BOOK OF ABSTRACTS

CoMFoS-NASC 2026

International Conference on
Co**ntinuum **M**echanics **F**ocusing **o**n **S**ingularities,
Numerical **A**nalysis, and **S**cientific **C**omputing

Lapu-Lapu City, Cebu, Philippines
20–23 June 2026

https://comfos-nasc2026.github.io/CoMFoSNASC2026/

Editors

Rhudaina Z. Mohammad, Institute of Mathematics, University of the Philippines Diliman
Marian C. Lantacon, Mathematics Programs, College of Science, University of the Philippines Cebu

Committees

Scientific Committee

Masato Kimura, Kanazawa University, Japan
Hirofumi Notsu, Kanazawa University, Japan
Julius Fergy Rabago, Kanazawa University, Japan

Rhudaina Z. Mohammad, University of the Philippines Diliman, Philippines
Renier G. Mendoza, University of the Philippines Diliman, Philippines
Rachelle R. Sambayan, University of the Philippines Diliman, Philippines

Cherrylyn P. Alota, University of the Philippines Cebu, Philippines
Daisy A. Romeo, University of the Philippines Cebu, Philippines
Jimboy R. Albaracin, University of the Philippines Cebu, Philippines

Local Organizing Committee

University of the Philippines Cebu, Philippines

Cherrylyn P. Alota
Daisy A. Romeo
Jimboy R. Albaracin
Ramises G. Manzano Jr.
Marian C. Lantacon
Keneth Joshua P. Sardan

Contents

About CoMFoS-NASC 2026

The **2026 International Conference on Continuum Mechanics Focusing on Singularities, Numerical Analysis, and Scientific Computing (CoMFoS-NASC 2026)** is a conference dedicated to recent advances in modeling, analysis, and scientific computation of nonlinear phenomena arising in continuum mechanics and related fields. The conference covers a broad spectrum of topics in pure and applied mathematics, including partial differential equations, numerical analysis, inverse problems, control and optimization, free boundary problems, and emerging areas such as data science and computational imaging. Through invited talks and interactive scientific sessions, the conference aims to promote the exchange of ideas between pure and applied mathematicians working on complex nonlinear systems relevant to physics, biology, and engineering.

The conference is organized in conjunction with the long-standing CoMFoS (Continuum Mechanics Focusing on Singularities) series, initiated in 1995 under the Japan Society for Industrial and Applied Mathematics (JSIAM), now continuing as Mathematical Aspects of Continuum Mechanics. The 2026 edition represents a significant milestone, as it will be the first CoMFoS conference held outside Japan, reflecting the growing international collaboration between **Kanazawa University** and the **University of the Philippines (UP)**, particularly the **Numerical Analysis and Scientific Computing (NASC) Academic Group of the UP Diliman Institute of Mathematics** and the **UP Cebu Mathematics Programs**.

A central objective of CoMFoS-NASC 2026 is to enhance the participation and professional development of mathematicians from developing countries, especially from Southeast Asia and the broader Asia-Pacific region. Hosting the conference in the Philippines substantially lowers logistical and financial barriers for researchers, early-career scientists, and graduate students from developing countries who would otherwise face limited access to major international conferences. The conference provides a rare opportunity for these participants to interact directly with leading international experts, present their work in a high-level scientific setting, and establish long-term research collaborations.

This conference is partially funded by the **UP Office of International Linkages** through the UP System Supported CU Hosting of International Conferences and World Experts Lecture Series grants. Selected participants from developing countries are financially assisted by the **International Council for Industrial and Applied Mathematics** under its Conference Support grant. The conference is additionally supported by the **Mathematical Society of the Philippines (MSP)** through the **MSP Region 7 Chapter**.

Program of Activities

Day 1: Saturday, 20 June 2026

7:30 AM – 8:30 AM		Registration
8:30 AM – 9:00 AM	Opening Program Welcome Remarks	 **Atty. Leo B. Malagar**, UP Cebu Chancellor
9:00 AM – 9:30 AM	Invited Talk 01	**Dr. Masato Kimura**, Kanazawa University, Japan *A well-posed shape optimization flow arising from an inverse geometry problem*
9:30 AM – 10:00 AM	Invited Talk 02	**Dr. Jose Ernie Lope**, UP Diliman, Philippines *Solvability of Singular PDEs and Related Results: Filipino Contributions*
10:00 AM – 10:15 AM		*Coffee Break*
10:15 AM – 10:45 AM	Invited Talk 03	**Dr. Julius Fergy Rabago**, Kanazawa University, Japan *Topological and Shape Optimization Methods for Inverse Shape Reconstruction in Elliptic PDEs*
10:45 AM – 11:15 AM	Invited Talk 04	**Dr. Pu Zhao Kow**, National Chengchi University, Taiwan *Krylov methods for linear inverse problems in Hilbert spaces*
11:15 AM – 11:45 AM	Invited Talk 05	**Dr. Manabu Machida**, Kindai University, Japan *Reduced inverse Born series for the diffusion equation*
11:45 AM – 2:00 PM		*Lunch Break & Networking*
2:00 PM – 2:30 PM	Invited Talk 06	**Dr. Neil Jerome Egarguin**, UP Los Baños, Philippines *Active Control of Electromagnetic Waves: Optimization Strategies and Applications*
2:30 PM – 3:00 PM	Invited Talk 07	**Dr. Rhudaina Mohammad**, UP Diliman, Philippines *Integrating Differential Evolution with Deep Learning for EIT Inverse Problem*
3:00 PM – 4:30 PM		*Coffee, Snacks, and Poster Session*
4:30 PM – 6:00 PM		*Free Discussion*
6:00 PM – 8:00 PM		*Welcome Dinner*

Day 2: Sunday, 21 June 2026

9:00 AM – 9:30 AM	Invited Talk 08	**Dr. Karel Švadlenka**, Tokyo Metropolitan University, Japan *On an extension of the multiphase BMO algorithm to anisotropic energies*
9:30 AM – 10:00 AM	Invited Talk 09	**Dr. Takeshi Takaishi**, Musashino University, Japan *Crack propagation problem in environmental conditions and a method for crack shape control*
10:00 AM – 10:15 AM	*Coffee Break*	
10:15 AM – 10:45 AM	Invited Talk 10	**Dr. Helmut Harbrecht**, University of Basel, Switzerland *Shape optimization under uncertainty*
10:45 AM – 11:15 AM	Invited Talk 11	**Dr. Toshiaki Yachimura**, Tohoku University, Japan *Visualizing Shape Functionals via Sinkhorn Multidimensional Scaling*
11:15 AM – 11:45 AM	Invited Talk 12	**Dr. Lorenzo Cavallina**, Tohoku University, Japan *Can you hear the shape of a triangle?*
11:45 AM – 2:00 PM	*Lunch Break & Networking*	
2:00 PM – 2:30 PM	Invited Talk 13	**Dr. Rachelle Sambayan**, UP Diliman, Philippines *Topological Detection of Singularities in Nonlinear Time Series via Persistent Homology*
2:30 PM – 3:00 PM	Invited Talk 14	**Dr. Andrei Domogo**, UP Baguio, Philippines *How do muscles move blood?*
3:00 PM – 3:15 PM	*Coffee Break*	
3:15 PM – 3:30 PM	Student Talk 01	**Shuhei Sasajima**, Kanazawa University, Japan
3:30 PM – 3:45 PM	Student Talk 02	**Kyrho Corum**, UP Diliman, Philippines
3:45 PM – 4:00 PM	Student Talk 03	**Yuma Nakamura**, Kanazawa University, Japan
4:00 PM – 4:15 PM	Student Talk 04	**James Arnold Nogra**, UP Diliman, Philippines
4:15 PM – 4:30 PM	Student Talk 05	**Takehiro Matsumoto**, Kanazawa University, Japan

Day 3: Monday, 22 June 2026

9:00 AM – 9:30 AM	Invited Talk 15	**Dr. Patrick van Meurs**, Kanazawa University, Japan *Collisions of signed Coulomb particles*
9:30 AM – 10:00 AM	Invited Talk 16	**Dr. Bituin Cabarrubias**, UP Diliman, Philippines *Homogenization of an anisotropic perturbation problem in a domain with an imperfect interface*
10:00 AM – 10:45 AM	*Group Photo & Coffee Break*	
10:45 AM – 11:15 AM	Invited Talk 17	**Dr. Gilbert Peralta**, UP Baguio, Philippines *Stokes Equation with Low Regular and Measure Data*
11:15 AM – 11:45 AM	Invited Talk 18	**Dr. Shinya Uchiumi**, Saga University, Japan *Dependency on triangular shapes in bifurcation diagrams of stationary cavity flows*
11:45 AM – 2:00 PM	*Free Discussion, Lunch Break & Networking*	
2:00 PM – 2:30 PM	Invited Talk 19	**Dr. Hirofumi Notsu**, Kanazawa University, Japan *Error estimates of Lagrange–Galerkin moving mesh schemes for the one-dimensional convection-diffusion equation*
2:30 PM – 3:00 PM	Invited Talk 20	**Dr. Renier Mendoza**, UP Diliman, Philippines *Fast Tsunami Wave Height Prediction using Deep Neural Networks for the Shallow Water Equations*
3:00 PM – 3:15 PM	*Coffee Break*	
3:15 PM – 4:00 PM	AMC2028 Invitation Closing Program	**Dr. Jose Ernie C. Lope**, SEAMS President **Dr. Masato Kimura**, Co-chair, Scientific Committee **Dr. Rhudaina Z. Mohammad**, Co-chair, Organizing Committee **Dr. Daisy A. Romeo**, Co-chair, Local Organizing Committee

Invited Talks

20 JUNE 2026 · 9:00 AM - 9:30 AM

A well-posed shape optimization flow arising from an inverse geometry problem

Masato Kimura

Faculty of Mathematics and Physics, Kanazawa University

mkimura@se.kanazawa-u.ac.jp

Inverse geometry problems arise in many applications, including non-destructive testing, medical imaging, and material characterization. A common approach to solving such problems is to reformulate them as shape optimization problems and then employ gradient-based numerical methods to identify unknown geometries.

