments, with Prandtl number $Pr = 0.71$ and Reynolds number of $Re = 100$. The framework correlates the temporal evolution of the surface-averaged Nusselt number with the dynamic behavior of Lagrangian saddle points, formed at the intersection of repelling and attracting Lagrangian Coherent Structures (LCSs). The study is conducted within a precisely constructed observational domain, a previously unreported influential region in the near-wake, where the trajectory analysis of the newly defined saddle points (active saddle points) consistently aligns with the trends in surface heat transfer. This domain enables predictive identification of transitional events in the Nusselt number profile, including local extrema and slope inflections, across varying angular inclinations. The analysis reveals that oblique displacement of active saddle points enhances convective heat transfer by promoting the shedding of repelling LCSs, while parallel displacement weakens heat transfer. The proposed framework enables the construction of a reduced-order temporal function that closely replicates the monotonicity and transitional features of the Nusselt number evolution. Furthermore, threshold displacement metrics are defined for dominant repelling LCSs to quantify peak heat transfer efficiency. To the best of our knowledge, this is the first study to formu- late an LCS-based framework that provides an algorithmic foundation for predicting the thermal performance of a heated cylinder in unsteady flows across a wide range of inclination angles.

Contributed Talks

Finite element method for parabolic optimal control problem with a bilinear state equation

Pratibha Shakya

Indian Institute of Science

Abstract

This article studies a finite element discretization of the optimal control problem governed by a parabolic equation in a convex polygonal domain. The control variable enters the state equation as a coefficient and is subject to the pointwise inequality constraints. We derive a priori error estimate in the $L^2(0,T;L^2(\Omega))$ norm for the state and control variables for both the spatially discrete and fully-discrete schemes. A numerical experiment is performed to illustrate our theoretical results.

Batched GPU solvers for large scale simulations

Pratik Nayak

Technical University of Munich

Abstract

This talk will give a brief overview of our work on high-throughput solution of tens of thousands of independent linear systems with direct and iterative solvers on GPUs. We will look at matrices arising from combustion applications, plasma physics and also consider generic matrices from the Suitesparse matrix collection. We show that by using such a batched strategy, one can maximize GPU utilization and accelerate the solution of linear systems, which forms a major bottleneck in many science applications.

A Meshless Hybrid Approach to the NavierStokes Equations

Priyal Garg

IIT Bhubaneswar

Abstract

Meshless methods offer flexibility for complex and moving boundary problems by discretizing derivatives at scattered points without requiring connectivity. Among them, Generalized Finite Difference method is robust but becomes computationally expensive for higher-order PDEs, whereas Radial Basis Function method provides high accuracy and extensibility, though its performance is shape parameter sensitive and suffers error stagnation with dense nodes. To address these issues, we developed Hybrid GFDRBF method and extended it to NavierStokes equations for lid-driven cavity problem, where convective terms are discretized by GFD and diffusive terms by RBF. Results are in good agreement with literature upto Re=2000.

Error analysis of a fast ADI compact finite difference method for two-dimensional semi-linear time-fractional problem with weak initial singularity

Priyanka

Indian Institute of Technology (BHU), Varanasi

Abstract

The study designs a computationally efficient L1ADI scheme for semi-linear time-fractional problems and provides error analysis. To reduce storage and computation, we approximate the singular kernel of the time-fractional derivative by a sum-of-exponentials on a graded mesh. A compact alternating direction implicit finite-difference method computes the two-dimensional solution. Using local truncation-error estimates and a discrete fractional Grönwall inequality, stability and convergence are established via a discrete-energy approach. Numerical results corroborate the theory and demonstrate the schemes computational efficiency.

Influence of Viscous Dissipation on Double-Diffusive Convection: Linear and Nonlinear Stability in a Couple-Stress Fluid-Saturated Porous Layer

Priyanshu Agrahari

National Institute of Technology Warangal

Abstract

This study examines the linear and nonlinear stability analyses of double-diffusive convection in a couple-stress fluid-saturated porous layer, incorporating the effects of viscous dissipation. The Darcy model is employed, considering a horizontal base flow with constant temperature and concentration differences at the boundaries. To analyze the stability, perturbations are introduced, and stability thresholds are obtained using the Chebyshev-Tau method for linear instability, while the Runge-Kutta and shooting methods are applied to determine nonlinear stability thresholds. Given the limited research on the nonlinear stability of convective instability with viscous dissipation, this study aims to bridge this gap. The present study extensively discusses the stability characteristics, treating R_z as the eigenvalue and examining critical wave numbers over a broad range of Lewis number (Le), Gebhart number (Ge), and solutal Rayleigh number (S_z). The findings reveal that viscous dissipation induces a nonlinear temperature distribution and acts as a destabilizing factor, while the couple-stress parameter enhances stability, mitigating the destabilizing effects of viscous heating. Additionally, a negative solutal Rayleigh number ($S_z < 0$) promotes system stability, whereas a positive solutal Rayleigh number ($S_z > 0$) has a destabilizing influence. These results provide valuable insights into the interplay between viscous dissipation, double diffusion, and couple-stress effects, offering a deeper understanding of stability transitions in porous media.

2-Stage 4-Dimensional Fuzzy Stochastic Multi-objective Transportation Problem and its Solution by Random Loop-Based Non-Dominated Sorting Evolutionary Algorithm

Radadiya Hardikkumar Sureshbhai

Sardar vallabhbhai national institute of technology -Surat

Abstract

The paper develops 2-stage 4-dimensional fuzzy stochastic multi-objective transportation problem model (2S4DFSMOTP) aiming to minimise transportation cost, carbon emission, labour time, and damageability risk. paper develops new evolutionary approach, the Random Loop-based Non-dominated Sorting Evolutionary Algorithm (RLNSEA). The paper presents case study on the 2S4DFSMOTP for transporting cement from 5 cities to warehouses and from warehouses to customers in 5 cities of Gujarat. Supply, demand, and conveyance capacity are stochastic; objectives are addressed using triangular fuzzy numbers. RLNSEA provides Pareto-optimal solutions that enable efficient transportation. Concludes that RLNSEA solves 2S4DFSMOTP in shorter time period, compared to other method's times.

Boundary Layer Physics-Informed Neural Networks for a class of Singularly Perturbed Fredholm Integro-Differential Equations

Raghvendra Pratap Singh

National Institute of Technology Kurukshetra, Haryana

Abstract

Singularly Perturbed Fredholm Integro-Differential Equations (SPFIDEs) arise in many scientific and engineering applications, where a small perturbation parameter induces sharp boundary or interior layers. Standard Physics-Informed Neural Networks (PINNs) often fail to capture these multiscale features due to steep gradients in localized regions. We propose a Boundary Layer PINN (BL-PINN) framework that uses separate sub-networks for the inner (layer) and outer (smooth) regions, matched through interface conditions. This decomposition enables accurate resolution of fine-scale behavior without sacrificing stability. Numerical results show that while standard PINNs lose accuracy near layers, BL-PINNs achieve several orders of magnitude lower error and maintain stability across a wide range of perturbation parameters, making them a robust and efficient approach for SPFIDEs.

On a Generalized Riemann problem solver for a rich hyperbolic system

Rahul Barthwal

University of Stuttgart

Abstract

This work is concerned with developing a second-order generalized Riemann solver for a hyperbolic system which governs the first order dynamics of a two-phase thin film flow model under the influence of a perfectly soluble anti-surfactant solute. The hyperbolic system is a rich hyperbolic system as it possesses an entire class of entropies and can be decoupled along its Riemann invariants. Extending the first-order Godunov approach, the solver is used to construct a temporal-spatial coupled second-order GRP-based finite-volume method. Numerical experiments including comparisons to MUSCL finite-volume schemes with Runge-Kutta time stepping confirm the accuracy, efficiency and robustness of the higher-order ansatz.

The construction of GRP methods requires to compute temporal derivatives of intermediate states in the entropy solution of the generalized Riemann problem. These derivatives are obtained from the Rankine-Hugoniot conditions as well as a characteristic decomposition using Riemann invariants. Notably, the latter can be computed explicitly for the two-layer thin film model, which renders this system to be very suitable for the GRP approach. Moreover, it becomes possible to determine the derivatives in an explicit, computationally cheap way.

