# The 3rd **Taiwan-Japan** International Workshop on **Applied Mathematics**

Department of Applied Mathematics, College of Science
**National Yang-Ming Chiao-Tung University**
https://www.math.nycu.edu.tw/faculty/e_index.php

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Research Center of Mathematics for Social Creativity
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## The 3rd Taiwan-Japan Joint Workshop on Applied Mathematics

V20250423

**Date: 1st May (9:50 - 20:00) and 2nd May (9:30 - 12:40), 2025**

**Place: Room 4-501, Building #4, Faculty of Science, Hokkaido University**

Organizers: NYCU in Taiwan / RIES and Math Dept in HU

Co-organizers: JSPS KAKENHI Grant-in-Aid for Transformative Research Area (A) (Integration of Extracellular Information by Multimodal ECM Activity), KAKENHI Grant-in-Aid for Transformative Research Area (A) (21A402: Ethological Dynamics in Diorama Environments)

### Day 1 (1st May)

9:50-10:00 Opening Remarks by KUBO Hideo, Hsin-Yuan Huang [chair: NAKAGAKI Toshiyuki]

**Session 1** chair: KOMATSUZAKI Tamiki

10:00-10:30 talk1 坂井哲 (SAKAI Akira)

10:30-11:00 talk2 黃信元 (Hsin-Yuan Huang)

+++ break (15 min) +++

**Session 2** chair: KUBO Hideo

11:15-11:45 talk3 香川 渓一郎 (KAGAWA Keiichiro)

11:45-12:15 talk4 陳鵬文 (Peng-Wen Chen)

+++ lunch break (1 h 45 min) +++

**Session 3** chair: NAGAYAMA Masaharu

14:00-14:30 talk5 薛名成 (Ming-Cheng Shiue)

14:30-15:00 talk6 眞崎聡 (MASAKI Satoshi)

+++ break (15 min) +++

**Session 4** chair: Peng-Wen Chen

15:15-15:45 talk7 吳金典 (Chin-Tien Wu)

15:45-16:15 talk8 田畑公次 (TABATA Koji)

+++ break (15 min) +++

**Session 5** chair: MASAMUNE Jun

16:30-17:00 talk9 陳子軒 (Chi-Hin Chan)

17:00-17:30 talk10 中野雄史 (NAKANO Yushi)

+++ break & movement to the poster session (30 min) +++

18:00-20:00 WS dinner with poster presentation at the common space on 5F

### Day 2 (2nd May)

**Session 6** chair: Chueh-Hsin Chang

9:30-10:00 talk11 大村拓也 (OHMURA Takuya)

10:00-10:30 talk12 科特林 (Catalin Carstea)

+++ break (15 min) +++

**Session 7** chair: SAKAI Akira

10:45-11:15 talk13 正宗淳 (MASAMUNE Jun)

11:15-11:45 talk14 張覺心 (Chueh-Hsin Chang)

+++ break (15 min) +++

**Session Final** chair: MASAKI Satoshi

12:00-12:30 talk15 千野由喜 (Yuki Chino)

12:30-12:40 Closing Remarks by Yuki Chino, NAKAGAKI Toshiyuki

Each presentation for 30 min (= talk for 25 min + discussion for 5 min)

To speakers, at the beginning of your presentation, please add a short introduction to your research background and career.

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This workshop is supported by JST Moonshot R&D Program Grant Number JPMJMS2023, JSPS KAKENHI Grant Number JP25K00918.

contact: NAKAGAKI Toshiyuki (MSC, RIES) nakagaki@es.hokudai.ac.jp

## List of participants

V20250423

**Taiwan:**

◉☆ 黃信元 (Hsin-Yuan Huang), full professor at NYCU, 4/29 - 5/3
◉☆ 薛名成 (Ming-Cheng Shiue), associate professor at NYCU, 4/30 - 5/4
◉☆ 吳金典 (Chin-Tien Wu), associate professor at NYCU, 4/30 - 5/4
◉☆ 陳子軒 (Chi-Hin Chan), associate professor at NYCU, 4/30 - 5/4
◉☆ 科特林 (Catalin Carstea), associate professor at NYCU, 4/30 - 5/4
◉☆ 千野由喜 (Yuki Chino), assistant professor at NYCU, 4/30 - 5/3
◉☆ 陳鵬文 (Peng-Wen Chen), full professor at NCHU, 4/30 - 5/4
◉☆ 張覺心 (Chueh-Hsin Chang), associate professor at CCU, 4/30 - 5/5