In this talk, we revisit a classical inverse geometry problem and its shape optimization formulation. Motivated by a simple and efficient numerical reconstruction algorithm, we derive a Hele-Shaw-like moving boundary problem that describes the continuous evolution of the unknown shape. The resulting free-boundary system can be interpreted as a shape optimization flow driven by boundary measurement data.

The main focus of the talk is the mathematical analysis of this evolution problem. We establish the local-in-time existence, uniqueness, and continuous dependence of classical solutions, thereby providing a rigorous well-posedness result for a class of shape optimization flows arising from inverse problems. The analysis is based on a transformation of the moving-boundary problem to a fixed domain and on classical techniques developed for quasi-stationary free-boundary problems.

Numerical examples illustrating the proposed reconstruction method and the associated shape evolution will also be presented. The results demonstrate that the proposed flow provides both an effective computational framework for shape identification and an interesting mathematical model connecting inverse problems, shape optimization, and free-boundary dynamics.

This is a joint work with Julius Fergy T. Rabago (Kanazawa University).

Keywords:
geometric inverse problem
shape optimization
free boundary problem
moving boundary problem

20 JUNE 2026 · 9:30 AM - 10:00 AM

Solvability of Singular PDEs and Related Results: Filipino Contributions

Jose Ernie C. Lope

Institute of Mathematics, University of the Philippines Diliman

jclope@up.edu.ph

We give a brief motivation on the study of a class of singular partial differential equations and present solvability results for those equations in the holomorphic and partially holomorphic categories. We highlight results obtained by Filipino researchers and mention their on-going investigations.

Keywords:
existence and uniqueness theorems
series solutions
singular PDEs

20 JUNE 2026 · 10:15 AM - 10:45 AM

Topological and Shape Optimization Methods for Inverse Shape Reconstruction in Elliptic PDEs

Julius Fergy T. Rabago

Faculty of Mathematics and Physics, Kanazawa University, Kanazawa, Japan

jftrabago@gmail.com

This talk focuses on inverse reconstruction problems governed by elliptic partial differential equations, where the objective is to identify unknown subregions associated with discontinuous coefficients from boundary measurements. We discuss numerical methods based on topological sensitivity analysis and shape optimization for recovering the location and geometry of hidden structures. Particular emphasis is placed on the development of efficient reconstruction algorithms, their numerical implementation, and robustness with respect to noisy measurements. Numerical examples are presented to demonstrate the accuracy and effectiveness of the proposed reconstruction methods.

Part of this talk is based on joint work with L. Afraites (Université Sultan Moulay Slimane, Morocco), A. Hadri (Université Ibn Zohr, Morocco), M. Hrizi (Université de Monastir, Tunisia), and H. Kahlaoui (Université de Tunis el Manar, Tunisia).

Keywords:
geometric inverse problem
topological sensitivity analysis
shape optimization
interface reconstruction

20 JUNE 2026 · 10:45 AM - 11:15 AM

Krylov methods for linear inverse problems in Hilbert spaces

Pu-Zhao Kow

Department of Mathematical Sciences, National Chengchi University

pzkow@g.nccu.edu.tw

In this talk, we present a general methodology for solving linear inverse problems modeled by injective compact operators on separable Hilbert spaces, using singular value decomposition combined with a carefully designed Krylov subspace method. Intuitively, a compact operator on a separable Hilbert space can be thought of as an infinite-dimensional matrix; it behaves like a matrix but in an infinite-dimensional setting.

A key advantage of our approach is that it requires no predefined low-rank approximation; we do not fix a Hilbert basis or truncate manually. Instead, the method automatically selects an appropriate basis and truncation level based on the residual. Once a suitable low-rank approximation is obtained, the linear inverse problem can be solved accordingly.
To illustrate the approach, we apply it to the unique continuation problem for Herglotz wave functions as discussed in [1].

[1] P.-Z. Kow, M. Salo, and S. Zou, *Increasing resolution and instability for linear inverse scattering problems*, J. Funct. Anal., **289(1)** (2025) https://doi.org/10.1016/j.jfa.2025.110923

Keywords:
linear inverse problem
injective compact linear operators
singular value decomposition
low-rank approximation
Krylov subspace method

20 JUNE 2026 · 11:15 AM - 11:45 AM

Reduced inverse Born series for the diffusion equation

Manabu Machida

Department of Informatics, Faculty of Engineering, Kindai University

machida@hiro.kindai.ac.jp

Inverse problems are solved by different methods. Optimization approaches iteratively minimize the distance between observed data and the solution to the forward problem. These methods often suffer from being trapped in a local minimum and from the computational cost of iteration. An alternative approach is to use perturbation theory. Perturbation of a coefficient of an equation can be determined from boundary values of the solution to the equation using the inverse Born series. Unlike the (first) Born approximation, the inverse Born series does not require linearization of nonlinear inverse problems (Moskow and Schotland, "Inverse Born series", in The Radon Transform (2019)). The inverse Born series obtains the solution to the inverse problem as an explicitly computable functional of the scattering data. This functional can be expressed in terms of the GreenâĂŹs function for the underlying partial differential equation.

In this talk, I will show that many terms in the inverse Born series approximately cancel and an efficient computation is possible using the reduced inverse Born series. This is joint work with Akari Ishida (Ishida and Machida, arXiv:2512.00423).

Keywords:
inverse problem
inverse Born series
diffusion equation

20 JUNE 2026 · 2:00 PM - 2:30 PM

Active Control of Electromagnetic Waves: Optimization Strategies and Applications

Neil Jerome Egarguin

Institute of Mathematical Sciences, University of the Philippines Los Baños

naegarguin1@up.edu.ph

Active manipulation of electromagnetic (EM) fields is reshaping modern communication and sensing technologies. This talk presents our recent research works on optimization-based strategies for controlling EM waves in free space and layered media [3, 2, 1], drawing on recent advances in inverse source formulations and numerical schemes. By employing classical regularization methods, such as truncated singular value decomposition and Tikhonov regularization, we demonstrate how stable solutions can be achieved even in ill-posed settings. In particular, we shall look at the effects of these regularization techniques in solving the resulting control equations obtained using either the Debeye potential formulation or the integral equation paradigm.

Applications include adaptive beam shaping, near-field focusing for wireless power transfer, and active cloaking. Sensitivity analyses highlight the limits and feasibility of these approaches, offering insights into how optimization can balance accuracy, energy efficiency, and robustness. The presentation bridges rigorous mathematical foundations with practical engineering outcomes, showcasing active EM control as a powerful paradigm for next-generation communication systems.

[1] C. Qi, S. Zeng, N.J.A. Egarguin, et al., *Active control of electromagnetic fields in layered media*, Journal of Electromagnetic Waves and Applications **38(1)** 66-8 (2024) https://doi.org/10.1134/S1990478925010028

[2] N.J.A. Egarguin and D. Onofrei, *Personal Sound Zones and Shielded Localized Communication through Active Acoustic Control*, J. Appl. Ind. Math. **19(1)** 7-32 (2025) https://doi.org/10.1080/09205071.2023.2270602

[3] C. Qi, N.J.A. Egarguin et al., *Sensitivity analysis for active electromagnetic field manipulation in free space*, Applied Mathematics in Science and Engineering **30(1)** 661-687 (2022) https://doi.org/10.1080/27690911.2022.2118270

Keywords:
active EM control
EM field synthesis
regularization techniques
TSVD
Tikhonov regularization

20 JUNE 2026 · 2:30 PM - 3:00 PM

Integrating Differential Evolution with Deep Learning for EIT Inverse Problem

Rhudaina Z. Mohammad

Institute of Mathematics, University of the Philippines Diliman, Philippines

rmohammad@math.upd.edu.ph

Electrical impedance tomography (EIT) is a noninvasive imaging technique that reconstructs the internal conductivity distribution of an object by measuring electric potentials on its surface. Mathematically, EIT is twofold: the forward problem solves a generalized Laplace equation with conductivity coefficients to determine the electric potential, while the inverse problem requires estimating conductivity from noisy and incomplete boundary measurements–an ill-posed task highly sensitive to noise. In this paper [1], we proposed a hybrid deep learning-evolutionary framework for EIT image reconstruction. The fully-connected feedforward neural networks (FNNs) and convolutional neural networks (CNNs) were trained to approximate the forward map from conductivity to electric potential, eliminating the need for repeated finite element simulations during inversion. For the inverse problem, we formulate the recovery of conductivity distributions as a global optimization task using differential evolution and its variants. Among them, success-history based adaptive differential evolution (SHADE) achieved the most accurate and robust results. While the proposed CNN-SHADE algorithm demonstrated competitive reconstruction performance, the FNN-SHADE approach provided a favorable trade-off between accuracy and computational efficiency. Furthermore, the FNN-SHADE framework outperformed the traditional finite element-based method in computational speed, while maintaining accuracy. By embedding a neural forward operator into the differential evolution loop, the framework offered a scalable, data-driven alternative to traditional EIT reconstruction methods.

This is a joint work with Margaret Esther C. Cruz and Renier G. Mendoza.

[1] M.E.C. Cruz, R.G. Mendoza, R. Mohammad, *Image reconstruction in electrical impedance tomography using deep neural networks with differential evolution*, AIMS Electronic Research Archive, **33(12)** 7637-7675 (2025) https://doi.org/10.3934/era.2025338

Keywords:
inverse problem
electrical impedance tomography
deep learning
differential evolution

21 JUNE 2026 · 9:00 AM - 9:30 AM

On an Extension of the Multiphase BMO Algorithm to Anisotropic Energies

Karel Svadlenka

Department of Mathematical Sciences, Tokyo Metropolitan University, Japan

karel@tmu.ac.jp

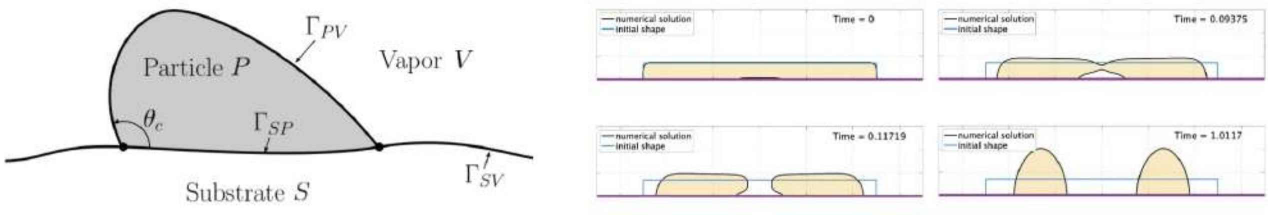
Thresholding schemes, often referred to as the Bence-Merriman-Osher (BMO) algorithm [1] provide a remarkably simple yet powerful way to approximate curvature-driven interface motion. Each time step consists only of a convolution with a kernel followed by a thresholding operation. Despite this apparent simplicity, such schemes admit a deep variational interpretation: they can be viewed as minimizing movements for nonlocal energies that Γ-converge to interfacial energies as the time step tends to zero [2]. This connection has made thresholding methods an attractive tool both for analysis and for numerical simulation of geometric evolution problems involving topology changes.