Magneto-Hydrodynamics Ternary Nanofluids Flow over an Exponentially Stretching Porous Sheet with Variable Properties: Entropy Generation

Rajesh Chary Kandukoori

National Institute of Technology Warangal

Abstract

This study focuses the magneto hydrodynamics flow, heat transfer properties of MgO-ZnO-Cu/H2O ternary nanofluids across an exponentially stretching sheet when radiation, Joule heating, and porous media are present. The Tiwari-Das model used in the analysis, which takes into account fluid variables like Prandtl number, viscosity, and thermal conductivity. Similarity transformations used to convert a system of partial differential equations governing the problem into a set of Ordinary differential equations, which are then numerically solved using MATLABs bvp4c routine. Comparisons with previously published studies revealed an excellent agreement. The effects of numerous parameters on temperature, velocity, Nusselt number, skin friction, Entropy generation shown through graphs. The study shows that as the Eckert number, thermal conductivity, magnetic parameter, radiation parameter increase, the temperature rises. However, the velocity reduces when magnetic parameter rises. Furthermore, the ternary nanofluid temperature increased by 63.75%, while the hybrid Nano fluid temperature increased by 65.76% when the radiation parameter increased form Rd=0.2 to Rd=0.8. As moves from Br=0.1 to Br=0.3, the entropy production decreases by 10.58%when shifting ternary to hybrid nanofluid whereas it decreases 10.91% when changing from hybrid to mono nanofluid. The present work finds applications in advanced cooling systems, aerospace engineering, wire drawing stretching, biomedical engineering, and solar collectors.

Contributed Talks

Higher order accurate numerical schemes for hyperbolic conservation laws

Rakesh Kumar

Mahindra University

Abstract

The system of hyperbolic conservation laws is the first order partial differential equations of the form

$$\frac{\partial \mathbf{u}}{\partial t} + \sum_{\alpha=1}^{d} \frac{\partial \mathbf{f}_\alpha(\mathbf{u})}{\partial x_\alpha} = 0, \qquad (\mathbf{x}, t) \in \Omega \times (0, T], \tag{1}$$

subject to initial data

$$\mathbf{u}(\mathbf{x}, 0) = \mathbf{u}_0(\mathbf{x}),$$

where $\mathbf{u} = (u_1, u_2, \ldots, u_m) \in \mathbb{R}^m$ are the conserved variables and $\mathbf{f}_\alpha : \mathbb{R}^m \to \mathbb{R}^m$, $\alpha = 1, 2, \ldots, d$ are the Cartesian components of flux. It is well-known that the classical solution of (1) may ceases to exist in finite time, even the initial data is sufficiently smooth. The appearance of shocks, contact discontinuities and rarefaction waves in the solution profile make difficult to devise higher-order accurate numerical schemes because numerical schemes may develop spurious oscillations or sometimes blow up of the solution may occur.

In this talk, we will discuss recently developed Weighted Essentially Non-oscillatory (WENO) and hybrid schemes for hyperbolic conservation laws. These schemes compute the solution accurately while maintaining the high resolution near the discontinuities in a non-oscillatory manner.

Metaheuristic Optimization and Fuzzy Modelling for M/G/1 Fault-Tolerant Machining System with Vacation

Rakesh Kumar Meena

School of Physical Sciences, Jawaharlal Nehru University, New Delhi

Abstract

In this talk, I will discuss a non-Markovian queueing model developed for fault-tolerant machining systems, incorporating optimal control strategies and server vacation schemes in a fuzzy environment. The steady-state queue size distributions are established using the supplementary variable approach. Moreover, to determine the optimal design parameters, advanced metaheuristic optimization approaches namely, Grey Wolf Optimization and Particle Swarm Optimization are employed.

Existence and uniqueness of C^1 solution to the boundary value problem for blood flow model with body forces

Rakib Mondal

Birla Institute of Technology and Science, Pilani, K K Birla Goa Campus

Abstract

In this talk, we introduce a simplified 1-dimensional inhomogeneous system of conservation laws governing blood flow in the cardiovascular system. We then consider the interaction of two centered rarefaction waves. First, we analyze the Riemann solutions, demonstrating that the solutions lose self-similarity due to the source term. By transforming the system into non-reducible diagonal form in Riemann-invariant coordinates, we show how the interaction gives rise to a Goursat boundary value problem (GBVP). Consequently, discuss the existence and uniqueness of a global C^1 solution to the GBVP using a priori uniform C^1 bounds. This paper has been published in Studies in Applied Mathematics.

Numerical study of brain tumor growth in 2D irregular domain with variable-order time-fractional derivative

Ravi Shankar Prasad

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY, SURAT

Abstract

Understanding tumor growth in the brain is crucial and complex. This paper explores a brain tumor model that integrates variable-order time-fractional derivatives within a two dimensional irregular domain. The models stability is demonstrated through Ulam-Hyers stability analysis, and the existence and uniqueness of the solution are established. The finite difference method is utilized for temporal discretization, while Gaussian radial basis functions are employed for spatial variables. Code verification is performed to confirm the accuracy and reliability of the computational approach. The study investigates the behavior of tumor cells, considering cell heterogeneity, the impact of the mutation rate Kc, and growth parameters 1 and 2, along with various orders of time-fractional derivatives, including variable orders. The results and discussion provide a thorough analysis with graphical representations, highlighting novel behaviors induced by variable-order time-fractional effects on the brain tumor model.

Fast higher order approximations for a nonlinear time-fractional biharmonic equation with initial singularity

Richa Singh

IIT BHU

Abstract

This work presents a high-order, fast algorithm for a nonlinear time-fractional biharmonic equation with an initial singularity. The Caputo derivative is discretized by a second-order scheme on a nonuniform time grid tailored to the initial layer, while the spatial operator is approximated using a high-order non-polynomial parametric quintic spline. The resulting method both resolves the initial singularity and lowers cost via a fast nonuniform-time discretization, achieving computational complexity $\mathcal{O}(MN\log^2 N)$ and memory $\mathcal{O}(M\log^2 N)$, where N and M denote the numbers of temporal and spatial grid points, respectively. We prove unconditional stability and convergence with error $\mathcal{O}\big(h^{4.5} + N^{-\min(r\mu,2)}\big)$, where μ is the fractional order, r the grading parameter, and h the spatial mesh size. Numerical experiments corroborate the theory, demonstrating high accuracy together with strong computational efficiency.

Darcy-Forchheimer equations : Robust stability and preconditioning

Rishi Das

IIT Bombay & Monash University, Australia

Abstract

We derive parameter-robust error estimates for mixed finite element methods for the nonlinear Darcy-Forchheimer equations with mixed boundary conditions. Using the framework of operator preconditioning, we also design efficient block preconditioners that exhibit robustness with respect to the coefficients that modulate permeability and inertia of the system. The properties of the formulation (parameter and mesh-size independence of the convergence rates) are illustrated by means of several numerical examples.

Numerical solution of delay differential equation using wavelet method

Rupal Aggarwal

Manipal University Jaipur

Abstract

Technique that involves the application of the wavelet method is introduced to find numerical solutions to linear and non-linear delay difference equations. The obtained solutions are compared with other existing solutions. Numerical examples are presented to show the robustness and reliability of the proposed method. The convergence results and error analysis are also discussed. It is demonstrated that the accuracy of the result increases as the degree of resolution increases.

BUOYANCY DRIVEN CONVECTION IN A PARTIALLY OPEN C-SHAPED ENCLOSURE FILLED WITH A NANOFLUID

Ruthra J S

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY KATTANKULATHUR

Abstract

This paper numerically investigates the natural convection in a partially C- shaped enclosure filled with nanofluid that has two openings and a heat source. The governing equations are discretized using the Finite Difference Method (FDM) with a central differencing scheme, and the resulting algebraic equations are solved through iterative solvers. We then explore different ranges of the parameter regime, considering the Rayleigh number, aspect ratio, heat source length, source location, and nanoparticle volume. The results indicates that larger aspect ratio weaken the streamlines and the fluid inflow through the bottom opening is greater than the top. Increasing the nanoparticle volume fraction reduces the stream strength and temperature gradients. An increase in the Ra number enhance the fluid flow and the heat transfer rate depends greatly on heat source length.

Semi-Analytical Solutions of Counter-Current Imbibition Phenomena Using DTM and RDTM

Sahu Nagesh Sumanshankar

Sardar Vallabhbhai National Institute of Technology, Surat

Abstract

This study investigates the counter-current imbibition phenomenon, a critical process in oil recovery governed by a nonlinear partial differential equation that is challenging to solve analytically. We employ two semi-analytical techniques, the Differential Transform Method (DTM) and the Reduced Differential Transform Method (RDTM), to obtain solutions. A comparative analysis reveals that RDTM offers a more efficient and computationally less intensive approach without compromising accuracy. The investigation into the fraction of oil recovered over time provides crucial insights for optimizing recovery rates, demonstrating the utility of these methods for practical petroleum engineering applications.

Semi-implicit central scheme for hyperbolic systems of balance laws with relaxed source term

Samala Rathan

Indian Institute of Petroleum and Energy Visakhapatnam

Abstract

Quasi-linear hyperbolic systems with source terms introduce significant computational challenges due to the presence of stiffness. To address this, a numerical scheme is developed and applied to benchmark models such as the JinXin relaxation model, the Broadwell model, and the Euler equations with heat transfer to evaluate its effectiveness. The method extends the NessyahuTadmor central scheme to non-homogeneous systems via a non-splitting strategy, enabling consistent source term treatment. A second-order IMEX scheme is formulated using cell-averaging, with the stiff source term handled implicitly through midpoint spatial discretization, trapezoidal time integration, and a backward semi-implicit Taylor expansion. Theoretical analysis and numerical validation confirm the stability and accuracy of the method, highlighting its potential for efficiently solving stiff hyperbolic balance laws.