**Japan:**

◉☆ 田畑公次 (TABATA Koji), associate professor at RIES, HU
◉☆ 大村拓也 (OHMURA Takuya), assistant professor at RIES, HU
◉☆ 香川渓一郎 (KAGAWA Keiichiro), assistant professor at RIES, HU
◉☆ 坂井哲 (SAKAI Akira), full professor at Math Dept, HU
◉☆ 眞崎聡 (MASAKI Satoshi), full professor at Math Dept, HU
◉☆ 中野雄史 (NAKANO Yushi), associate professor at Math Dept, HU (absent am on 5/1)
◉☆ 正宗淳 (MASAMUNE Jun), full professor at Tohoku University (absent 12:30-14:30 on 5/1)

☆ 久保英夫 (KUBO Hideo), full professor at Math Dept, HU
☆ 宮尾忠宏 (MIYAO Tadahiro), full professor at Math Dept, HU
☆ 小林政晴 (KOBAYASHI Masaharu), full professor at Math Dept, HU
☆ 喜多航佑 (KITA Kosuke), assistant professor at Math Dept, HU
？ 長谷部高広 (HASEBE Takahiro), associate professor at Math Dept, HU
☆ 長山雅晴 (NAGAYAMA Masaharu), full professor at RIES, HU
☆ 小松崎民樹 (KOMATSUZAKI Tamiki), full professor at RIES, HU
☆ 中垣俊之 (NAKAGAKI Toshiyuki), full professor at RIES, HU
☆ 西上幸範 (NISHIGAMI Yukinori), associate professor at RIES, HU
☆ 石井宙志 (ISHI Hiroshi), assistant professor at RIES, HU
☆ 長山ゆい (NAGAYAMA Yui), M2 at Graduate School of Science, HU
佐藤僚亮 (SATO Ryosuke), assistant professor at Math Dept, HU
宮川遼大 (MIYAKAWA, Ryodai), M1 at Graduate School of Science, HU
○☆ poster presenter 渡邊陸 (WATANABE Riku), M2 at Graduate School of Science, HU
○☆ poster presenter 野田裕真 (NODA Yuma), D1 at Graduate School of Science, HU
○☆ poster presenter 本橋樹 (MOTOHASHI Natsume), D1 at Graduate School of Science, HU
○☆ poster presenter 内海晋弥 (UCHIUMI Shinya), assistant professor at RIES, HU
○☆ poster presenter 水野雄太 (MIZUNO Yuta), visiting associate professor at RIES, HU
○☆ poster presenter 和田康司 (WADA Koji), D1 at Graduate School of Science, HU
○☆ poster presenter 廣瀬和也 (HIROSE Kazuya), D3 at Graduate School of Science, HU
○☆ poster presenter 津原俊 (TSUHARA Shun), Postdoc at Graduate School of Science, HU

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◉ : lecturer
○ : poster presenter
☆ : WS dinner & poster session
？ : not confirmed

# Day 1 (1st May)

10:00-10:30 talk1 坂井哲 (SAKAI Akira)

**“Critical points for various spread-out statistical-mechanics models in high dimensions”**

10:30-11:00 talk2 黃信元 (Hsin-Yuan Huang)

**“Degree Counting Formulas of curvature equations”**

11:15-11:45 talk3 香川 渓一郎 (KAGAWA Keiichiro)

**“The free energy landscape of a coupled Cahn–Hilliard system”**

11:45-12:15 talk4 陳鵬文 (Peng-Wen Chen)

**“ONE-BIT DIFFRACTION TOMOGRAPHY”**

14:00-14:30 talk5 薛名成 (Ming-Cheng Shiue)

**“On the long-time stability of a class of second-order time-stepping schemes for the Navier-Stokes equations”**

14:30-15:00 talk6 眞崎聡 (MASAKI Satoshi)

**“On integrability of 2-coupled NLS systems”**

15:15-15:45 talk7 吳金典 (Chin-Tien Wu)

**“Applications of State Dependent Riccati Control”**

15:45-16:15 talk8 田畑公次 (TABATA Koji)