In this talk, we first revisit the BMO algorithm in its classical form for isotropic mean curvature flow and explain its interpretation as a time discretization of the L^2-gradient flow of the perimeter functional. We then survey several extensions of this idea to multiphase flows, weighted surface tensions, and problems with volume constraints [3, 4], emphasizing how convolution-based schemes can be systematically adapted to increasingly complex interfacial energies. As an illustration of its versatility, we discuss applications to biological modeling, including our recent work on a numerical algorithm for modeling cellular rearrangements in tissue morphogenesis, where thresholding methods allow one to simulate large interfacial networks undergoing frequent topological transitions [5].

The main focus of the talk is a new analytical result concerning anisotropic mean curvature flow of a particle constrained by a rigid, inhomogeneous substrate [6]. The system consists of three interfaces: particle-vapor, particle-substrate, and vapor-substrate, each endowed with its own surface tension, possibly depending on position and, for the free interface, also on orientation. The evolution is given by the L^2-gradient flow of the total anisotropic interfacial energy

$$E(P) = \int_{\Gamma_{PV}} \psi_{PV}(x,\nu)\, d\mathcal{H}^{d-1} + \int_{\Gamma_{SP}} \gamma_{SP}(x)\, d\mathcal{H}^{d-1} + \int_{\Gamma_{SV}} \gamma_{SV}(x)\, d\mathcal{H}^{d-1},$$

leading to a weighted anisotropic mean curvature motion coupled with a generalized Herring contact angle condition at the substrate. The derivation is naturally formulated in the framework of anisotropic (Finsler) geometry following Bellettini-Paolini [7].



Setting of the problem (left) and an example of numerical simulation (right).

Such problems arise naturally in cell motility, coating processes, and solid-state dewetting, where topology changes and heterogeneous surface energies play a crucial role. While related isotropic problems with obstacles have been studied [8, 9], and anisotropic flows without obstacles are well understood in the thresholding framework [10], the combination of anisotropy, spatial inhomogeneity, and an obstacle presents significant analytical challenges. In particular, standard convergence proofs for thresholding schemes rely on monotonicity properties of the approximate energies that fail when different interfaces carry different anisotropies.

We show how this difficulty can be overcome in the present setting. We construct a family of nonlocal approximate energies of the form

$$E_h(u) = \frac{1}{\sqrt{h}} \int \left(\widetilde{\gamma}_{PV} u K_h * (1_\Omega - u) + \widetilde{\gamma}_{SP} u K_h * 1_S + \widetilde{\gamma}_{SV} \left(1_\Omega - u\right) K_h * 1_S \right) \, dx,$$

where a single anisotropic kernel K_h encodes the orientation dependence and suitably modified surface tensions $\widetilde{\gamma}_{ij}$ incorporate the spatial inhomogeneity.

Our main result proves that these energies Γ-converge in L^1 to the desired anisotropic interfacial energy under a strengthened triangle inequality for the surface tensions. This provides the first rigorous step toward an existence theory for anisotropic mean curvature flow with obstacle based on the thresholding approach and suggests a pathway to treat more general multiphase problems with differing anisotropies. We conclude the talk by briefly outlining the proof of convergence of the corresponding thresholding scheme, leading to existence of weak BV solutions to the anisotropic obstacle problem.

[1] J.W. Bence, B. Merriman, and S. Osher, *Diffusion Generated Motion by Mean Curvature*, UCLA CAM Report, 92-18 (1992)

[2] S. Esedoğlu, and F. Otto, *Threshold dynamics for networks with arbitrary surface tensions*, Communications on Pure and Applied Mathematics, **68(5)** 808-864 (2015)

[3] T. Laux, and M. Lelmi, *Convergence of the thresholding scheme for mean curvature flow with volume constraint*, Interfaces and Free Boundaries, **20** 1-48 (2018)

[4] T. Laux, and F. Otto, *Convergence of the thresholding scheme for multi-phase mean-curvature flows*, Calculus of Variations and Partial Differential Equations, **55** 129 (2016)

[5] R.Z. Mohammad, H. Murakawa, K. Svadlenka, et al., *A numerical algorithm for modeling cellular rearrangements in tissue morphogenesis*, Communications Biology, **5(1)** 239 (2022) https://doi.org/10.1038/s42003-022-03174-6

[6] A. Chiesa, Andrea and K. Svadlenka, *Convergence of thresholding energies for anisotropic mean curvature flow on inhomogeneous obstacle* (2026) https://arxiv.org/abs/2503.20524

[7] G. Bellettini and M. Paolini, *Anisotropic motion by mean curvature in the context of Finsler geometry*, Hokkaido Mathematical Journal, **25** 537–566 (1996)

[8] M. Mercier and M. Novaga, *Mean curvature flow with contact angle condition*, Interfaces and Free Boundaries, **17** 421–442 (2015)

[9] X. Xu, W. Wang, and C. Wang, *Threshold dynamics for interface motion with contact angle*, SIAM Journal on Scientific Computing, **43** B1–B28 (2021)

[10] M. Elsey and S. Esedoğlu, *Threshold dynamics for anisotropic surface energies*, Mathematics of Computation, **86** 1721–1756 (2017)

Keywords:
thresholding scheme
anisotropic mean curvature flow
obstacle problem
Γ-convergence
interfacial energies with spatial inhomogeneity
topology changes in interface evolution

21 JUNE 2026 · 9:30 AM - 10:00 AM

Crack propagation problem in environmental conditions and a method for crack shape control

Takeshi Takashi

Musashino University, Japan

taketaka@musashino-u.ac.jp

The integrity of a building is affected by environmental conditions such as temperature, humidity, and ultraviolet rays, which affect its lifespan. In this presentation, I will introduce an example of crack propagation due to environmental conditions (temperature and humidity), particularly cracks in earthen walls of buildings. I will also propose a method for controlling the shape of crack propagation and tracing appropriate cracks.

Keywords:
crack propagation
shape control

21 JUNE 2026 · 10:15 AM - 10:45 AM

Shape optimization under uncertainty

Helmut Harbrecht

Department of Mathematics & Computer Science, University of Basel, Switzerland

helmut.harbrecht@unibas.ch

This presentation aims to provide an overview of shape optimization in case of random input parameters. Besides the minimization of the expected objective, we also consider the minimization of failure probabilities. We show that in some situations the objective and its gradient are deterministic despite the random input. We can thus derive cheap, deterministic algorithms to minimize the objective. Several applications and numerical computations are given.

Keywords:
shape optimization
uncertainty quantification
high-dimensional approximation

21 JUNE 2026 · 10:45 AM - 11:45 AM

Visualizing Shape Functionals via Sinkhorn Multidimensional Scaling

Toshiaki Yachimura

toshiaki.yachimura.a4@tohoku.ac.jp

Mathematical Science Center for Co-creative Society, Tohoku University

Many problems in shape optimization are formulated on nonlinear and effectively infinite-dimensional spaces, which makes the global structure of shape functionals difficult to analyze and even harder to visualize. In this talk, I introduce Sinkhorn multidimensional scaling (Sinkhorn MDS), a method for visualizing shape functionals by combining multidimensional scaling with the Sinkhorn divergence from entropic optimal transport.

In this framework, each shape is identified with a probability measure on its boundary, and pairwise Sinkhorn divergences are used to construct a low-dimensional Euclidean embedding. Compared with approaches based directly on the Wasserstein distance, the proposed method is computationally more tractable and numerically more robust. I will also present a quantitative estimate for the discrepancy between the embedding obtained from Sinkhorn MDS and that arising from the unregularized transport cost.

The method is illustrated through several examples from shape optimization, including the classical Dido problem and shape functionals with multiple minima, such as double-well and triple-well type functionals. These examples show that Sinkhorn MDS provides an effective way to visualize the global structure of shape functionals and gives a low-dimensional picture of complicated shape spaces.

This talk is based on the paper [1].

[1] T. Yachimura, J. Okamoto, and L. Cavallina, *Visualizing shape functionals via sinkhorn multidimensional scaling.*, SIAM Journal on Imaging Sciences, **18(3)** 1632–1652 (2025)

Keywords:
shape functional
optimal transport
Sinkhorn divergence
multidimensional scaling

21 JUNE 2026 · 11:15 AM - 11:45 AM

Can you hear the shape of a triangle?

Lorenzo Cavallina

Mathematical Institute, Tohoku University

cavallina.lorenzo.e6@tohoku.ac.jp

In this talk, we address the problem of identifying the shape of a triangular domain from three of its Dirichlet eigenvalues $\{\lambda_i, \lambda_j, \lambda_k\}$. It is known that the knowledge of the first three Dirichlet eigenvalues $\{\lambda_1, \lambda_2, \lambda_3\}$ is sufficient to determine a triangular domain up to rigid motions. On the other hand, not all triplets uniquely determine the shape of a triangular domain (a known example of such an "unhearable triplet" is given by $\{\lambda_1, \lambda_2, \lambda_2\}$). In this talk, we describe two that lead to unhearability and, as a byproduct, we provide an infinite family of unhearable triplets.