A high-order numerical scheme based on L2-1_σ-ADI difference method on nonuniform meshes for a 2D variable coefficients time fractional reaction-diffusion equation

Sameer Nitin Khandagale

VNIT

Abstract

This paper presents a high-order numerical approximation based on the L2-1_σ-ADI difference method on nonuniform meshes for solving a two-dimensional time-fractional reaction-diffusion (TFRD) problem with spatially variable coefficients. This model exhibits a weak singularity at the initial time. To deal with this singularity, the Caputo time-fractional derivative is discretized on the graded mesh. We design the L2-1_σ scheme on non-uniform mesh for the discretization of the time-fractional derivative and a high-order compact finite difference (CFD) scheme for the discretization of the space derivatives. The resultant fully-discrete scheme is computationally expensive. In order to reduce the computational complexity of the scheme, we introduce a compact alternating direction implicit (ADI) scheme of fourth order. A global H^1 stability and convergence analysis are established for the suggested method. We prove that the proposed scheme possesses $\min\{r\alpha, 1+\alpha\}$-th order accuracy in time direction, where $\alpha \in (0,1)$ denotes the order of temporal derivative and fourth-order accuracy in space direction. Numerical experiments are performed to support the theoretical results and demonstrate the accuracy and efficiency of the method. We compare the computed results on the variable graded mesh with the results obtained over non-variable graded mesh and uniform mesh. A comparison of computed results with the results obtained by the method in citeMulti3 is provided to show the advantage of the proposed method. Moreover, a comparison between ADI method and non-ADI method is presented to demonstrate the advantage of ADI method.

Second order central schemes for 1D systems of nonlocal balance laws.

Sanjibanee Sudha

Indian Institute of Petroleum and Energy, Visakhapatnam, Andhra Pradesh 530003.

Abstract

We develop second order finite volume central schemes for nonlocal balance laws, motivated by applications with long range interactions such as traffic flow and biological systems. Our main contribution is a non staggered adaptation of the Nessyahu Tadmor (NT) scheme. This modification ensures key structural properties such as positivity preservation are retained, thereby guaranteeing physically meaningful solutions. To further reduce numerical dissipation, we extend the Kurganov Tadmor (KT) scheme framework to the nonlocal setting by incorporating accurate nonlocal flux reconstructions. The resulting schemes maintain high resolution and stability without requiring Riemann solvers. Extensive numerical experiments confirm their ability to resolve sharp interfaces and capture complex nonlocal dynamics with improved accuracy and robustness.

Adaptive Epidemic Control Algorithm: Integrating Pa-rameter Estimation and Multi-Scenario Optimisations for Dynamic Vaccination Strategies

Saratha Sathasivam

Universiti Sains Malaysia

Abstract

Public health interventions in outbreak-prone areas like Malaysia require precise modelling of disease dynamics. This study analyses a modified SIR model with time-dependent vaccination, applying optimal control to reduce transmission while balancing costs. Unlike conventional short-term models, it incorporates parameter uncertainty, resource limits, and sustainability. Numerical solutions via Differential Transformation Method (DTM) and Finite Difference Method (FDM) use influenza data (20152025). Pontryagins Maximum Principle frames the control problem. Key outputs include reproduction number, peak infection, and epidemic size, with sensitivity to transmission and control weights. Results show DTM converges quickly, while FDM better captures complex control dynamics.

Physics-Informed Deep Learning for Solving Coupled Nonlinear Systems: A PINN-Based Approach for Multiphysics Transport

Sarthak Sharma

National institute of technology warangal

Abstract

Physics-Informed Neural Networks (PINNs) have emerged as a transformative framework that seamlessly integrates machine learning with the governing laws of physics to solve complex nonlinear partial differential equations (PDEs). In this presentation, a PINN-based methodology is developed to model coupled multiphysics transport phenomena involving magnetohydrodynamic (MHD) bioconvective flow, thermal radiation, and porous media interactions. The governing equations are transformed into a nondimensional form and encoded directly into the loss function of the neural network, ensuring that both data and physical constraints are satisfied during training. The workflow includes the formulation of the mathematical model, network architecture design, hyperparameter optimization, and convergence diagnostics through loss and residual analysis. The model accurately reconstructs velocity, temperature, concentration, and microorganism density fields while maintaining consistency with the physical boundary conditions. Comparative validation with classical benchmark results confirms the robustness and accuracy of the proposed framework. Finally, the presentation highlights how PINNs can be generalized to solve other nonlinear and parametric PDE systems, demonstrating their potential as a unified deep learning paradigm for scientific computing and physics-based modeling.

Keywords: Deep learning; Physics-informed neural network; Residual analysis; Bioconvection; Collocation points; Multiphysics Transport.

Time-Fractional Smoluchowski Coagulation Equation : Analytical Study

Shantanu

Birla Institute of Technology And Science, Pilani, Pilani Campus

Abstract

This study extends the classical Smoluchowski coagulation equation into a time-fractional framework. Using the variational principle, we formulate a non-integer order Smoluchowski model for three aggregation kernelsconstant, sum, and productemploying Caputo and RieszCaputo fractional derivatives to incorporate long-range temporal memory into the aggregation process. The model effectively captures non-Markovian kinetics, anomalous diffusion, and history-dependent gelation phenomena relevant to viscoelastic colloids, polymerization, and astrophysical clustering. To obtain analytical approximations, we apply the LaplaceHomotopy Perturbation Method (LHPM), yielding rapidly convergent series solutions that preserve mass conservation. We examine the influence of the fractional order on coagulation dynamics for each kernel type, with numerical experiments validating the accuracy and robustness of the approach across fractional orders 0<1 and diverse initial conditions. The findings provide a versatile modelling framework for predicting and controlling memory-dependent aggregation phenomena in materials science, environmental engineering, biopharmaceuticals, and planetary science.

Direct numerical simulation of plane Poiseuille flow of a viscoplastic fluid in a channel with hydrophobic wavy walls

Sheetal

Malaviya National Institute of Technology Jaipur

Abstract

The plane Poiseuille flow of a viscoplastic fluid in a two-dimensional channel with hydrophobic wavy walls is considered to analyse the behavior of the unyielded region using the direct numerical simulation (DNS). The slip condition due to hydrophobicity of both walls is modeled using the Navier slip law. The rheological properties of the viscoplastic fluid are defined by the Bingham model and the discontinuity associated with yield stress is addressed by the Papanastasiou regularization approach. The OpenFOAM framework is used to perform numerical simulations using the semi-implicit method for pressure linked equations (SIMPLE) algorithm for pressurevelocity coupling.

Finite Difference Method for Global Stabilization of the Viscous Burgers' Equation with Nonlinear Neumann Boundary Feedback Control

Shishu pal singh

Rajiv Gandhi Institute of Petroleum Technology

Abstract

In this talk, we presents a nonlinear Neumann boundary feedback control problem associated with global stabilization of the viscous Burgers' equation using a class of finite difference methods. The proposed procedure, known as the θ scheme, where $\theta \in [0, 1]$, encompasses both explicit and implicit schemes, offering a novel numerical approach to this nonlinear problem. Through the discrete energy method, we establish that the difference scheme is conditionally stable for $0 \leq \theta < \frac{1}{2}$ and unconditionally stable for $\theta \geq \frac{1}{2}$. Error analysis of the state variable demonstrates a first-order convergence rate concerning the discrete L^2, H^1 and L^∞-norms in space for $\theta \geq \frac{1}{2}$. Additionally, we achieve a first-order convergence rate for the control inputs. Numerical examples are presented to validate the theoretical results, showcasing the effectiveness of our approach in solving the inhomogeneous nonlinear Neumann boundary control problem for the viscous Burgers' equation.

Analytical study of the continuous Redner-Ben-Avraham-Kahng coagulating cluster dynamic model

Shweta

Birla Institute of Technology And Science, Pilani, Pilani Campus

Abstract

Population balance equations are vital for modeling turbulent gasliquid flows, aerosols, liquidliquid dispersions, colloids, pharmaceutical granulation, and raindrop breakage. Their nonlinear and complex nature makes analytical solutions for empirical kernels challenging. This work investigates the continuous RednerBen-AvrahamKahng coagulation model using the Homotopy Analysis Method (HAM) and Accelerated HAM (AHAM). Approximate series solutions are compared with Finite Volume Method benchmarks, confirming accuracy and flexibility. AHAM delivers improved long-term precision with fewer truncated terms than HAM. A convergence analysis based on Banachs fixed-point theorem further verifies AHAMs efficiency, establishing it as a reliable semi-analytical tool for modeling coagulating cluster dynamics.