**“Optimization of Raman Microscopy via Multi-Armed Bandit Algorithm”**

16:30-17:00 talk9 陳子軒 (Chi-Hin Chan)

**“The Gauss formula for the Laplacian on a hypersurface.”**

17:00-17:30 talk10 中野雄史 (NAKANO Yushi)

**“Metastable limit theorems in chaotic dynamical systems”**

# Critical points for various spread-out statistical-mechanics models in high dimensions

**SAKAI Akira**

**Department of Mathematics,**
**Hokkaido University**

**Abstract**

Identifying the value of the critical point is important in many situations, such as an infection spreading and a nuclear chain reaction. In statistical mechanics, self-avoiding walk (SAW), lattice trees (LT) and lattice animals (LA) are models for linear/branched polymers in a good solvent. Define them on $\mathbb{Z}^d$ with the spread-out edges in $E_L = \{\{x, y\} \subset \mathbb{Z}^d : 0 < \| x - y \| \leq L\}$. All statistical properties of each model are encoded in the generating function with fugacity $p/\Delta$, where $\Delta = \sharp\{ x \in \mathbb{Z}^d : \{o, x\} \in E_L\} = O(L^d)$ is the degree of a vertex. We are interested in the model-dependent critical point $p_c$ and its asymptotics in the spread-out limit $L \uparrow \infty$. (N.b., $p_c$ for random walk is always 1 for any $d$ and any $L$.)

Van der Hofstad and I [1] show that $p_c$ for SAW, percolation, oriented percolation (OP, in $d + 1$ space-time dimensions) and the contact process (CP) above their respective upper-critical dimension $d_c$ (e.g., 4 for SAW, 6 for percolation, 8 for LT/LA) are all equal to $1 + CL^{-d} + O(L^{-d-1})$ as $L \uparrow \infty$, where the model-dependent constant $C$ is

$$C_{\mathrm{SAW/CP}} = \sum_{n=2}^{\infty} U^{*n}(o), \qquad C_{\mathrm{OP}} = \frac{1}{2}\sum_{n=2}^{\infty} U^{*2n}(o), \qquad C_{\mathrm{perc}} = U^{*2}(o) + \sum_{n=3}^{\infty} \frac{n+1}{2} U^{*n}(o),$$

where $U^{*n}$ is the $n$-fold convolution in $\mathbb{R}^d$ of the uniform distribution $U$ on $\{ x \in \mathbb{R}^d : \| x \| \leq 1\}$. Recently, Kawamoto and I [2] prove a similar result for LT/LA in dimensions $d > 8$: $p_c = 1/e + CL^{-d} + O(L^{-d-1})$ as $L \uparrow \infty$, where the model-dependent constant $C$ is

$$C_{\mathrm{LT}} = \sum_{n=2}^{\infty} \frac{n+1}{2e} U^{*n}(o), \qquad\qquad C_{\mathrm{LA}} = C_{\mathrm{LT}} - \frac{1}{2e^2}\sum_{n=3}^{\infty} U^{*n}(o).$$

The best bound before our work is by Penrose [3]: $p_c = 1/e + O(L^{-2d/7} \log L)$ for both models in any dimensions.

The common tool to obtain the above results is the lace expansion. At the workshop, I will show how to use the lace expansion to derive the leading term (1 or $1/e$ depending on the models) and the above random-walk representations for the coefficient $C$ of $L^{-d}$ and give intuitive explanation of why $d$ has to be above $d_c$.

**References**

[1] R.v.d. Hofstad and A. Sakai. Critical points for spread-out self-avoiding walk, percolation and the contact process above the upper critical dimensions. *Probab. Theory Relat. Fields*, **132** (2005): 438–470.

[2] N. Kawamoto and A. Sakai. Spread-out limit of the critical points for lattice trees and lattice animals in dimensions $d > 8$. *Comb. Probab. Comput.*, **33** (2024): 238–269.

[3] M.D. Penrose. Self-avoiding walks and trees in spread-out lattices. *J. Stat. Phys.*, **77** (1994): 3–15.