Keywords:
triangular domains
Dirichlet eigenvalues

21 JUNE 2026 · 2:00 PM - 2:30 PM

Topological Detection of Singularities in Nonlinear Time Series via Persistent Homology

Rachelle R. Sambayan

Institute of Mathematics, University of the Philippines Diliman

*rrivero@math.upd.edu.ph

The detection of abrupt transitions and structural breakpoints in nonlinear systems remains a fundamental challenge in scientific computing and applied analysis. In complex systems, these transitions often represent a loss of regularity or a shift in the underlying manifold, manifesting as topological singularities in the system's evolution. This work proposes a robust computational framework for the identification of such phenomena using Topological Data Analysis (TDA). By employing delay embeddings to reconstruct the phase space of an implicit nonlinear dynamical system, we utilize persistent homology to track deviations in the persistence landscape of topological invariants, specifically H_0 (clusters) and H_1 (loops) persistence. These changes serve as indicators of structural breakpoints, signaling regime shifts that traditional statistical methods often fail to capture. We demonstrate the efficacy of this nonparametric approach by analyzing Philippine stock price data during the COVID-19 pandemic, where the method successfully identifies singular events corresponding to major market disruptions. Our findings suggest that TDA provides a powerful lens for the modeling and analysis of nonlinear phenomena, offering a stable, noise-robust algorithm.

Keywords:
nonlinear dynamics
topological data analysis
persistent homology
singularities
scientific computing

21 JUNE 2026 · 2:30 PM - 3:00 PM

How do muscles move blood?

Andrei Domogo

Department of Mathematics and Computer Science, University of the Philippines Baguio

aadomogo1@up.edu.ph

The venous system plays a crucial role in circulation by serving as a reservoir that stores and redirects blood. Compared to arteries, venous flow is more complex due to low pressure, variable flow rates, gravitational effects, vessel collapsibility, the presence of valves, and a large storage capacity. In an upright position, venous return from the lower extremities must work against gravity, but forward flow is supported by venous valves and the action of the muscle pump.

In this talk, we present a closed-loop ODE model of blood circulation that includes the heart, as well as the arterial and venous systems of the upper and lower body. The model incorporates muscle pump activity, venous valves, and gravity, and reproduces physiologically realistic flows, volumes, and pressures. Simulations quantify how leg muscle contractions increase venous return, while sensitivity analysis identifies contraction frequency, intramuscular force, and contraction time as important parameters influencing venous return and cardiac output.

The model also provides a framework for studying circulation during activities such as walking, jogging, and squatting, and offers insights into conditions like vertigo associated with insufficient blood supply to the brain due to pooling of blood in the lower extremities.

Keywords:
cardiovascular modeling
venous system dynamics
muscle pump
sensitivity analysis

Collisions of signed Coulomb particles

Patrick van Meurs

Faculty of Mathematics and Physics, Kanazawa University

pjpvmeurs@staff.kanazawa-u.ac.jp

By Coulomb particles I mean electrically charged particles ($+1$ or -1) in 2D. They move by a first-order ‘velocity = electric force’ law. Since the electric force scales by one over the distance between the particle, it becomes singular at collisions. Hence, at collisions the standard well-posedness theory breaks down. This makes it interesting to study existence and uniqueness of solutions that contain collisions, and to figure out what kind of (possibly multi-particle) collisions can occur. I will do this both for the absence and presence of noise.

My presentation will cover parts of several papers. [2] treats the 1D deterministic case, [1] treats part of the 2D stochastic case, [3] completes the 2D stochastic case, and ongoing work addresses the 2D deterministic case.

[1] P. van Meurs, M.A. Peletier, and T. Slangen, *Global existence and mean–field limit for a stochastic interacting particle system of signed Coulomb charges*, Potential Analysis (Open Access, **63(4)** 1699–1733 (2025)

[2] P. van Meurs, M.A., Peletier, and N. Požár, *Discrete-to-continuum convergence of charged particles in 1D with annihilation*, Archive for Rational Mechanics and Analysis, **246(1)** 241–297 (2022)

[3] P. van Meurs and Y. Tardy, *Well-posedness for the SDE of a Coulomb gas with mixed signs*, Preprint (Hopefully on ArXiv by now), (2026)

Keywords:
Coulomb interactions
ODE
SDE

22 JUNE 2026 · 9:30 AM - 10:00 AM

Homogenization of an anisotropic perturbation problem in a domain with an imperfect interface

Bituin Cabarrubias

Institute of Mathematics, University of the Philippines Diliman

bituin@math.upd.edu.ph

This work aims to provide a study on the limiting behavior of some class of anisotropic elliptic problem posed in a bounded domain with two components in $\mathbb{R}^N$ for $N \geq 2$ as $\varepsilon \to 0$, representing the thermal diffusion in a composite material made up of two constituents. We suppose that there is a discontinuity on the common interface depicted by a jump on the flux as well as on the temperature between the two materials. We first formulate a suitable adaptation of the Periodic Unfolding Method for some bounded sequences in this geometric setting. Then comes its application to find the asymptotic behavior of the problem up to the associated convergence of the energy.

Keywords:
anisotropic problem
asymptotic behavior
homogenization
periodic unfolding method
two-component domain

22 JUNE 2026 · 10:45 AM - 11:15 AM

Stokes equation with Low Regular and Measure Data

Gilbert Peralta

Department of Mathematics and Computer Science, University of the Philippines Baguio

grperalta@up.edu.ph

The Stokes equations in bounded smooth domains will be examined with respect to the class of anisotropic fractional Bessel potential and Besov spaces. Notions of solutions extending the usual maximal parabolic regularity for the Stokes operator will be considered. In particular, low regular or singular data, such as those that involve Radon measures either in the interior, boundary, or at the initial time, will be addressed. Having in mind applications to optimal control problems dealing with point evaluations of the velocity, stress, or pressure, we shall also deal with the corresponding analysis for the linearized Navier–Stokes equation and its associated dual problem. Trace, mixed-derivative, and time-space embedding theorems concerning anisotropic function spaces obtained from abstract vector-valued harmonic analysis play important roles in the study.

Keywords:

PDEs with measures

interpolation-extrapolation spaces

generalized solutions

maximal parabolic regularity

22 JUNE 2026 · 11:15 AM - 11:45 AM

Dependency on triangular shapes in bifurcation diagrams of stationary cavity flows

Shinya Uchiumi

Saga University

uchiumi@cc.saga-u.ac.jp

We consider lid-driven cavity flow problems, which are boundary value problems for the stationary Navier-Stokes equations.

These are often used as benchmark problems when the shape of the cavity are square [1]. The shapes of the vortices are often compared for various Reynolds numbers.

Although reports on the triangular cavity problems are relatively few compared to the square ones, we can observe various streamline patterns [4, 2]. These two papers deal with isosceles triangles, but the apex angles are different. We observe difference between the bifurcation diagrams of the stationary solutions in [4, 2].

In order to reveal different structure of two diagrams, we compute the triangular cavity problems by the finite element method (FEM) for various apex angles θ. We make bifurcation diagrams with focusing on θ by FreeFEM [3].

[1] U. Ghia, K.N. Ghia, and C.T. Shin, *High-Re solutions for incompressible flow using the Navier-Stokes equations and a multigrid method*, Journal of Computational Physics, **48(3)** 387-411 (1982) `https://doi.org/10.1016/0021-9991(82)90058-4`

[2] M. Tabata and S. Uchiumi, *Numerical computation of triangular cavity flows by a Lagrange-Galerkin scheme with a locally linearized velocity*, Journal of Advanced Simulation in Science and Engineering, **4(1)** 1-13 (2018)

[3] F. Hecht, *New development in FreeFem++*, Journal of Numerical Mathematics, **20(3-4)** 251-265 (2012) `https://freefem.org/`

[4] B. An, J.M. Bergada, and F. Mellibovsky, *The lid-driven right-angled isosceles triangular cavity flow*, Journal of Fluid Mechanics, 476-519 (2019)

Keywords:
stationary Navier–Stokes problem
lid-driven cavity problem
finite element method
bifurcation

22 JUNE 2026 · 2:00 PM - 2:30 PM

Error estimates of Lagrange–Galerkin moving mesh schemes for the one-dimensional convection-diffusion equation

Hirofumi Notsu

Kanazawa University

notsu@se.kanazawa-u.ac.jp

Adaptive moving mesh methods are highly effective for achieving high-accuracy numerical computations. However, their error analysis is nontrivial, since the movement of the mesh induces time dependence in the interpolation operator, which requires careful treatment when interchanging differentiation in time and integration in space. In this talk, we present a framework for Lagrangian finite element schemes with moving meshes for convection-diffusion problems. We introduce a concrete moving mesh scheme for the one-dimensional case and discuss its fundamental properties together with rigorous optimal error estimates. Numerical experiments demonstrate that the proposed approach can accurately capture sharp spike-type solutions. This talk is given based on the paper [1].

[1] K.S. Putri, T. Mizuochi, N. Kolbe, and H. Notsu, H., *Error estimates for first- and second-order Lagrange–Galerkin moving mesh schemes for the one-dimensional convection-diffusion equation*, Journal of Scientific Computing, **101** 37 (2024) https://doi.org/10.1007/s10915-024-02673-4

Keywords:
moving mesh
error estimates

22 JUNE 2026 · 2:30 PM - 3:00 PM

Fast Tsunami Wave Height Prediction using Deep Neural Networks for the Shallow Water Equations

Renier G. Mendoza

Institute of Mathematics, University of the Philippines Diliman

rmendoza@math.upd.edu.ph

This work presents a data-driven neural network framework for rapid tsunami wave prediction governed by the linear shallow water equations (SWEs). High-fidelity solution data are generated using a finite volume method (FVM) across a range of tsunami source parameters and initial conditions. These simulations are used to train a deep fully connected neural network that maps source parameters to maximum wave heights and arrival times at predefined gauge locations.

The proposed model is compared with FVM simulations and shows significant reduction in computational time while maintaining comparable accuracy, indicating suitability for real-time tsunami early warning systems. A theoretical analysis based on the Deep Universal Approximation Theorem is included, establishing the existence of neural network architectures that approximate the nonlinear parameter-to-observable mappings induced by the SWEs.