Uncertainty-Aware modeling and optimal control of Ransomware propagation

Soundarya G

PSG College of Technology, Coimbatore

Abstract

This paper presents a comprehensive mathematical model for controlling the network system. We develop a model capturing the sequential stages of ransomware attacks with fuzzy differential equation for uncertainty in transmission and recovery parameters. The disease-free equilibrium, the classical and fuzzy reproduction numbers of the model are studied. The qualitative analysis confirmed the well-posedness of the model and stability of a disease-free state. The optimal control strategies - network-level ransomware and signature-based antivirus are incorporated and solved using Pontryagins maximum principle. The obtained results demonstrate the effectiveness of combined interventions in cybersecurity by reducing infection prevalence and system damage.

Towards Accelerated ODE Solvers on GPU for Industrial Applications

Subhajit Sanfui

Siemens Technology and Services Pvt. Ltd.

Abstract

Accurate combustion simulations require detailed chemical kinetics, but the large number of species and reactions makes full-scale models computationally prohibitive. To enable faster chemistry, three complementary strategies are explored: (i) algorithmic techniques such as advanced integration methods, (ii) hardware acceleration methods that exploit modern computing architectures, and (iii) data-driven machine learning approaches for surrogate modeling. We present a comparative study of these approaches, highlighting their performance benefits, trade-offs, and potential synergies. The work provides insights into balancing accuracy, scalability, and efficiency for advancing realistic combustion simulations.

Adaptive nonconforming FEM for distributed optimal control problems governed by m-harmonic equations

Subham Nayak

IISER Thiruvananthapuram

Abstract

This talk addresses the convergence of adaptive finite element methods for distributed optimal control problems governed by m-harmonic operators with m=1,2. The control variable is discretized using piecewise constant polynomials, while the state and adjoint variables are approximated with nonconforming finite elements: the CrouzeixRaviart element for m=1 and the Morley element for m=2. A novel error equivalence result is established, relating the total error of the optimal control problem to that of associated auxiliary elliptic PDEs. Based on this, both a priori and a posteriori error estimates are derived. The proposed a posteriori estimator combines contributions from the state, adjoint, and control variables; for the control part, three reliable and efficient estimators are introduced and compared. The quasi-optimality of adaptive finite element method is established by verifying the standard adaptivity axioms. Numerical experiments confirm the theoretical results and demonstrate the effectiveness of the proposed estimators.

Global Polynomial Synchronization of Stochastic Reaction Diffusion Neural Networks via Dynamic Hybrid Triggered Control with Cyber-Attacks

Subhashri A R

Vellore Institute of Technology, Vellore

Abstract

This paper addresses global polynomial synchronization of stochastic reaction-diffusion neural networks (SRDNNs) under cyber-attacks via a dynamic hybrid-triggered control strategy. The SRDNN model includes spatial diffusion, stochastic perturbations, and time-varying delays. A hybrid control framework combining time-driven and event-triggered mechanisms adapts control updates based on system states and attack intensity. LyapunovKrasovskii functionals are constructed, and synchronization conditions are derived using linear matrix inequalities. The proposed method ensures resilience against attacks and efficient control execution. Two examples, including image encryption and decryption, demonstrate the practical applicability of global polynomial synchronization in SRDNNs.

Discontinuous Galerkin methods for Weak and Temple-type Hyperbolic conservation laws

Subhodip Ghosh

IISER THIRUVANANTHAPURAM

Abstract

We investigate high-order Discontinuous Galerkin (DG) schemes for the chromatography equations, a prototype Temple-type system, and the extended Burgers system, a representative weakly hyperbolic model. Both exhibit non-classical wave phenomena, including under-compressive and delta shocks, which present challenges for numerical approximation. The proposed method employs the Godunov flux within the DG framework, combined with strong stability preserving RungeKutta time integration and slope limiters to control spurious oscillations. The Godunov flux, derived from exact or approximate Riemann solvers, enables accurate resolution of wave interactions without relying on characteristic decomposition for non-diagonalizable systems. Numerical experiments confirm that the scheme achieves high-order accuracy in smooth regions, resolves discontinuities sharply, and captures the evolution of non-classical shocks in both Temple-type and weakly hyperbolic settings, including singular measure formation in the extended Burgers system.

Wavelet collocation method applied to study bioheat transfer in skin tissue

Subrahamanyam Upadhyay

Indian Naval Academy

Abstract

Metabolism varies with temperature is known as metabolic heat generation. While classical Pennes bioheat equation typically treats metabolic heat generation as a constant. In reality, faster metabolic activity cause tissue metabolism to rise with temperature. In this work, we investigate the temperature distribution of human skin tissue in four layers-epidermis, dermis, Subcutaneous fat and muscle-each characterized by different thermal conductivity. We employ a mathematical bioheat transfer model incorporating a temperature-dependent, nonlinear exponential form of metabolic heat generation. We consider temperature dependent non-linear exponential term of metabolic heat. The study is structured into three cases: (i) metabolic heat modeled as a constant; (ii) metabolic heat modeled as a linear function of temperature and (iii) metabolic heat modeled as an exponential function of temperature. To solve the bioheat transfer model, we employed The Legendre Wavelet Collocation Method. The results of cases 1 and 2 are validated by comparing them with an exact solution, showing excellent agreement. The effects of different variables are illustrated through detailed tables and figures.

ImEx second order central scheme for discrete velocity kinetic models

Sudipta Sahu

Indian Institute of Petroleum and Energy, Visakhapatnam, Andhra Pradesh

Abstract

Quasi-linear hyperbolic systems with source terms introduce significant computational challenges due to the presence of stiffness. To address this, a numerical scheme is developed and applied to benchmark models such as the Xin-Jin relaxation model, the Broadwell model, and the Euler equations with heat transfer to evaluate its effectiveness. The method extends the NessyahuTadmor central scheme to non-homogeneous systems via a non-splitting strategy, enabling consistent source term treatment. A second-order IMEX scheme is formulated using cell-averaging, with the stiff source term handled implicitly through midpoint spatial discretization, trapezoidal time integration, and a backward semi-implicit Taylor expansion inspired by. Theoretical analysis and numerical validation confirm the stability and accuracy of the method, highlighting its potential for efficiently solving stiff hyperbolic balance laws.

Contributed Talks

Bound preserving Lax-Wendroff flux reconstruction method for special relativistic hydrodynamics

Sujoy Basak

Indian Institute of Technology Delhi

Abstract

Lax-Wendroff flux reconstruction (LWFR) schemes have high order of accuracy in both space and time despite having a single internal time step. Here, we design a Jacobian-free LWFR type scheme to solve the special relativistic hydrodynamics equations on Cartesian grids. We then blend the scheme with a first-order finite volume scheme to control the oscillations near discontinuities. We also use a scaling limiter to preserve the physical admissibility of the solution after ensuring the scheme is admissible in means. A particular focus is given to designing a discontinuity indicator model to detect the local non-smoothness in the solution of the highly non-linear relativistic hydrodynamics equations. Finally, we present numerical results for a wide range of test cases to show the robustness and eciency of the proposed scheme.

A Mathematical Approach to Precision Therapeutics for Cholesterol Regulation

Sukdeb Manna

SRM University AP

Abstract

This study addresses high blood lipid levels through a novel five-compartment mathematical model encompassing the liver, blood, gallbladder, intestine, and tissues. It integrates direct drug administration into the bloodstream to specifically reduce cholesterol in blood and tissues. Sensitivity and stability analyses assess parameter influence and model reliability. MATLAB simulations demonstrate a steady decline in cholesterol after treatment, with theoretical and computational findings confirming model accuracy. This framework offers valuable guidance for designing optimized, targeted therapeutic strategies for effective hyperlipidemia management.

Turbulence of thermoacoustic internal gravity waves in the lower atmosphere through PDE modelling and simulation.

Sukhendu Das Adhikary

Visva-Bharati (A Central University)

Abstract

We introduce a novel two-dimensional partial differential equation (PDE) model describing the nonlinear coupling between internal gravity waves and thermal waves in stratified fluids of the Earths lower atmosphere (0-50km). The model predicts thermoacoustic internal gravity waves by incorporating temperature-dependent density inhomogeneities from thermal expansion. Numerical simulations show solitary vortices coupled to thermal modes generate thermoacoustic turbulence, producing large-scale potential flows and small-scale densitytemperature structures. Spectral analysis indicates Kolmogorov-like behavior in the troposphere, but in the stratosphere displays a steeper spectral decay, suggesting stronger turbulence in the troposphere and contributing valuable insights into waveturbulence interactions in atmospheric dynamics.