# Degree Counting Formulas of curvature equations

**Hsin-Yuan Huang**

**National Yang-Ming Chiao-Tung University**

## Abstract

In this talk, we study the monodromy matrices of second-order Fuchsian ordinary differential equations(ODEs) by employing the Leray-Schauder degree formulas for the corresponding curvature equations. More precisely, we obtain the form of the degree counting formulas. Let $k$ be the number of non-integer difference of the local exponents at the singular points of the ODEs. As an application of this result, we show that under certain assumptions, the degree does not vanish when $k = 3,4,5$, which implies that the corresponding monodromy matrices are unitary. To the best of our knowledge, this is the first work that assigns the Leray-Schauder degree to Fuchsian ODEs from the perspective of the corresponding curvature equations.

# The free energy landscape of a coupled Cahn–Hilliard system

**KAGAWA Keiichiro**

**Research Center of Mathematics for Social Creativity,**
**Research Institute for Electronic Science, Hokkaido University**

**Abstract**

Block copolymers form nanoscale particles, and experiments have confirmed that the combination of particle morphology and internal microphase separation leads to a variety of three-dimensional structures. Avalos et al. reproduced the observed three-dimensional morphologies in block copolymers through numerical simulations based on a three-dimensional coupled Cahn– Hilliard system with nonlocal term derived from the following free energy [1].

$$F[u,v](t) = \int_\Omega G[u,v](t,x)dx,$$

$$G[u,v] = \frac{\epsilon_u^2}{2}|\nabla u|^2 + \frac{\epsilon_v^2}{2}|\nabla v|^2 + \frac{(1-u^2)^2}{4} + \frac{(1-v^2)^2}{4} + \alpha uv + \beta uv^2 + \frac{\sigma}{2}|(-\Delta)^{-1/2}(v-\bar{v})|.$$

Here, the unknown function $u$ represents the ratio between the block copolymer and the solvent, while $v$ denotes the ratio between the two constituent polymers; $\bar{v}$ is the spatial average of $v$. We interpret $u \sim -1$ as indicating a solvent-rich region and $u \sim 1$ as one polymer-rich region. In addition, by labeling the two polymers as polymer A and polymer B, we interpret $v \sim -1$ as a polymer A-rich region and $v \sim 1$ as one where polymer B is dominant. The positive parameters $\epsilon_u$ and $\epsilon_v$ serve as coefficients of the gradient energy, corresponding to the thickness of the phase-separated interfaces in $u$ and $v$, respectively. The term with $\sigma > 0$ represents long-range interactions, characterizing the situation where polymers A and B are copolymerized. The $\alpha$ term indicates, depending on its sign, which polymer exhibits a higher affinity for the solvent. The term $\beta < 0$ indicates that polymers A and B tend to phase separate in the region, $u \sim 1$. Thus, the free energy $F$ consists of the Ginzburg–Landau free energy for $u$ and $v$, a nonlocal term (involving $\sigma$), and interaction terms (involving $\alpha$ and $\beta$).

In this talk, we report on our investigation of the energy landscape by examining a one-dimensional coupled Cahn–Hilliard system derived from the simplified free energy by removing the nonlocal term ($\sigma = 0$) from that in [1]. Using the variational derivatives of the free energy, the coupled Cahn–Hilliard equations are derived as follows:

$$\begin{cases} \tau_u \dfrac{\partial u(t,x)}{\partial t} = \dfrac{\partial^2}{\partial x^2}\dfrac{\delta G[u,v]}{\delta u} = \dfrac{\partial^2}{\partial x^2}\Big[-\epsilon_u^2\dfrac{\partial^2 u}{\partial x^2} - u + u^3 + \alpha v + \beta v^2\Big] \text{ for } t>0, x\in[0,L), \\ \tau_v \dfrac{\partial v(t,x)}{\partial t} = \dfrac{\partial^2}{\partial x^2}\dfrac{\delta G[u,v]}{\delta v} = \dfrac{\partial^2}{\partial x^2}\Big[-\epsilon_v^2\dfrac{\partial^2 v}{\partial x^2} - v + v^3 + \alpha u + 2\beta uv\Big] \text{ for } t>0, x\in[0,L) \end{cases},$$

Here, periodic boundary conditions are assumed. The time constant $\tau_u$, $\tau_v > 0$ control the rate of time evolution of $u$ and $v$. It is possible to consider the equivalence problem with $\tau_u = r$ and $\tau_v = 1$ by performing a scale transformation in time. These time constants do not affect the shape of the free energy.