The trained network is also used in an inverse setting to estimate tsunami source characteristics from observed wave data. The approach is further demonstrated on the 2018 Krakatau tsunami event using real bathymetry and gauge data, showing its potential for rapid hazard assessment, sensor-based forecasting, and source identification.

Keywords:
shallow water equations
tsunami modeling
neural networks
surrogate modeling
inverse problem

Student Talks

STUDENT TALK 01

Efficient Numerical Algorithm for Solving c-transform on Quadtree and Octree Meshes

Shuhei Sasajima[1,*] **and Požár Norbert**[1]

[1]Graduate School of Natural Science and Technology, Kanazawa University

[*]sashu2022@stu.kanazawa-u.ac.jp

[*]Presenter

Keywords:
machine learning
back-and-forth method
quadtree and octree
numerial algorithm
computational compexity

The back-and-forth method can be used as a solver for partial differential equations (PDEs) that can be expressed as a gradient flow of the Wasserstein distance [1]. These include many important moving boundary problems like the porous medium equation or the Hele-Shaw problem. The c-transform $\phi^c(x) := \inf_y c(x, y) - \phi(y)$ plays an important role in the back-and-forth method [2]. In this talk, we propose an algorithm for numerically solving the c-transform on quadtree and octree meshes. The use of quadtree and octree improves computational efficiency while maintaining high accuracy by subdividing only regions which require higher resolution.

Our algorithm uses monotonicity of quadratic cost $c(x, y) = \|x - y\|/2$ and recursive way that exploits the hierarchical data structure of quadtree and octree. Consequently, the computational complexity of the algorithm is $O(N \log N)$ where N is the number of nodes.

[1] M. Jacobs, W. Lee, and F. Léger, *The back-and-forth method for Wasserstein gradient flows*, ESAIM: Control, Optimisation and Calculus of Variations, **27(28)** (2021)

[2] M. Jacobs and F. Léger, *A fast approach to optimal transport: the back-and-forth method*, Numerische Mathematik, **146**, 513–544 (2020)

STUDENT TALK 02

Balancing economic cost and disease impact: Optimization models for Wolbachia-based dengue control

Kyrho Corum[1,*], **Renier G. Mendoza**[1], **Victoria May P. Mendoza**[1], **and Arrianne Crystal Velasco**[1]

[1]Institute of Mathematics, University of the Philippines Diliman

[*]kcorum@math.upd.edu.ph

[*]Presenter

Keywords:
dengue
Wolbachia
optimization

Dengue, which affects millions of people each year, is one of the most common diseases transmitted by infected *Aedes aegypti* mosquitoes. In the Philippines, the annual economic cost of dengue infections is estimated at around PHP 17 billion. Previous studies have shown that controlling the population of mosquitoes capable of transmitting the dengue virus can effectively reduce dengue infection rates. This study explores the use of *Wolbachia* as a strategy for dengue control by targeting mosquitoes. Since the release of *Wolbachia*-infected mosquitoes involves substantial costs, careful planning is necessary to balance disease control with the associated economic burden. To address this, we propose a mathematical model that captures the dynamics of releasing *Wolbachia*-carrying mosquitoes and the transmission of dengue in a population. We formulate single- and multi-objective optimization frameworks to minimize the economic costs associated with releasing *Wolbachia*-infected mosquitoes and the hospitalization costs resulting from dengue infections. This study aims to provide insights into the practical application of *Wolbachia*-based interventions for controlling dengue transmission. While the analysis is grounded in the Philippine context, the approach is general enough to be applicable to other dengue-endemic countries.

STUDENT TALK 03

Ensemble Reservoir Computing for Physical Systems

Yuma Nakamura[1,*], **Tomoyuki Kubota**[2,3], **Yusuke Imai**[2,3], **Sumito Tsunegi**[4], **Hirofumi Notsu**[5], and **Kohei Nakajima**[2,3]

[1]Division of Mathematical and Physical Sciences, Kanazawa University, Japan

[2]Graduate School of Information Science and Technology, The University of Tokyo, Japan

[3]Next Generation Artificial Intelligence Research Center (AI Center), The University of Tokyo, Japan

[4]National Institute of Advanced Industrial Science and Technology, Japan

[5]Faculty of Mathematics and Physics, Kanazawa University, Japan

*nakamurayuma@stu.kanazawa-u.ac.jp

*Presenter

Keywords:
reservoir computing
nonlinear dynamics
machine learning
ensemble average
spin-torque oscillator

Physical computing exploits unconventional physical substrates to overcome limitations such as the high energy consumption inherent in digital computation. However, intrinsic noise and temporal fluctuations (e.g., oscillations) generally deteriorate computational performance. Here, we propose ensemble reservoir computing (ERC), a novel framework that employs ensemble averaging of spatially multiplexed systems to achieve robust information processing despite noise and temporal fluctuations. First, we prove that ensemble averaging in ERC eliminates temporal fluctuations and noise from dynamical states under certain conditions, thereby restoring computational performance to its noise-free level. Next, we show that ERC not only removes the noise and fluctuations but also actively exploits the computational capabilities that conventional reservoir computing (RC) leaves unutilized. This computational enhancement is demonstrated across diverse dynamical systems (e.g., periodic, chaotic, and strange-nonchaotic systems), in which ERC outperforms conventional RC. Finally, using energy-efficient spin-torque oscillators (STOs), we demonstrate that ERC maintains high performance even under realistic conditions, in which noise and temporal fluctuations coexist: STOs with ERC achieved 99% accuracy on an error detection test, where conventional STO reservoir with linear regression only shows a chance level performance, highlighting ERC's robustness and performance gains for physical systems.

STUDENT TALK 04

Post-Training Quantized Convolutional Neural Networks for Efficient Baybayin Handwriting Recognition on Edge Devices

James Arnold E. Nogra[1,*] **and Rachelle R. Sambayan**[1,2]

[1]Data Science Program, College of Science, University of the Philippines Diliman, Quezon City 1101, Philippines
[2]Institute of Mathematics, College of Science, University of the Philippines Diliman, Quezon city 1101, Philippines
[*]jamesnogra@gmail.com

Since the approval of Baybayin as the national handwriting of the Philippines in 2016, many handwriting recognition systems have been developed. However, these models are limited in running on desktop computers or servers due to their computational requirements. This study investigates the feasibility of deploying a convolutional neural network (CNN) or inception network for Baybayin handwriting recognition into web or mobile devices. Using post-training quantization (PTQ), several models were trained in standard 32-bit floating point (fp32) format and then quantized down to 8-bit integer (int8). One of the objectives is that the model should correctly identify 58 out of the 59 Baybayin characters correctly (98.3% accurate). The quantization experiments show that quantization using PTQ offers almost no degradation in accuracy while reducing the file size up to 4 times. The smallest model meeting the 98.3% accuracy threshold has a file size of 122 kilobytes for the int8 model down from 432 kilobytes fp32. With 109,243 parameters, this model has a validation accuracy rate of 98.62% (fp32) and 98.49% (int8). The largest inception model with 464,955 parameters has a validation accuracy rate of 99.07% for both int8 and fp32 while having a file size of 489 kilobytes for the quantized int8. The results show that PTQ is an effective strategy to reduce file size of neural network models making it possible to run these models in edge devices without the need of powerful machines.

[*]Presenter

Keywords:
quantization
post-training quantization
CNN
inception networks
Baybayin
handwriting recognition

STUDENT TALK 05

Finite Element Simulation of Aqueous Humour Flow with Thermal Convection in the Human Eye

Takehiro Matsumoto[1,*], **Hiroki Mieno**[2], **Morio Ueno**[2], **and Hiroshi Suito** [3]

[1]Graduate School of Natural Science and Technology, Kanazawa University
[2]Department of Ophthalmology, Kyoto Prefectural University of Medicine
[3]Advanced Institute for Materials Research, Tohoku University
*tmatsumoto@stu.kanazawa-u.ac.jp

*Presenter

Keywords:
finite element method
thermal convection

Aqueous humour is a transparent fluid filling the space between the cornea and lens. It is said to be driven not only by production and drainage but also by thermal convection when opening the eye. It plays a crucial role in biological functions and is strongly related to glaucoma, the leading cause of blindness in Japan. However, its flow remains unclear due to its transparency. This study presents a 3D FEM simulation of the flow and estimation using clinical video.

We simulated the 3D aqueous humour flow on a patient-specific tetrahedral mesh derived from clinical images. Over a time interval, the velocity, pressure, and temperature were assumed to be governed by the incompressible Navier-Stokes and heat advection-diffusion equations under the Boussinesq approximation. We accounted for posture-dependent gravity directions and corneal cooling during eye opening. To prevent unintended backflow at the outlet, we applied a Signorini-type backflow prevention term [1]. The governing equations were discretized by the finite element method using P1/P1 elements, integrating pressure stabilization and the method of characteristics [2].

For the validation, we estimated the flow field from clinical videos using an optical flow method. After surgery, red blood cells mixed into the aqueous humour and they acted as tracers. Figure 1 shows simulated and estimated flow fields in the vertical cross-section.

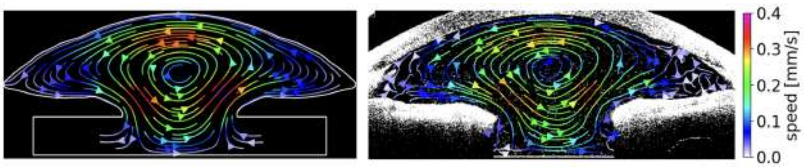


Fig 1. Comparison of flow fields in the vertical cross-section. (Left: Simulation, Right: Estimation)

The comparison demonstrates good agreement between the estimation and simulation.