Investigating Secondary and Tertiary Vortex Phenomena in Flow Past a Circular Cylinder Using Explicit RK-Type HOC Methods

Sumit Kumar

Indian Institute of Technology Guwahati

Abstract

We present an explicit high-order compact (HOC) finite-difference scheme for simulating 2D unsteady flow past a circular cylinder using fourth-order RungeKutta (RK4) time integration. The nine-point stencil ensures fourth-order spatial accuracy, while RK4 provides computational efficiency. Von Neumann analysis confirms robustness under strong convective conditions. Our results accurately capture secondary and tertiary flow structures for various Reynolds numbers up to Re = 5000, including -, -, sub--, and sub--type vortices in the wake region. Excellent agreement with experimental and numerical data demonstrates the methods reliability for studying complex vortex phenomena in large-scale flow simulations.

Stabilised Galerkin-FE Approximations with POD-ROM for Real-Time Cardiovascular Flow Simulation

Surabhi Rathore

SISSA, Trieste, Italy

Abstract

Cardiovascular flow simulations play a crucial role in understanding cardiac diseases and enabling real-time decision-making. However, traditional finite element (FE) methods for incompressible Navier-Stokes equations require substantial computational resources, hindering real-time applications. We propose a framework combining stabilised Galerkin-FE with reduced-order modelling (ROM) for efficient real-time simulation. High-fidelity solvers generate velocitypressure snapshots for basis construction with appropriate pressure treatment (i.e., supremizer enrichment). ROM uses the Offline-Online paradigm: the offline stage assembles POD bases and reduced operators; the online stage delivers rapid state updates for parametric changes without compromising high-fidelity; these reduction techniques enable clinically viable real-time cardiovascular CFD.

Contributed Talks

A Dimensional-Splitting Non-symmetric Interior Penalty Galerkin Method for 2D Singularly Perturbed Degenerate Parabolic Problems

Suraj Kumar

IIT Guwahati

Abstract

We study the numerical solution of two-dimensional singularly perturbed parabolic problems with multiple boundary turning points. An alternating direction implicit (ADI) operator-splitting scheme is used to reduce the 2D problem into one-dimensional subproblems. The Backward Euler method is applied for time discretization, and the Non-symmetric Interior Penalty Galerkin method is employed in space on exponentially graded meshes to resolve boundary layers. Rigorous stability and error estimates are established. Numerical experiments demonstrate the efficiency and accuracy of the scheme, showing excellent agreement between theoretical predictions and computed results.

A priori error analysis of discontinuous Galerkin method for coupled surface and subsurface flow: Navier-Stokes and Darcy system.

Sweta Chakraborty

Tezpur University

Abstract

This paper investigates a fully discrete discontinuous Galerkin finite element method for the evolutionary Navier-Stokes/Darcy coupled system with BeaversJosephSaffman interface conditions. The first-order backward Euler method has been employed for the time discretization. Based on that, an optimal a priori error estimates for the fluid velocity, the pressure and the piezometric head are obtained in $L^\infty(\mathbf{L}^2)$ and $L^\infty(L^2)$-norms, respectively. We use modified Oseen operator on the appropriate discontinuous Galerkin setup along with standard L^2-projections to delicately tackle the interface terms and achieve these results. Finally, a few numerical experiments are conducted to verify our theoretical findings.

Lie symmetry analysis of a nonlinear system of partial integro differential equations arising in thermoviscoelasticity

Tapan Kumar Muduli

Visvesvaraya National Institute of Technology (VNIT), Nagpur

Abstract

In this work, we analyze a one-dimensional system of partial integro-differential equations that represents a quasi-static contact problem in the context of thermoviscoelasticity. Here, we want to derive similarity solutions of the system through the application of Lie symmetry analysis. Initially, we identify a five-dimensional Lie point symmetry algebra by extending the invariance criterion to the system of integro-differential equations. Subsequently, a one-dimensional optimal classification is conducted for the five-dimensional Lie algebra. Moreover, invariant solutions are derived for each class within the optimal set by reducing the system of integro-differential equations (IDEs) with two independent variables to a scalar integro-ordinary differential equation. In the end, we use the traveling wave transformation to find physically relevant solutions, including traveling wave solutions.

Adaptive Mixed Finite Element Method for Distributed Optimal Control Problems : Quasi-Optimality

Tooba M. Shaikh

Indian Institute of Science Education and Research Thiruvananthapuram

Abstract

This talk presents a quasi-optimality analysis of an adaptive mixed finite element method for distributed optimal control problems governed by elliptic equations. A mixed formulation is used to handle flux and displacement, discretized via Raviart-Thomas and piecewise constant spaces, with control treated variationally. Novel error equivalence results in suitable norms enable reliable and efficient error estimation. To handle data oscillation issues in the flux estimator, a separate marking strategy is employed. Convergence and quasi-optimality are rigorously established using an axiomatic framework. Numerical results support the theory and confirm optimal convergence rates.

Streaming potential and electro viscous behavior in soft cylindrical nanochannels incorporating slip effects

Udeshna Bhattacharya

National Institute of Technology, Silchar

Abstract

In this work, we analyze the impact of viscoelastic effects on streaming potential and EKEC efficiency using the fractional Maxwell model. We consider a soft cylindrical nanochannel with surface charge density σ under oscillatory pressure-driven flow. The ion partitioning effect arises due to the permittivity difference of the PEL and the electrolyte solution. Using modified Poisson-Boltzmann and Cauchy-momentum equations, we derive the analytical expressions for induced streaming potential, velocity and energy conversion efficiency and explore the influence of the fractional order, Deborah number, pressure gradient, relaxation time and ion partition effect on streaming potential and energy conversion efficiency. Keywords- Streaming potential, Maxwell fluid, EKECE, Ion-partition effect.

Review on mathematical model for permeable reactive barrier to contain volatile organic compound remediation.

Utsavkumar Dhansukhbhai Patel

Sardar Vallabhbhai National Institute of Technology, Surat

Abstract

Volatile Organic Compounds (VOCs) from natural and man-made sources harm air, soil, and groundwater, causing health risks like dizziness, organ damage, and cancer. Their migration through unsaturated soil occurs via diffusion, advection, and dispersion. Horizontal Permeable Reactive Barriers (HPRBs) are an effective in-situ method to intercept and oxidize VOCs (e.g., TCE, toluene) in the vadose zone. Studies review experimental and mathematical modeling approaches, analyzing barrier geometry, material properties, and placement. Analytical, semi-analytical, and numerical models are compared to optimize HPRB performance and improve field application efficiency.

Existence and Stability Results for Impulsive Fractional Integrodifferential Equations Involving the Hadamard Derivative in Sobolev Spaces

V Umapathi

Department of Mathematics, Bharathiar University.

Abstract

This study investigates the existence and stability of solutions for impulsive fractional integrodifferential equations governed by the Hadamard derivative in Sobolev spaces. The existence results are established through Schaefers fixed point theorem. In addition, three stability concepts are analysed in detail: Ulam-Hyers stability, generalized Ulam-Hyers stability, and Ulam-Hyers-Rassias stability. Illustrative examples are provided to demonstrate the main theoretical results.

Learning Hidden Physics and System Parameters with Deep Operator Networks

Vijay Kag

Robert Bosch Research and Technology Center Bangalore

Abstract

Discovering hidden physical laws and identifying governing system parameters from sparse observations are central challenges in computational science and engineering. Existing data-driven methods, such as physics-informed neural networks (PINNs) [1] and sparse regression, are limited by their need for extensive retraining, sensitivity to noise, or inability to generalize across families of partial differential equations (PDEs). In this work, we introduce two complementary frameworks based on deep operator networks (DeepONet) [2] to address these limitations. The first, termed the Deep Hidden Physics Operator (DHPO), extends hidden-physics modeling [3] into the operator-learning paradigm, enabling the discovery of unknown PDE terms across diverse equation families. The second is a parameter identification framework that combines pretrained DeepONet with physics-informed inverse modeling to infer system parameters directly from sparse sensor data. We demonstrate the effectiveness of these approaches on benchmark problems including the reaction-diffusion system, Burgers equation, and the 2D heat equation. Across all cases, the proposed methods achieve high accuracy, with relative solution errors on the order of $O(10^(- 2))$ and parameter estimation errors on the order of $O(10^(- 3)$), even under limited and noisy observations. By uniting operator learning with physics-informed modeling, this work offers a unified and data-efficient framework for physics discovery and parameter identification, paving the way for robust inverse modeling in complex dynamical systems. References: [1] M. Raissi, P. Perdikaris, G.E. Karniadakis, Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations, Journal of Computational Physics Journal of Computational Physics [2] L. Lu, P. Jin, G. Pang, Z. Zhang, G. E. Karniadakis, learning nonlinear operators via DeepONet based on the universal approximation theorem of operators, Nature machineintelligence 3 (3) (2021) 218229. [3] M. Raissi, Deep Hidden Physics Models: Deep Learning of Nonlinear Partial Differential Equations, Journal of Machine Learning Research 19(25)(2018)124.