This is joint work with Takeshi Watanabe (Nagano Univ.) and Yasumasa Nishiura (Hokkaido Univ.). This work was supported by JSPS KAKENHI Grant Number 23K19003 and 23K17653.

## References

[1] E. Avalos, T. Teramoto, Y. Hirai, H. Yabu, and Y. Nishiura, ACS Omega **9**, 17276 (2024).

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# ONE-BIT DIFFRACTION TOMOGRAPHY

**Peng-Wen Chen**

**National Chung Hsing University**

**Abstract**

The compressive sensing (CS) framework is proposed to address the burden of analog-to-digit converters. One-bit CS is the extreme case where only the sign of the measurements are recorded. A few years ago, we proposed null initializations as one initialization scheme for phase retrieval reconstruction. The null initialization can be regarded as one-bit measurements. In this talk, we shall present a noise-robust framework for 1-bit diffraction tomography, a novel imaging approach that relies on intensity-only binary measurements obtained through coded apertures. The proposed reconstruction scheme leverages random matrix theory and shifted inverse power iteration, to effectively recover 3D object structures under high-noise conditions. We develop one accurate 3D reconstruction scheme for tomographic phase retrieval. The tomographic reconstruction replies on solving a Toeplitz system, where FFT based preconditioners can be employed to improve the convergence speed. The numerical tool is employed to study the correlation of dose fractionation. We present mathematical analysis on the correlation curve.

# On the long-time stability of a class of second-order time-stepping schemes for the Navier-Stokes equations

**Ming-Cheng Shiue**

**National Yang-Ming Chiao-Tung University**

## Abstract

This talk explores the long-time stability of a class of second-order time-stepping schemes designed for the Navier-Stokes equations including BDF or SAV-BDF methods. The main results are to demonstrate that these time-stepping schemes enjoy long-time $L^2$ stability without requiring a small time step size. Additionally, for smoother initial data, these algorithms achieve long-time $H^1$-stability, also without imposing constraints on the time step size. Therefore, these results match the well-known theory for the Navier-Stokes equations and these numerical schemes are accurately capturing the asymptotic dynamical system to the Navier-Stokes equations.

This presentation investigates a novel class of second-order time-stepping methods for the Navier-Stokes equations, specifically incorporating BDF and SAV-BDF approaches. The key findings reveal that these schemes maintain long-time $L^2$ stability without the restriction of the time step size. Moreover, when the initial data is sufficiently smooth, the algorithms achieve enduring $H^1$ stability without requiring the smallness condition on the time step size. These results confirm that the numerical methods accurately reproduce the asymptotic behavior of the Navier-Stokes dynamics, in full agreement with the established theoretical framework.

# On integrability of 2-coupled NLS systems

**MASAKI Satoshi**

**Department of Mathematics,**
**Hokkaido University**

**Abstract**

The one-dimensional cubic nonlinear Schrödinger (NLS) equation is known as an integrable equation. Integrable equations enjoy remarkable properties, such as the existence of infinitely many conserved quantities, and their solutions can be analyzed in great detail—for instance, via the inverse scattering method. However, equations with such structures are extremely special. For instance, if we consider the NLS equation in general space dimensions and with nonlinearities of general power, no example other than the one-dimensional cubic case is known to be integrable. The integrability of an equation is characterized by the existence of a Lax pair. However, no general method for constructing a Lax pair is known, making it difficult to determine whether a given equation is integrable.

In this talk, I will investigate the integrability of two-component (2-coupled) cubic NLS systems in one space dimension. Among such systems, several examples are known to be integrable, including the Manakov system and certain nonlocal-type NLS equations. By focusing on the existence of a fourth conserved quantity following the mass, momentum, and energy, we show that general 2-coupled NLS systems fall into one of the following three categories:

(1) Integrable case: If a system admits a nontrivial fourth conserved quantity and a conserved energy whose quadratic part is non-degenerate, then it is integrable and can be reduced to one of fifteen standard forms.

(2) If a system admits a nontrivial fourth conserved quantity, but all conserved energies have degenerate quadratic parts, then the system contains a closed single-component cubic NLS equation. The third and fourth conserved quantities arise from that single equation.

(3) The system does not possess any nontrivial fourth conserved quantity.

The latter two cases indicate a defect in the infinite sequence of conserved quantities, suggesting that the system is not integrable.