[1] G. Zhou, G. and N. Saito, *The Navier–Stokes equations under a unilateral boundary condition of Signorini's type*, Journal of Mathematical Fluid Mechanics, **18(3)** 481–510 (2016) https://doi.org/10.1007/s00021-016-0248-7

[2] H. Notsu, H. and M. Tabata, *Error estimates of a stabilized Lagrange–Galerkin scheme for the Navier–Stokes equations*, ESAIM: Mathematical Modelling and Numerical Analysis **50**, 361–380 (2016) https://doi.org/10.1051/m2an/2015049

Poster Session

POSTER 01

Modeling Influenza Transmission in the Philippines: A Vaccination-Enhanced SEIRS Framework with Reporting Dynamics

Racquel Bandong[1,2*], **Jenevieve S. Catulong**[1], **Dehcontee Gbotoe**[1], **and Allen L. Nazareno**[1]

[1]Institute of Mathematical Sciences, College of Science, University of the Philippines Los Baños

[2]Mathematics Program, College of Science, University of the Philippines Cebu

*rtbandong@up.edu.ph

*Presenter

Influenza remains a significant public health concern in the Philippines [1, 2], yet its true burden is obscured by underreporting, waning immunity, and the unmeasured impact of vaccination programs. We developed and analyzed a vaccination-structured Susceptible-Exposed-Infectious-Recovered-Susceptible (SEIRS) compartmental model that incorporated loss of immunity and reporting factor to characterize influenza transmission from 2017 to 2023 in the Philippines. The model was calibrated to national cumulative influenza-like illness incidence data for each year. Numerical simulations reasonably reproduced observed incidence trends, including the reduced incidence during the COVID-19 pandemic and the pronounced rebound in 2023. Sensitivity analyses using partial rank correlation coefficients identified the transmission rate as the dominant driver of incidence, while the recovery rate exerts the strongest mitigating influence. Vaccination showed a limited impact under current coverage levels. These findings underscore the importance of transmission control, improved surveillance, and expanded vaccination to reduce influenza burden in the Philippines.

Keywords:
numerical analysis
delay differential equations
vaccination public health
underreporting
surveillance

[1] K. Cheng, et al., *Influenza-associated excess mortality in the Philippines, 2006–2015*, PLoS ONE,**15(6)** (2020)

[2] V.L. Tallo, et al., *Estimating influenza outpatients' and inpatients' incidences from 2009 to 2011 in a tropical urban setting in the Philippines*, Influenza and Other Respiratory Viruses, (2014)

POSTER 02

Solutions of first-order linear homogenous sytems of neutral delay differential equations with simultaneously triangularizable coefficients using the r-Lambert W function

Emmanuel David[1,*], **Renier G. Mendoza**[1], **and Victoria May P. Mendoza**[1]

[1]Institute of Mathematics, University of the Philippines Diliman

*ebdavid2@up.edu.ph

*Presenter

Keywords:
numerical analysis
delay differential equations
transcendental matrix equations

Neutral delay differential equations (NDDEs) are a class of DDEs where the derivative of the state variable depends on its past values. While recent work in [1] has established that the r-Lambert W function, analyzed in [2], provides analytical solutions for first-order scalar NDDEs, this paper extends that framework to systems of equations. We demonstrate that a first-order linear homogeneous NDDE system of the form

$$P'(t) + AP(t) + BP'(t-h) + CP(t-h) = \vec{0},$$

where $A, B, C \in \mathbb{R}^{n\times n}$ are simultaneously triangularizable [3], with B, C commuting with A but not necessarily with each other, has a formal series solution in terms of a generalization of the r-Lambert W function to upper triangular matrices that finds $W \in \mathbb{C}^{n\times n}$ that solves

$$We^W + RW = X$$

where $R, X \in \mathbb{C}^{n\times n}$ are simultaneously triangularizable. Coupled with a history function $P(t) = \Phi(t)$, over $[t_0 - h, t_0]$, where $t_0 \in \mathbb{R}$ and $\Phi \in \mathcal{C}^1([t_0 - h, t_0]; \mathbb{R}^n)$, the NDDE system admits a particular solution, which we then approximate by truncating our series and solve coefficients using least-square approximation. We test our method on examples with known solutions and compare the results with those obtained via method of steps using a built-in ODE solver.

[1] C.U. Jamilla, R.G. Mendoza and I. Mezö, *Solutions of neutral delay differential equations using a generalized Lambert W function*, Applied Mathematics and Computation, **382** (2020)

[2] I. Mezö, *On the structure of the solution set of a generalized Euler-Lambert equation*, Journal of Mathematical Analysis and Applications, **455(1)** 538-553 (2017)

[3] R.A. Horn and C.R. Johnson, *Matrix Analysis*, Applied Mathematics and Computation, Cambridge University Press (2013)

POSTER 03

Optimization of MBO-based models for Kernel Recovery and Threshold Dynamics

Jose Aries E. De Los Santos[1,2,*], **and Rhudaina Z. Mohammad**[1,2]

[1]Institute of Mathematics, College of Science, University of the Philippines Diliman

[2]Data Science Program, College of Science, University of the Philippines Diliman

*jedelossantos1@up.edu.ph

*Presenter

Keywords:
MBO algorithm
inverse problem
adaptive learning rates
kernel recovery
mean curvature flow
computer vision

The Merriman-Bence-Osher (MBO) algorithm provides a robust computational framework for tracking the time evolution of sets moving by mean curvature. This evolution is governed by a *time-discrete thresholding* scheme, iteratively alternating between a linear operation (*heat diffusion*) and a nonlinear operation (*thresholding*). While traditionally utilized for forward simulations, this study addresses the *inverse problem* introduced by Negrini et al. [1]: given N consecutive video frames of an evolving front, we aim to recover the underlying *convolution kernel* and *threshold parameter* that best approximate the observed dynamics. We present a comprehensive performance evaluation of the two core training methodologies proposed by [1]: the *MBO Network* and the *Meta-learning MBO Network*. A three-way comparative study was conducted to evaluate optimization strategies for these models, pitting the standard *Adam* [2] optimizer against *Perturbed Accelerated Gradient Descent (PAGD)* [3] and our proposed algorithm, *Perturbed Accelerated Gradient Descent with Adaptive learning rate (PAGDA)*, and their occupational time variants. To bridge the gap between theory and application, the models were initially trained on a *synthetic dataset* designed to simulate ideal curvature flow, before being applied to *real-world dataset images*.

[1] E. Negrini, et al., *Neural networks for threshold dynamics reconstruction*, Inverse Problems and Imaging, **20(0)** (2026)

[2] D.P. Kingma and J. Ba, *Adam: A Method for Stochastic Optimization*, ICLR (2015) http://arxiv.org/abs/1412.6980

[3] G. Guo , et al., *Escaping saddle points efficiently with occupation-time-adapted perturbations*, Journal of Computational Mathematics and Data Science, **10** (2024)

POSTER 04

Adaptive Keep-Ratio Selection in Partial-Sample Regression via Nested Cross-Validation

Aarhus M. Dela Cruz[1,*]

[1]College of Science, Bulacan State University

*aarhus.delacruz@bulsu.edu.ph

*Presenter

Selecting the right neighborhood size is crucial for nonparametric regression, especially when data conditions shift. We study two automated rules for Partial-Sample Regression (PSR), which predicts by averaging only the most relevant observations. The first rule, Fit-Max, minimizes training error, while the second, Risk-Min, minimizes cross-validated error. To avoid biased estimates, both are embedded in a nested cross-validation design that separates tuning from final testing. On synthetic data with regime changes, we find a clear U-shaped error curve with an optimum when keeping only 5-7% of the data, cutting mean squared error by more than 45% compared with a fixed 50% rule. Fit-Max and Risk-Min perform almost identically out of sample, with a small bootstrap edge for Fit-Max. On benchmark datasets, adaptive PSR consistently reduced error relative to the fixed rule, with gains ranging from about 17% in moderate settings to over 80% in more complex cases. Compared with classical methods, PSR achieved accuracy competitive with k-nearest neighbors and Nadaraya-Watson kernel regression. These findings establish adaptive keep-ratio selection as a simple, reproducible, and effective strategy for relevance-based regression.

Keywords:
bias-variance trade-Off
hyperparameter tuning
nested cross-validation
partial-sample regression
relevance-based prediction

POSTER 05

Pattern Formation and Spatial Heterogeneity in an Eco-Epidemiological Reaction-Diffusion Model

Mark Lois Fortin[1,*], **and Gervy Marie Angeles**[1]

[1]Institute of Mathematics, University of the Philippines Diliman

*mpfortin@up.edu.ph

*Presenter

Keywords:
Turing instability
reaction-diffusion equations
predator-prey model

This study presents an analysis of pattern formation in a class of nonlinear reaction-diffusion predator-prey systems that incorporate prey infection and intraspecific predator competition. The dynamics of the system are analyzed through linear stability analysis to determine conditions for diffusion-driven instability, commonly known as Turing instability, around stable steady states. Numerical simulations are then conducted to investigate the emergence of spatial heterogeneity across variations in diffusion rates and biological parameters on a two-dimensional domain. We adapt the finite difference method presented in [1] to accommodate the three-species model considered in this study. We highlight the impact of the inclusion of disease dynamics and predator competition, which significantly alter both the onset and structure of spatial patterns. These findings demonstrate how ecological interactions and epidemiological factors shape spatial organization in predator-prey systems.

[1] M.R. Garvie, *Finite-difference schemes for reaction–diffusion equations modeling predator–prey interactions in MATLAB*, Bulletin of mathematical biology, **69** (2007)

POSTER 06

Data-Driven Discovery of the Background Dynamics of the Universe using Physics-Informed Deep Learning

Christian James Galotera[1,*], **Renier G. Mendoza**[1,2], **and Reinabelle Reyes**[3,4]

[1]Data Science Program, University of the Philippines Diliman, Quezon City 1101, Philippines

[2]Institute of Mathematics, University of the Philippines Diliman, Quezon City 1101, Philippines

[3]Philippine Space Agency, Eastwood Avenue, Bagumbayan, Quezon City, Philippines

[4]Research Center for Theoretical Physics, Central Visayan Institute Foundation, Jagna, Bohol, Philippines

[*]`cygalotera@up.edu.ph`

[*]Presenter

Keywords:
physics-informed neural networks
physics-informed Kolmogorov-Arnold networks
cosmology machine learning
parameter inference
data discovery

This study develops Physics-Informed Neural Networks (PINNs) and Physics-Informed Kolmogorov–Arnold Networks (PIKANs) as data-driven discovery frameworks for reconstructing cosmological expansion and recovering cosmological parameters across three cosmological models: ΛCDM, the Chevallier–Polarski–Linder (CPL) parametrization, and quintessence cosmology. Cosmological datasets motivated by theoretical dark-energy scenarios were used to evaluate expansion-history reconstruction and data-driven inference of key cosmological parameters [1]. For the quintessence model, scalar-field equation-of-state data $w_\phi(z)$ were additionally incorporated, improving parameter recovery through stronger constraints on scalar-field dynamics[2].