H^1-norm error estimate of a compact ADI finite difference scheme for the 2D multi-term time-fractional convection-diffusion equation governing groundwater pollution

Vikas Kumar

Visvesvaraya National Institute of Technology, Nagpur, Maharashtra

Abstract

In this paper, we propose a high-order compact alternating direction implicit (ADI) finite difference technique for the 2D multi-term time-fractional convection-diffusion equation (TFCDE) governing groundwater pollution. Notably, the solution to this equation generally displays a singular behavior near the initial time. Each time-fractional derivative is approximated using the L1 scheme on a graded mesh, and spatial derivatives are computed using a compact finite difference (CFD) method.

To reduce the high computational complexity of the fully discrete scheme, an ADI approach is used to split the 2D problem into two simpler 1D problems. The stability and convergence of the method are rigorously proven using the discrete energy method. The error estimate of the scheme is provided in both the L^2 and H^1 norms. Finally, numerical experiments are conducted to verify the theoretical results and demonstrate the accuracy of the method.

L2-3 Approximation of the Generalized Fractional Derivative with Application to 1D and 2D Generalized Time-Fractional Electromagnetic Wave Models

Vikash Sharma

Department of Mathematical Sciences, Indian Institute of Technology (BHU), Varanasi

Abstract

This work introduces a novel L2-3 approximation for the Generalized fractional derivative (GFD) of order ϑ, $\vartheta \in (1, 2)$ based on scale and weight functions. The proposed approximation uses a uniform time mesh, applying Newtons quadratic interpolation on the first time sub-interval and cubic interpolation on the subsequent ones. We provide an exhaustive study of the coefficients $\mathcal{A}_{j,k}^{\vartheta}$ and $\mathcal{B}_{j,k}^{\vartheta}$, which are used in the proposed approximation, and analyze the local truncation errors. This approximation is applied to find a computational algorithm for generalized time-fractional electromagnetic wave models (GTFEWMs) in one and two-dimensional domains with Dirichlet boundary conditions, using the central difference method for spatial derivatives. In addition, we establish the uniqueness, unconditional stability, and convergence of the proposed computational algorithm. The accuracy and efficiency of the proposed method are confirmed by evaluating the process using a variety of examples.

A novel numerical method for the CahnHilliard equation with degenerate mobility and logarithmic potential

Vishal Tiwari

Indian Institute of Technology Ropar

Abstract

The numerical simulation of the CahnHilliard equation incorporating the FloryHuggins logarithmic free-energy potential presents considerable difficulties, primarily due to the singular nature of the potential as the order parameter approaches 0 or 1. A widely adopted strategy to circumvent this issue is to introduce a regularization of the free-energy potential in the vicinity of these singularities. However, when coupled with a degenerate mobility, the problem becomes even more intricate, restricting the applicability and robustness of conventional numerical schemes. In this study, we develop a novel numerical method that requires no regularization near singularities and robustly handles degenerate mobility, thereby overcoming two long-standing challenges in the field.

Contributed Talks

Heat and mass transfer enhancement of convection driven by thermal and solutal buoyancy under concentration modulation

Vivek Lodwal

National Institute of Technology, Warangal

Abstract

This study investigates the linear and weakly nonlinear stability of convection driven by thermal and solutal buoyancy in a porous medium, focusing on the effect of concentration modulation. A perturbation analysis is conducted to examine the weakly nonlinear regime near the small supercritical Rayleigh number. Heat and mass transport, expressed through the Nusselt and Sherwood numbers, are described by a non-autonomous Ginzburg-Landau equation, assuming the concentration modulation amplitude remains small. The impact of varying Lewis number, Prandtl number, separation parameter, Soret parameter, and amplitude modulation on heat and mass transfer is thoroughly investigated. The results indicate that (a) an increase in the Lewis number and Soret parameter leads to a lower Nusselt number and a higher Sherwood number. (b) Furthermore, the averaged heat transfer decreases by 5.65% for $\Phi = 0$ and 5.51% for $\Phi = \Pi$, while mass transfer increases by 4.63% and 5.54%, respectively, relative to the case without the Soret parameter.

A high-order numerical method and its analysis for solving a three-dimensional time-fractional advectiondiffusion model

Vivek Subhedar Pathak

Visvesvaraya National Institute of Technology Nagpur

Abstract

This paper presents a numerical scheme for approximating the solution of a three-dimensional time-fractional advectiondiffusion equation (TFADE) model that exhibits a weak singularity at ($t = 0$). The temporal fractional derivative is discretized using the ($L2$-1_σ) scheme on nonuniform meshes, while the spatial derivative is discretized using a fourth-order compact finite difference (CFD) scheme. The resultant fully discrete scheme is computationally expensive; therefore, we propose an alternating direction implicit (ADI) scheme to reduce computational complexity. A theoretical analysis of the stability and convergence of the proposed numerical method is carried out using the (H^1)-norm and (L^2)-norm. The methods performance, robustness, and accuracy are tested through numerical experiments. Additionally, a comparison of numerical results obtained on uniform, graded, and variable graded meshes is provided to highlight the advantages of the proposed nonuniform mesh method over the uniform mesh method. We compare the numerical results obtained by the present method with those reported in Zhou, Z., Zhang, H., Yang, X.: H^1-norm error analysis of a robust ADI method on graded mesh for three-dimensional subdiffusion problems, Numer. Algorithms 96, 15331551 (2024) and Roul, P., Rohil, V.: A high-order numerical scheme based on graded mesh and its analysis for the two-dimensional time-fractional convectiondiffusion equation, Comput. Math. Appl. 126, 113 (2022). The numerical results, presented in both tabular and graphical forms, confirm the schemes high accuracy and versatility.

Physics Informed Optimal Homotopy Analysis Method (PI-OHAM): A Hybrid AnalyticalComputational Framework for Solving Differential Equations

Ziya Uddin

BML Munjal University, Gurugram, India

Abstract

We present a Physics-Informed Optimal Homotopy Analysis Method (PI-OHAM) for solving nonlinear differential equations. Extending the classical HAM, PI-OHAM systematically tunes convergence-control parameters via a physics-informed residual loss, integrating governing equations, boundary conditions, and data, akin to PINNs. Applied to the Blasius boundary-layer equation, PI-OHAM converges faster and with higher accuracy than standard HAM, closely matching numerical benchmarks. By combining the interpretability of analytical series with optimization principles, the framework offers a systematic, flexible, and reliable approach for nonlinear flow problems, bridging traditional perturbation techniques with modern physics-informed machine learning.

Asymptotic Behaviour of the Generalised KDV-Burgers Equation with Initial Mass Zero.

Abhishek Gupta

NIT Warangal

Abstract

We study the large time asymptotic behaviour of solutions to the generalised KDV-Burgers equation with zero initial mass. Under small, rapidly decaying initial data in $L^1_1(\mathbb{R}) \cap H^s(\mathbb{R})$, the global solution is constructed via the contraction mapping principle. Using sharp Green function estimates and nonlinear analysis, we show that the solution converges to the diffusive N-wave of the Burgers equation. Moreover, the difference between both profiles decays as $O((1+t)^{-1})$ in L^∞. The results clarify how dispersion modifies the diffusion-dominated asymptotic structure in the massless case.

Deep Learning Framework for Pseudospectra Prediction of Hypersensitive Non-Normal Problems

Amit Punia

Department of Mathematics and Statistics, Jai Narain Vyas University Jodhpur

Abstract

The computation of pseudospectra is fundamental to understanding the instability and transient behavior of non-normal linear operators arising in fluid dynamics, control theory, and numerical analysis [1]. Traditional methods for computing ε-pseudospectra require solving $\mathcal{O}(N^2)$ singular value problems across a complex grid, making the analysis computationally prohibitive for large matrices, a critical bottleneck in applications such as hydrodynamic stability analysis and model order reduction [2,3].

In this talk, we will present a novel deep learning framework that learns to predict the pseudoresolvent norm field $\|R(z,A)\| = \sigma_{\min}(A - zI)^{-1}$ directly from matrix features, bypassing expensive grid-based SVD computations. The proposed multi-input neural network architecture combines sinusoidal positional encodings for complex plane coordinates with dense feature extraction from normalized matrix elements and spectral properties, trained on 1,500 randomly generated non-symmetric tridiagonal matrices ($n = 32$) using a physics-informed loss function $\mathcal{L} = \mathrm{MSE} + \alpha\|\nabla^2\Phi\|^2$. This enforces smoothness constraints consistent with analytic continuation principles [5].

The trained model achieves 4500× speedup (∼0.01s per matrix vs. ∼45s for traditional methods) with mean absolute error MAE < 0.15 in log-space, accurately capturing ε-pseudospectrum contours ($\varepsilon \in \{10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}\}$) and correctly classifying stable versus unstable eigenvalues based on their position relative to pseudospectral boundaries [4]. This dramatic acceleration enables real-time stability assessment in computational fluid dynamics and control applications where repeated pseudospectrum computations are required, opening new avenues for incorporating neural surrogates in iterative design and optimization workflows involving non-normal operators [5].