# Applications of State Dependent Riccati Control

**Chin-Tien Wu**

**Department of Applied Mathematics,**
**National Yang-Ming Chiao-Tung University**

## Abstract

In this talk, we shall introduce the state dependent control problems based on solving the Riccati equation (SDRE). State equations with external perturbation and noisy observer are handled by optimal Kalman gain and $H^{\infty}$-control. Some numerical studies will be presented.

# Optimization of Raman Microscopy via Multi-Armed Bandit Algorithm

**TABATA Koji**

**Research Institute for Electronic Science, Hokkaido University**
**ktabata@es.hokudai.ac.jp**

## Abstract

In this presentation, we propose an innovative "on-the-fly" Raman microscopy technique that significantly enhances both the speed and accuracy of sample discrimination. This method is particularly effective for complex biological analyses, such as cell phenotype classification, and provides substantial advantages in situations where high-resolution, molecular-level information must be acquired in a short time. By incorporating machine learning techniques into the measurement process, the system dynamically optimizes illumination patterns in real-time, focusing on the most informative regions of the sample, thereby reducing data acquisition time while achieving high classification performance.

Traditional Raman microscopy is highly valued for its ability to provide label-free, non-destructive, and chemically specific information. However, it has the drawback of weak signal intensity, which leads to long measurement times for each point, and the conventional raster scanning or point-by-point methods require excessive time for data acquisition. To address this issue, our proposed method introduces a feedback control mechanism that sequentially determines which regions should be prioritized for illumination during the measurement process. Based on the data acquired from the sample, the measurement strategy is updated and optimized in real-time, avoiding unnecessary measurements and accurately targeting the key areas.

At the core of this method is the multi-armed bandit algorithm, a machine learning technique that balances exploration and exploitation to quickly identify the most informative areas of a sample, prioritizing them for observation. We validated this approach using Raman images of human follicular thyroid cells and follicular thyroid carcinoma cells. The results showed that, compared to traditional raster scanning, we were able to significantly reduce the number of required illuminations while maintaining theoretical guarantees for classification accuracy.

This technology addresses the long-standing challenge in Raman spectroscopy and optical microscopy of balancing "measurement speed" with "analytical precision." It represents an important step towards realizing faster and smarter diagnostic imaging. Moreover, this algorithm is not limited to Raman microscopy; it can be easily applied to other imaging techniques that allow real-time control of measurement conditions, opening up new possibilities for applications in diverse fields such as healthcare, drug discovery, and materials science.

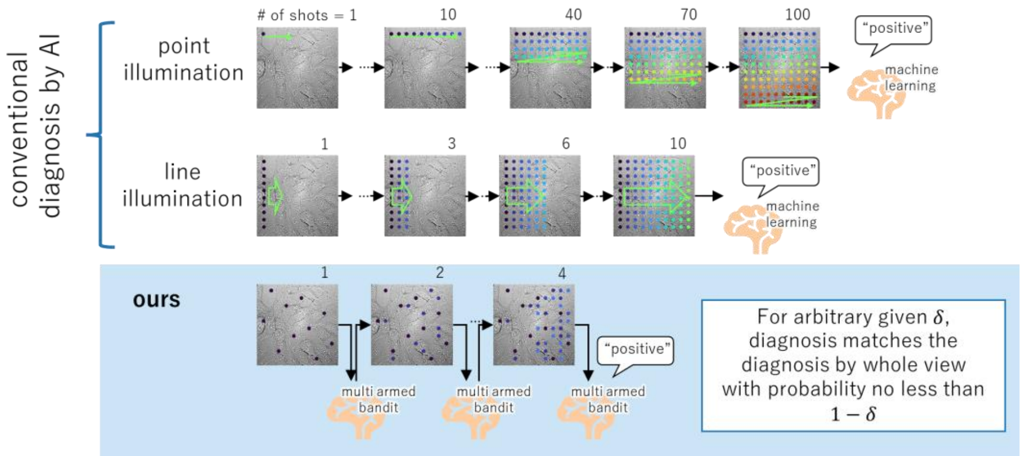


Figure 1: While conventional methods otain entire image, and then diagnosis is performed, our method sequentially determines the next points to measure, enabling high-speed diagnosis. Even with fewer measurement points, diagnosis accuracy is theoretically guaranteed within any given allowable error rate $\delta$.