The proposed frameworks used Friedmann and Klein–Gordon physics constraints to guide cosmological reconstruction during training[2]. To reduce mild overfitting, additional observational samples, weak regularization, and smoothness penalties were introduced [3]. Equation-based Partial Rank Correlation Coefficient (PRCC) analysis combined with Latin Hypercube Sampling (LHS) was performed to evaluate the physical sensitivity of cosmological parameters directly from the governing equations, independent of neural-network optimization.

Results show that both PINNs and PIKANs successfully reconstruct the cosmological expansion history and recover key cosmological parameters. PINNs demonstrated more stable performance for the coupled quintessence system, while PIKANs remained competitive for the simpler ΛCDM and CPL models. These findings highlight the potential of physics-informed deep learning for interpretable cosmological modeling and data-driven discovery in dark-energy cosmology.

[1] L. Röver, et al., *PINNferring the Hubble function with uncertainties*, SciPost Physics, **12** (2022)

[2] A. Chantada, et al., *Cosmology-informed neural networks to solve the background dynamics of the Universe*, SciPost Physics, **79** (2023)

[3] G. Karniadakis, et al., *Physics-informed machine learning*, Nature Reviews Physics, **3** (2021)

POSTER 07

An Integrated Routing and Inventory Optimization for Water Buffalo *Bubalus bubalis L.* Artificial Insemination Technicians

Rachelle Anne S. Guanga[1,*], Renier G. Mendoza[1,2], Jimmy C. Espina, Jr.[4,6], Kloudene A. Salazar[5], Arnel N. del Barrio[6], Kimberly I. B. Turaja[6], Christian V. Lualhati[6], Ralph Jovi B. Saldajeno[6], Edwin C. Atabay[4], and Edoardo Fadda[3]

[1]Data Science Program, College of Science, University of the Philippines Diliman
[2]Institute of Mathematics, College of Science, University of the Philippines Diliman
[3]Department of Mathematical Sciences "Giuseppe Luigi Lagrange", Politecnico di Torino
[4]Department of Agriculture-Philippine Carabao Center, Science City of Muñoz, Nueva Ecija, Philippines
[5]Materials Science and Engineering Program, College of Science, University of the Philippines Diliman, Quezon City, Philippines
[6]Institute of Animal Science, University of the Philippines Los Baños, Laguna, Philippines
[*]rsguanga@up.edu.ph

[*]Presenter

Efficient routing of service personnel is important in systems where timely service delivery and limited resources affect operational performance. In the Philippines, the Department of Agriculture-Philippine Carabao Center (DA-PCC) implements a nationwide artificial in- semination (AI) program to improve the genetic quality and productivity of water buffalos. However, the coordination of AI services and the deployment of AI technicians are still done manually. This often results in inefficient travel, delayed response times, and suboptimal resource utilization. Analysis of national AI data further indicates that both the distance between farmers and service centers and the location of these centers significantly influence AI outcomes, with longer distances associated with lower service volumes and reduced success rates. To address these issues, this study proposes a mathematical optimization model for the AI Technician Routing Problem. The model integrates farmer-technician assignment, route planning, and inventory management within a single framework. The problem is formulated as a mixed integer linear program that determines optimal routes for each AI technician while ensuring that each farmer is served and that inventory requirements are met. The model is applied to real-world data from two DA-PCC centers: the Don Mariano Marcos Memorial State University office, which covers Benguet, La Union, and Pangasinan, and the University of the Philippines Los Baños office in Laguna. The road network data for these provinces are extracted from OpenStreetMap using the OSMnx Python package. The proposed approach aims to support more efficient and reliable delivery of AI services.

Keywords:
vehicle routing
mixed integer programming
service logistics
inventory routing
agricultural operations

POSTER 08

Level Set Method for Multiphase Serrin-type Overdetermined Boundary Problem

Marian C. Lantacon[1,*], **and Rhudaina Z. Mohammad**[2]

[1]Mathematics Program, University of the Philippines Cebu

[2]Institute of Mathematics, University of the Philippines Diliman

*mtcantal@up.edu.ph

*Presenter

Keywords:
overdetermined boundary
boundary variation
level set method

In this poster, we consider a multiphase Serrin-type overdetermined boundary value problem, characterized by a generalized Poisson equation with piecewise constant coefficients, subject to both Dirichlet and Neumann boundary conditions on the entire boundary [1]. We investigate the outer problem of identifying a domain partitioned into a concentric outer shell and multiple cores for which a Serrin-type overdetermined boundary value problem admits a solution. To approximate domains with a prescribed volume, we develop a numerical approach that employs an implicit representation of admissible geometries within the Osher-Sethian level-set formulation [2].

[1] J. Serrin, *A symmetry problem in potential theory*, Archive for Rational Mechanics and Analysis, **43** (1971)

[2] S. Osher and J.A. Sethian, *Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton-Jacobi formulations*, Journal of Computational Physics, **79** (1988)

POSTER 09

Structure-aware message passing graph neural network models to predict protein-protein interaction

Dan Mark Orapa[1,*], **Renier G. Mendoza**[1], **and Victoria May P. Mendoza**[1]

[1]Institute of Mathematics, College of Science, University of the Philippines Diliman

[*]dorapa@up.edu.ph

[*]Presenter

Keywords:
protein-protein interaction
graph neural networks
protein language models
interaction proteomics
deep learning
bioinformatics

Computational, data-driven predictors of protein-protein interactions have become an active research area in interaction proteomics. Interestingly, high-performing baseline sequence-based models designed to predict interacting protein pairs were recently demonstrated to be trained on datasets of high similarity, resulting in data leakage during model training. In this study, we analyze protein-protein interaction networks (PPINs) and its biological and topological implications for computational models. We experiment with structure-aware machine learning models using various message-passing graph neural networks (MP-GNNs) paired with protein language models on varying PPINs-an unprocessed dataset from [1] and a clustered dataset from [2]. We found that MP-GNN models trained on clustered dataset paired with the protein language model ProtTrans perform best. Moreover, we found that model performance evidently changed when trained on an unprocessed dataset and evaluated on an unseen clustered dataset. In essence, findings highlight that the framework can effectively learn interaction patterns, but its predictive power is still constrained by the quality and composition of the training data. Extensively, we discuss what the limitations of MP-GNNs are as computational models to enhance PPINs and, in turn, how they should be used as effective predictive models.

[1] X.-Y. Pan, et al., *Large-Scale prediction of human protein- protein interactions from amino acid sequence based on latent topic features*, Journal of proteome research, **9(10)** (2010)

[2] J. Bernett, et al., *Cracking the black box of deep sequence-based protein–protein interaction prediction*, Briefings in Bioinformatics, **25(2)** (2024)

POSTER 10

Modeling Tuberculosis dynamics using exponential random graphs and temporal centrality-driven interventions

Shawnrick Andrei S. Pacura[1,*], **and Victoria May P. Mendoza**[1]

[1]Institute of Mathematics, College of Science, University of the Philippines Diliman

*shawnrick27@up.edu.ph

*Presenter

Keywords:
tuberculosis
social networks
ERGM
MCMC
temporal centrality

Tuberculosis remains a persistent public health concern, particularly in densely connected populations where social interactions facilitate disease transmission. This study presents a network-based modeling framework from [1] that integrates exponential random graph models and a Markov Chain Monte Carlo method to generate statistically representative networks that reflect both random and structured social interactions. The framework constructs dynamic contact networks that evolve over time and incorporates epidemiological parameters with the SEIL compartmental model from [2] to simulate the temporal progression of infection. To identify individuals who play an important role in sustaining disease spread, we apply temporal centrality measures such as degree, closeness, and betweenness [3, 4] on the evolving network's nodes. These metrics identify critical individuals whose targeted intervention could most effectively disrupt transmission paths. Results demonstrate that while centrality-driven interventions can effectively reduce high-risk latent cases in networks with strong structural drivers, their advantage over random strategies is not consistent in weaker or less structured networks. This highlights the importance of context-dependent intervention designs. This framework offers a quantitative basis for targeted, data-driven public health intervention especially in resource-constrained situations where broad population isolation is impractical.

[1] C. Pando, et al., *A social network analysis model approach to understand tuberculosis transmission in remote rural Madagascar*, BMC Public Health, **23** (2023)

[2] S. Kim, et al., *Mathematical model and intervention strategies for mitigating tuberculosis in the Philippines*, Journal of Theoretical Biology, **443** (2018)

[3] H. Kim and R. Anderson, *Temporal Node Centrality in Complex Networks*, Physical Review E, **85** (2011)

[4] I. Tsalouchidou, et al., *Temporal betweenness centrality in dynamic graphs*, International Journal of Data Science and Analytics (2019)

POSTER 11

An LLM-integrated Optical Character Recognition System for Contextual Disambiguation of Baybayin Scripts

Rodney B. Pino[1,*], **Renier G. Mendoza**[1,2], **and Rachelle R. Sambayan**[1,2]

[1]Data Science Program, University of the Philippines Diliman, Quezon City, Philippines

[2]Institute of Mathematics, University of the Philippines Diliman

*rbpino@up.edu.ph

*Presenter

Keywords:
Baybayin
optical character recognition
transliteration ambiguation
Filipino contextual analysis
large language models
natural language processing

Recent advances in natural language processing (NLP) and large language models (LLMs) have significantly enhanced optical character recognition (OCR) systems, enabling automatic text analysis, spelling correction, and syntactic refinement. However, these integrated OCR-NLP pipelines have largely focused on widely used scripts such as Latin, Arabic, Indian, and Han, while underrepresented writing systems like Baybayin, a precolonial Tagalog script, remain underexplored. This gap reflects both the scriptâĂŹs antiquity and the limited availability of digital resources. To support ongoing efforts in its cultural revival and digital preservation, this study integrates advanced NLP into Baybayin OCR. Building on a previous framework, which accepts images containing Baybayin or Latin texts, recognizes Baybayin characters via support vector machines, and transliterates them into Latin, we address a key limitation: Baybayin words often map to multiple Latin equivalents, leading to ambiguous or inaccurate interpretations when reconstructed in phrases. To resolve this, we incorporate GPT-5, a state-of-the-art LLM, to perform Filipino contextual analysis and select the most appropriate transliteration within the given phrase. Results demonstrate that GPT-5 reliably disambiguates meanings and improves phrase-level accuracy, making Baybayin-to-Latin conversion more robust and comprehensible. The proposed algorithm and dataset are made publicly available to ensure reproducibility. This work not only advances Baybayin OCR and promotes cultural heritage but also demonstrates the broader potential of LLM-driven contextual analysis for low-resource and underrepresented languages.