Keywords: Pseudospectrum, Deep Neural Networks, Non-normal Operators, Physics-Informed Learning, Spectral Stability, Computational Linear Algebra

References

1. L.N. Trefethen and M. Embree, *Spectra and Pseudospectra: The Behavior of Nonnormal Matrices and Operators*, Princeton University Press, 2020.
2. T.A. Driscoll, Eigenmodes of isospectral drums, *SIAM Review*, 39(1), 1997.
3. L.N. Trefethen, Pseudospectra of linear operators, *SIAM Review*, 39(3), 1997.
4. S.C. Reddy and L.N. Trefethen, Pseudospectra of the convection-diffusion operator, *SIAM Journal on Applied Mathematics*, 54(6), 1994.
5. M. Raissi, P. Perdikaris, and G.E. Karniadakis, Physics-informed neural networks, *Journal of Computational Physics*, 378, 2019.

Memory-Induced Stabilization in Fractional-Order Tri-Trophic Food Web: Revealing Iso-Spike Structures and Chaos Transitions

Anuj Kullu

Banaras Hindu University

Abstract

This study presents a fractional-order tri-trophic intraguild predation (IGP) model incorporating Caputo derivatives to capture memory effects in ecological dynamics. By combining a LeslieGower predator growth model with a Holling type-II functional response, the model captures realistic predatorprey dynamics. A novel iso-spike method is introduced to visualize periodic behaviors and identify shrimp-shaped periodic islands in bifurcation diagrams. Results show that stronger memory (lower fractional order) enhances stability and suppresses chaos, while weaker memory sustains oscillations. Simulations on the PARAM SHIVAY supercomputer reveal how memory-driven dynamics influence ecosystem stability and offers insights into ecological management under changing environmental conditions.

Evolution of an acceleration waves in a non-ideal relaxing gas subjected to rotating medium

Deepak Lather

MNNIT Allahabad, Prayagraj

Abstract

Evolution of an acceleration wave in a non-ideal relaxing gas within a rotating medium. Using the method of characteristics, we construct a reference frame aligned with the eigenvalues of the governing quasilinear hyperbolic equations and derive a transport equation for amplitude evolution. A shock forms when the initial compressive disturbance exceeds a critical amplitude; otherwise, the disturbance decays. The effects of the rotational parameter, adiabatic index, relaxation parameter, and non-idealness parameter are examined.

Problems On A Nonconservative System In Elastodynamics

Divya Joseph Kayyunnapara

IISER TVM

Abstract

In this poster, we present a work where we constructed the explicit solution to the initial boundary value problem for the elastodynamics system in the space time domain when the initial and boundary data lie on the level sets of one of the Riemann invariants, using the vanishing viscosity method. The difficulty we face is in understanding the boundary condition in a generalised way, because the number of boundary conditions to be prescribed at the boundary depend on the number of characteristics entering the domain. Since our system is nonlinear, the characteristic speeds depend on the unknown and the direction of the characteristics curves are not known a priori. As a continuation of this work, we also consider the general initial and boundary data of Riemann type, formulate the boundary value problem based on the Riemann problem and construct explicitly the solution.

Inexact Uzawa Approach in Deep Minimal Residual PDE Problems

Emin Benny Chacko

University of Nottingham

Abstract

In recent advances in scientific computing, neural network-based methods such as the Deep Ritz approach have demonstrated strong potential for solving partial differential equations (PDEs) by reformulating them as variational problems. Within this framework, Uzawa-type iterative algorithms have emerged as powerful tools for addressing saddle point problems. However, computing exact updates at each iteration can be computationally expensive, especially in high-dimensional parameter spaces. Inexact Uzawa methods address this challenge by allowing the iterative subproblems to be solved approximately, while still ensuring convergence to the true solution under appropriate error control. This work explores the use of inexact Uzawa methods for neural network-based PDE solvers, with particular attention to WAN(Weak Adversarial Networks) and related architectures, and we extend classical inexact theory to settings where trial and test functions are parameterized by neural networks. We also provide conditions that support convergence under inexact updates.

Haar Wavelet Collocation Method for Three-dimensional Squeezing Flow of Hybrid Carbon Nano-tubes in a Rotating Channel

Govind Gaur

National Institute of Technology Warangal

Abstract

This study employs a hybrid suspension of single-wall and multi-wall carbon nanotubes (SWCNTs and MWCNTs) dispersed in water within a rotating channel to examine the characteristics of three-dimensional (3D) squeezing flow. A system of nonlinearly coupled ordinary differential equations is formulated, illustrating the flow dynamics in a porous stretching channel affected by rotational effects, utilizing similarity transformations. The Haar wavelet collocation method (HWCM) is employed to solve the resulting complex system. To assess the efficacy and convergence of the current method, the results are compared with those from the *bvp4c* solver, demonstrating a notable agreement between the two approaches. Graphical representations are used to examine the effects of important physical parameters, such as the volume fraction of carbon nanotubes, suction rate, squeezing intensity, rotating speed, and nanoparticle type.

Virtual element method for Maxwell-Cattaneo equation with discontinuous coefficients

M.Arrutselvi

Indian Institute of Technology Madras

Abstract

We discuss the first order virtual element method for the numerical solution of the Maxwell-Cattaneo equation on a two-dimensional domain with an interface. A modified optimal order virtual element interpolation employing an extension operator due to the low global regularity of the exact solution, is presented. A new elliptic projection operator is defined and an optimal approximation order is proved while accounting for the discontinuous coefficient. For the semi-discrete virtual element formulation, an optimal order convergence estimate in the $L^\infty(L^2)$ norm is given. For the fully discrete scheme, we use the implicit Euler method for approximation of the time derivative. The well-posedness of the discrete formulation and error estimates demonstrating the optimal rate of convergence in the $L^\infty(L^2)$ norm are obtained. Numerical studies on polygonal meshes confirm the theoretical estimations and demonstrates the robustness of the virtual element method.

Communication-Efficient Strategies for Accelerating Large-Scale Sparse Eigenproblems

Nishant Gupta

Indian Institute of Science, Bengaluru

Abstract

Authors: Nishant Gupta*, Nikhil Kodali, Kartick Ramakrishnan, Phani Motamarri Affiliation: Department of Computational and Data Sciences, Indian Institute of Science, Bengaluru.

Emerging GPU architectures, with enhanced support for AI/ML workloads, offer powerful low-precision arithmetic capabilities. Algorithms designed to operate effectively at reduced precision without compromising accuracy can significantly accelerate large-scale scientific computations by leveraging the high computational throughput of these architectures. However, as computational throughput increases, performance bottlenecks increasingly shift toward internode communication and intranode data movement, which can dominate overall cost. Addressing these bottlenecks requires strategies specifically aimed at reducing data-movement overhead on distributed GPU systems. Large-scale sparse eigenproblemscentral to many scientific domainsstand to benefit substantially from such approaches. To this end, we build on the recently developed residual-based Chebyshev filtered subspace iteration[1] (RChFSI) eigensolver that operates on eigenproblem residuals rather than eigenvector estimates, suppressing error propagation and thereby being inherently resilient to inexact matrixvector products. Exploiting this resilience, we first explore half-precision formats such as BF16 for internode communication during matrix-vector products arising in R-ChFSI eigensolver, reducing the data volume by half compared to single precision and alleviating bandwidth demands for large-scale problems on distributed systems. Furthermore, we explore lightweight lossy compression schemes to reduce communication volume in both bandwidth-bound and latency-sensitive phases. When combined with low-precision communication, these techniques form an optimized communication strategy that leverages the inherent error resilience of RChFSI. We demonstrate the robustness and computational efficiency of these strategies on large-scale, sparse, finite-elementdiscretized eigenproblems, focusing particularly on those arising in density functional theory. The proposed techniques are implemented in the open-source DFT-FE [2] codethe workhorse behind the 2023 ACM Gordon Bell Prize [3]. Subsequently, using these methods, we showcase substantial improvements in scalability and time-to-solution for quantum-mechanical simulations on emerging heterogeneous exascale platforms when solving up to tens of thousands of eigenpairs.

References [1] Kodali, N.; Ramakrishnan, K.; Motamarri, P. Residual-based Chebyshev filtered subspace iteration for sparse Hermitian eigenvalue problems tolerant to inexact matrixvector products. arXiv preprint arXiv:2503.22652. [2] S. Das, P. Motamarri, V. Subramanian, D. M. Rogers, V. Gavini: DFT-FE 1.0: A massively parallel hybrid CPU-GPU density functional theory code using finite-element discretization. Computer Physics Communications 280, 108473 (2022). [3] S. Das, B. Kanungo, V. Subramanian, G. Panigrahi, P. Motamarri, D. Rogers, P. Zimmerman, V. Gavini: Large-scale materials modeling at quantum accuracy: Ab initio simulations of quasicrystals and interacting extended defects in metallic alloys (SC Proceedings 23) (ACM Gordon Bell Prize 2023).