# The Gauss formula for the Laplacian on a hypersurface.

**Chi-Hin Chan**

**National Yang-Ming Chiao-Tung University**

## Abstract

In this talk, we discuss how extend the Gauss formula relating the extrinsic connection to the intrinsic connection to a formula for the extrinsic, Euclidean Laplacian to the intrinsic Laplacian of a vector field on a hypersurface. As a byproduct, we derive a formula for the Laplacian of a 1-form on a surface of revolution in terms of the Lie derivatives. Physically, these formulas are motivated by the study of the formulation of the incompressible Navier-Stokes equations on a Riemannian manifold. This is a joint work of Chi Hin Chan and Magdalena Czubak.

# Metastable limit theorems in chaotic dynamical systems

**NAKANO Yushi**

**Department of Mathematics,**
**Hokkaido University**

**Abstract**

A metastable state is a state which is not a real stable state, but can be observed for a long time. This is a concept that appears in several areas of natural science, like chemical kinetics, meteorology, neuroscience, etc. Some of these phenomena can be modeled as a dynamical system, but traditional dynamical systems theory was developed by analyzing behaviors of the system in the infinite time limit, so mathematical theory for understanding (non-trivial) dynamics on metastable time scales would be far from complete (although there are several important developments recently).

In this talk, I try to concentrate on a (famous) toy model dynamics, which is a piecewise expanding interval map without statistical stability (i.e. its "physical" invariant measure does not vary continuously under perturbations), to make the presentation of our idea/formulation transparent. Our results include strong laws of large numbers, central limit theorems with Berry-Esseen type error estimates, large deviation principles, almost sure invariant principles on metastable time scales. This is partially based on joint works in progress with J. Atnip, C. Gonzalez-Tokman, G. Froyland, S. Vaienti, and with J. Leppanen, Y. Nakajima.

# Day 2 ($2^{nd}$ May)

9:30-10:00 talk11 大村拓也 (OHMURA Takuya)

**"How do numerical swimmers achieve behavior of microorganisms contacting a non-slip boundary?"**

10:00-10:30 talk12 科特林 (Catalin Carstea)

**"Reconstruction of coefficients in the double phase problem"**

10:45-11:15 talk13 正宗淳 (MASAMUNE Jun)

**"Construction of signed distance functions with an elliptic equation"**

11:15-11:45 talk14 張覺心 (Chueh-Hsin Chang)

**"Bistable wavefronts of three-species competition-diffusion systems"**

12:00-12:30 talk15 千野由喜 (Yuki Chino)

**"Frog Model: a model of interacting random walks"**

# How do numerical swimmers achieve behavior of microorganisms contacting a non-slip boundary?

**OHMURA Takuya**

**Research Institute for Electronic Science,**
**Hokkaido University**

## Abstract

Swimming behaviors of single-cell microorganisms can be described as hydrodynamic phenomena at low Reynolds number. Even though single-cell microorganisms do not have brains, they can behave very efficiently for their survival strategies. Instead of biological approaches, physical mechanics directly help quantifying the behavioral efficiency of the microorganisms. For instance, swimming ciliates are known to accumulate on a wall surface due to nutrient sedimentation, however it has been unclear how they keep staying on the non-slip boundary despite hydrodynamic repulsion. This talk represents that, by implementing simplified experimental results, numerical calculations of hydrodynamic swimming models reproduced the actual microorganism's behavior.

# Reconstruction of coefficients in the double phase problem

**Catalin Carstea**

**National Yang-Ming Chiao-Tung University**

**Abstract**

In this talk I will discuss the inverse boundary value problem for the equation $div(|\nabla u|p-2\nabla u+a|\nabla u|q-2\nabla u)=0$, which is known as the "double phase equation" or "double phase problem". The coefficient a is a sufficiently smooth non-negative function and the two exponents satisfy $1<p\neq q<\infty$. The goal of the talk is to describe how the coefficient a can be recovered from the Dirichlet-to-Neumann (DN) map for this equation. The method involves asymptotic analysis of the solutions for either small or large Dirichlet data which will identify certain integral identities that can be derived from the DN map, as well as a construction of special $p$-harmonic functions to be used in these integral identities. The talk is based on recent work with P. Zimmermann.