POSTER 12

Finite Element Approximation of Batchelor's Cornerflow Model for Mantle-Wedge Dynamics in Subduction Zones

Jeremiah Daniel A. Regalario[1,*], **and Rhudaina Z. Mohammad**[1]

[1]Institute of Mathematics, University of the Philippine Diliman

*jaregalario@up.edu.ph

*Presenter

Keywords:
mantle-wedge flow
finite element method
Batchelor's cornerflow
Stokes equation
subduction zone

Mantle-wedge flow in subduction zones governs the kinematic structures of convergent plate boundaries. Due to the complex rheology of the Earth's mantle, mathematical modeling of this phenomenon involves solving the Stokes equations for creeping, highly viscous, and incompressible fluids. In this paper, we present a numerical approach to approximate mantle-wedge flow using the Finite Element Method (FEM). By defining the descending slab motion as a kinematic boundary constraint and temporarily neglecting thermal buoyancy under an isoviscous rheology, we simplify the system to a classic linear Stokes flow. We compute the exact analytical solution for this idealized scenario, known as Batchelor's cornerflow model. Specifically, we investigate three distinct wedge geometries corresponding to acute, right, and obtuse angles. Comparisons between our computed numerical flow fields and Batchelor's analytical solutions demonstrate high accuracy and numerical stability across all considered geometries. Analysis of the varied angles reveals that narrower wedges severely compress the return flow, generating intense dynamic pressure gradients near the trench. Geologically, this correlates with high-friction, shallow-dipping subduction zones. As the wedge angle increases to right and obtuse configurations, the flow field broadens and pressure gradients dissipate, mimicking the uninhibited mantle-wedge circulation required to drive back-arc spreading centers. Building upon these fundamental insights, we extend our numerical framework to incorporate geologically realistic boundaries. We adapt the validated solver to simulate localized flow constrained by 2D empirical cross-sections and ultimately construct a fully three-dimensional volumetric model of the Philippine subduction zone using the USGS Slab2 dataset. These extensions demonstrate the solver's robustness in resolving the complex spatial kinematics, flow perturbations, and localized shear zones induced by the natural, curvilinear topography of the Philippine Sea Plate.

POSTER 13

Predicting Calf Production Outcomes in Artificially-Inseminated Philippine Carabaos Using Machine Learning

Kloudene A. Salazar[1,*], **Jimmy C. Espina, Jr.**[2,3], **Rachelle Anne S. Guanga**[4], **Gay Marie S. Castillo**[5], **Aizobelle Huelgas-Fernan**[5], **Kimberly I. B. Turaja**[3], **Christian V. Lualhati**[1], **Ralph Jovi B. Saldajeno**[3], **Edwin C. Atabay**[2], **Arnel N. del Barrio**[2], **and Renier G. Mendoza**[1]

[1]Institute of Mathematics, University of the Philippines Diliman
[2]Philippine Carabao Center, Department of Agriculture
[3]Institute of Animal Science, University of the Philippines Los Baños
[4]Data Science Program, University of the Philippines Diliman
[5]School of Statistics, University of the Philippines Diliman
[*]ksalazar@science.upd.edu.ph

[*]Presenter

Keywords:
artificial insemination
machine learning
predictive analysis
XGBoost

The Philippine carabao industry remains an important component of the Philippine agricultural sector, providing milk, meat, hide, and livelihood opportunities for smallholder farmers.Artificial insemination (AI) is widely used to improve genetic quality and productivity; however, not all AI services result in successful calf production.Identifying the factors associated with AI success is therefore essential for improving reproductive efficiency and farmer income.

To optimize national breeding strategies, this research provides the first comprehensive analysis of nationwide AI service records (2018-2022) from all 12 Philippine Carabao Center regional sites. The study evaluates how biological, seasonal, and logistical factors work together to predict calf production. To account for the Philippine geography, we developed a geospatial framework that calculates farm-to-center proximity using shortest-path analysis in OSMnx for land routes and a hybrid Haversine-shortest-path method for inter-island transport. This data was then used to develop a machine learning model for predicting calf production at a national scale.

We evaluated several interpretable machine learning models using standard performance metrics. Feature importance measures and interpretability techniques were also applied to assess the relative influence of each predictor on AI success. Among the models considered, the Random Forest model achieved the highest predictive performance. The results show that operational factors, including the distance between farms and service centers, regional variation, and technician-related characteristics, have the strongest effect on calf production outcomes. In comparison, biological and environmental factors have only moderate influence. These findings indicate that the conditions under which services are delivered play a crucial role in determining the success of artificial insemination.

A prototype decision-support dashboard was also developed to help farmers and program managers identify cost-effective AI service options and improve breeding decisions. The findings demonstrate the value of integrating geospatial analytics and machine learning to enhance reproductive outcomes and support data-driven livestock management strategies in the Philippines.

POSTER 14

Numerical Analysis of Neural Networks with Hyperbolic Tangent Linear Unit Activation and Applications to Differential Equations

Russell Fitzgerald L. Santos[1,2,*], **Rhudaina Z. Mohammad**[1,2], **and Rachelle R. Sambayan**[1,2]

[1]Institute of Mathematics, University of the Philippines Diliman

[2]Natural Sciences Research Institute, University of the Philippines Diliman

[*]rlsantos10@up.edu.ph

*Presenter

The choice of activation function is critical for the approximation capabilities of neural networks, yet its theoretical understanding remains an active area of research. We aim to provide a theoretical foundation for a promising hybrid activation function, the hyperbolic tangent linear unit (tanhLU), defined as $\sigma(x) = \alpha \tanh(\lambda x) + \beta x$, where $\alpha, \lambda > 0$ and $\beta \geq 0$. We will derive error bounds in high-order Sobolev norms for the approximation of univariate, multivariate polynomials and a class of Sobolev functions by neural networks with tanhLU activation. The theoretical results will be validated to the results of numerical simulations of approximating solutions to linear and nonlinear differential equations. we will also compare tanhLU with other standard activation functions in these numerical simulations.

Keywords:
neural networks
tanhLU activation
function approximation
differential equation

POSTER 15

Physics-Informed Machine Learning for Forward and Inverse Problems in Delay Differential Equations

Celso Villano Jr.[1,*], **Reinabelle Reyes**[2], **and Renier G. Mendoza**[3]

[1]Computational Science Research Center, University of the Philippines Diliman

[2]Research Center for Theoretical Physics, Central Visayan Institute Foundation

[3]Institute of Mathematics, University of the Philippines Diliman

[*]ctvillano@up.edu.ph

[*]Presenter

Keywords:
delay differential equations
physics-informed neural networks
inverse problem
genetic algorithms
epidemiological modeling

Delay differential equations (DDEs) describe systems with state dependence on past trajectories, yielding fundamentally different dynamics and increased sensitivity to delays and history functions in both forward and inverse problems. This dependence introduces significant challenges for parameter estimation, as it requires repeated evaluation of trajectory-dependent dynamics under complex constraints. Classical optimization approaches, such as genetic algorithms, can be applied to these problems but often rely on computationally expensive simulation-based search. Recent advances in physics-informed machine learning provide a framework for learning solutions constrained by governing equations, offering a potential alternative for addressing these challenges [1, 2].

In this study, we develop a unified framework for solving forward and inverse problems in delay differential equations using numerical solvers, genetic algorithms, and physics-informed machine learning approaches. We construct numerical DDE solvers to generate synthetic data and establish baseline solutions, and implement a genetic algorithm-based approach for parameter estimation as a non-neural benchmark. To improve computational efficiency, we introduce physics-informed neural network-based surrogate models for approximating forward dynamics and extend physics-informed machine learning methods to directly solve the inverse problem through physics-constrained learning. We evaluate the proposed approaches on delayed dynamical systems, including delayed SIR models, and demonstrate the trade-offs between classical optimization and physics-informed methods in terms of accuracy and computational cost.

[1] J. He, and A.T. Tiamiyu, *Physics-informed neural networks in iterative form of nonlinear equations for numerical algorithms and simulations of delay differential equations*, Physica A: Statistical Mechanics and its Applications, **660** 130368 (2025)

[2] M. Raissi, et al., *Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations*, Journal of Computational physics, **378** 686–707 (2019)

Authors Index

Keywords Index

Acknowledgements

CoMFoS-NASC 2026 gratefully acknowledges the financial support from the following grants:

- **UP System Supported CU Hosting of International Conferences (Hosting) Grant** of the UP Office of International Linkages (`https://oil.up.edu.ph/oil-programs/hosting/`)
- **World Experts Lecture Series (WELS) Grant** of the UP Office of International Linkages (`https://oil.up.edu.ph/oil-programs/wels/`)
- **ICIAM Conference Support Grant** of the International Council for Industrial and Applied Mathematics (`https://iciam.org/iciam-conference-support`)
- **MSP Financial Support for Organizing Mathematics Conferences/Workshops** of the Mathematical Society of the Philippines through MSP Region 7 Chapter (`https://www.mathsociety.ph/`)