Poster Presentation

Mathematical and Machine Learning Integration for Colorectal Cancer Survival Prediction: A PDE-Constrained and Data-Driven Approach

Padmasri Sridharan

Vellore Institute of Technology, Chennai

Abstract

Colorectal cancer (CRC) poses major clinical challenges due to its biological complexity. This study proposes a hybrid framework combining partial differential equations (PDEs) with interpretable machine learning for survival prediction. Tumor dynamics are modeled via PDEs incorporating vascular diffusion, proliferation, and treatment response, solved using finite element methods. Inverse problems are addressed via adjoint-based optimization. Survival modelsCox, XGBoost, DeepSurvleverage clinical and genomic features, enhanced by SHAP and L1 regularization. The framework is deployed on GPU-based HPC systems, ensuring scalability. Performance is validated using Kaplan-Meier curves and C-index, demonstrating improved precision and transparency in CRC prognosis through mathematical-ML integration.

Tackling tumor growth based on multilevel approaches

Rimpa Pal

Heidelberg university

Abstract

The growth of tumors is a highly complex phenomenon that involves biological processes acting and interacting across multiple spatial and temporal scales. At the tissue level, tumor development is governed by mass transport, mechanical interactions, and nutrient availability, which can be described using continuum models based on partial differential equations. At the cellular scale, the collective behavior of different cell populations, including proliferation, migration, and death, determines the heterogeneity of tumor structure. On the subcellular level, intracellular signaling pathways regulate cellular responses and adaptation, linking molecular activity to tissue-scale outcomes. In this work, we aim to develop a fully coupled multiscale mathematical framework that brings these levels together in a consistent way. The formulation ensures that conservation laws are satisfied and that tumor volume evolution remains consistent when bridging cellular and tissue scales. Different modeling strategies are incorporated for the respective scales, allowing flexibility to represent essential biological mechanisms without restricting the approach to a single methodology. The resulting system provides a platform to study key features of tumor growth such as morphological instabilities, heterogeneous cell density distributions, and the impact of therapeutic interventions on proliferation dynamics. The framework is implemented using the high-performance finite element software HiFlowş, which provides the computational tools required for solving large-scale, coupled systems. By formulating a multiscale mathematical model, this study links biological mechanisms across different scales in a consistent manner. The resulting framework captures essential features of tumor progression while remaining adaptable to diverse modeling approaches

---

Poster Presentation

A posteriori and a priori error estimates for linearized thin sheet folding.

Rohit Khandelwal

South Asian University, New Delhi

Abstract

We describe a posteriori error analysis for a discontinuous Galerkin (DG) method for a fourth order elliptic interface problem that arises from a linearized model of thin sheet folding. The primary contribution is a local efficiency bound for an estimator that measures the extent to which the interface conditions along the fold are satisfied, which is accomplished by constructing a novel edge bubble function. We subsequently conduct a medius analysis to obtain improved a priori error estimates under the minimal regularity assumption on the exact solution. The performance of the method is illustrated by numerical experiments.

Epsilon-Uniform error analysis for 2D turning point problem

Shallu

LNMIIT, JAIPUR

Abstract

This poster presents error analysis for a finite element method applied to a 2D singularly perturbed convection-diffusion turning point problem. Utilizing layer adapted Shishkin mesh, we prove epsilon-uniform convergence in the maximum norm. The analysis, critically based on the properties of a discrete Green's function, guarantees the method's robustness and accuracy in capturing sharp solution layers.

Data-driven models for acoustic wave scattering

Souryajit Roy

Centre For Applicable Mathematics, TIFR

Abstract

We develop data-driven models for a fundamental wave-vortex interaction problem: acoustic wave scattering by a turbulent vortex. The original dynamics are governed by the Euler equations. The wave-vortex interaction terms present in the PDEs are responsible for the scattering effect. Using numerical simulations with various plane wave initializations and vortex configurations, we train different neural networks - ANN, U-Net, and GAN to find an approximation of the wave-vortex interaction term present in the governing PDEs. This gives us a neural net-PDE hybrid model for the problem, which can be evolved in time to capture the scattering dynamics.

Efficient finite-element methods for quantum modelling of materials using mGGA functionals with accelerated convergence of fixed-point iterations using low rank preconditioning schemes.

Srinibas Nandi

Department of Computational and Data Sciences, Indian Institute of Science, Bengaluru

Abstract

First-principles modelling methods are ubiquitous in studying materials properties, with KohnSham density functional theory (DFT) being the frontrunner. Although DFT is theoretically exact, the universal exchangecorrelation (XC) functional, which captures all many-body quantum-mechanical interactions, remains elusive and is, therefore, approximated with successive levels of complexity. The underlying Coulomb and exchangecorrelation kernels depend on eigenfunctions of the DFT Hamiltonian. Consequently, the resulting DFT governing equations can be cast in the form of a nonlinear eigenproblem, a fixed-point problem in electron-density computed from DFT eigenfunctions and is solved using a self-consistent field (SCF) iterative scheme. Recently, XC functionals in DFT that incorporate the kinetic energy density of electrons alongside the local electron density and its gradient (referred to as -mGGA functionals), have gained renewed attention due to their enhanced capability for accurately predicting a wide-variety of material properties. However, these -mGGA functionals are known to exhibit numerical instabilities [1] and slower SCF convergence rate. Furthermore, the state-of-the-art Fourier-basis implementations of DFT currently incur at least four-fold computational overhead for -mGGA functionals compared to the GGA functionals. In addition, the existing SCF mixing schemes are often inadequate for systems where the SCF either converges slowly or fails to converge, a situation more frequently encountered with -mGGA functionals. To address these challenges, we develop an efficient and scalable finite-element (FE) implementation of -mGGA functionals in the open-source DFT-FE code [2], enabling large-scale electronic-structure calculations with minimal computational overhead. Furthermore, we introduce a novel preconditioned mixing scheme that accelerates SCF iterations by employing a low-rank approximation of the Jacobian matrix [3] of residual of the Kohn-Sham fixed-point iteration within the framework of -mGGA functionals. The robustness and efficiency of the approach are demonstrated across diverse system sizes and material classes, underscoring its applicability to generic boundary conditions.

References : 1. Lehtola, S.; Marques M.A.L. J. Chem. Phys, 2022, 157, 174144 2. Das, S.; Motamarri, P.; Subramanian, V.; Rogers D.M.; Gavini V. Comput. Phys. Commun., 2022, 280, 108473 3. Das S.; Gavini V. Phys. Rev. B, 2023, 107, 125113

Time-Fractional Reaction-Diffusion Equations via Fractional Physics-Informed Neural Networks with Parameter Estimation

Vighnesh Vinod Alavani

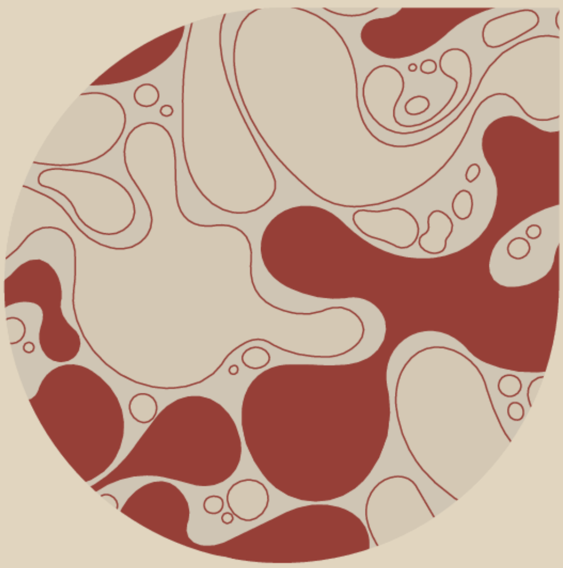
BITS Pilani K. K. Birla Goa Campus

Abstract

In this work, the time-fractional reaction-diffusion equation and estimation of key parameters like diffusion coefficient (γ), and fractional order (α) have been studied using fractional Physics Informed Neural Networks (fPINNs). In addition, we also study the inverse problems for predicting the initial value, given the final value. The essence of this fPINNs algorithm is that it can utilize the fractional differential equation, initial condition and boundary condition efficiently to estimate the parameters even with a small dataset. We show that our fPINNs can be very competent and estimate the key model parameters effectively. Sensitivity analysis has been performed to validate the accuracy and robustness of our fPINNs approximation.

Computational and Applied Mathematics are pivotal in addressing a myriad of national needs and societal concerns. This international conference serves as a convergence point for experts in computational mathematics, fostering the exchange of ideas that span both theoretical and computational realms.

This conference provides an invaluable opportunity for newly minted Ph.D. students venturing into the world of research. It creates a conducive environment for them to delve into cutting-edge developments, connect with seasoned experts, and build a robust foundation for their research endeavors.



Brochure Design: **Shyam M**
(Batch '19, IISER Thiruvananthapuram)
| s.m.designs.business@gmail.com