# Construction of signed distance functions with an elliptic equation

**MASAMUNE Jun**

**Tohoku University**

**Abstract**

Motivated by recent advances in structural optimization, we propose a novel method for constructing the distance function to the boundary of a given domain. Building on and extending the celebrated Varadhan asymptotic theory, our approach reformulates the governing equation into a more appropriate framework. A central contribution of this work is the derivation of convergence rates within this new setting, which are shown to be optimal in one dimension and offer significant improvements over existing results in higher dimensions. This study is a joint work with Takahiro Hasebe, Tomoyuki Oka, Kota Sakai, and Takayuki Yamada.

# Bistable wavefronts of three-species competition-diffusion systems

**Chueh-Hsin Chang**

**National Chung Cheng University**

**Abstract**

In this talk, we study the existence of wavefront solutions of the bistable three-species competition-diffusion system. Due to the lack of the maximum principle, we first consider the existence and asymptotic stability of traveling fronts for a simplified system without competition between two species. This simplified system has the comparison principle. Then we use the heteroclinic bifurcation approach and perturbation theory of linearized operators to obtain the existence and asymptotic stability of traveling fronts to the original system within specific parameter ranges in which the competition rates between the above two species are small enough. The monotone dependence of the wave speed on parameters is also discussed. This is a joint work with Professor Chang-Hong Wu.

# Frog Model: a model of interacting random walks

**Yuki Chino**

**National Yang-Ming Chiao-Tung University**

**Abstract**

Through this talk we consider a statistical-mechanical model called frog model, which can describe infection spreading, information propagation and so on. In frog model we observe infinitely many random walks interacting each other. Basically we put an active particle at the origin/root of a certain graph. The active particle moves to the next vertex according to a certain law of random walk and activate a certain number of non-active particles there. We are interested in recurrence/transience, asymptotic shape, and the first passage at some vertex.

# Poster presentations

18:00-20:00 WS dinner with poster presentation at the common space on 5F

渡邊陸 (WATANABE Riku)
**“The behavior of spot solutions to a neural field equation on spheroids”**
野田裕真 (NODA Yuma)
**“Data analysis using a mathematical model of body circulation describing Glucose, Insulin, and C-peptide kinetics”**
本橋樹 (MOTOHASHI Natsume)
**“Reaction-Diffusion Modeling for Self-Motion of a Rigid Body”**
内海晋弥 (UCHIUMI Shinya)
**“Guaranteed bounds of eigenvalues for Laplacian on planar curved domains”**
水野雄太 (MIZUNO Yuta)
**“A quantum algorithm for dynamic mode decomposition: Toward operator-theoretic analysis of dynamical systems on quantum computers”**
和田康司 (WADA Koji)
**“Complexity of attractor-ruin for globally coupled map by using optimal transport distance”**
廣瀬和也 (HIROSE Kazuya)
**“Lower gradient estimates for viscosity solutions to first-order Hamilton-Jacobi equations depending on the unknown function”**
津原俊 (TSUHARA Shun)
**“Global well-posedness of multi-component nonlinear Schrödinger systems with general Sobolev critical nonlinearities”**

# The behavior of spot solutions to a neural field equation on spheroids

**WATANABE Riku**

**Department of Mathematics, Faculty of Science,**
**Hokkaido University**
**E-mail：watanabe.riku.y9@elms.hokudai.ac.jp**

## Abstract

In this study, we analyze the behavior of localized spot solutions in a neural field equation defined on a spheroidal surface $S$:

$$u_t(t, \mathbf{x}) = \int_S K\big(d(\mathbf{x}, \mathbf{y})\big) H(u(t, \mathbf{y}) - u_T) ds(\mathbf{y}) - u(t, \mathbf{x}), \qquad (t > 0, \mathbf{x} \in S, u_T \in \mathbb{R}),$$

where $K$, $H$, and $d$ denote the integral kernel, the Heaviside function, and the geodesic distance between $\mathbf{x}$ and $\mathbf{y}$ on $S$, respectively. The neural field equation is a nonlinear integro-differential equation developed as a mathematical model to describe the spatiotemporal evolution of excitation patterns in the brain. We consider a spheroid obtained by slightly flattening a sphere, treating it as a perturbation of the spherical case. Using regular perturbation methods, we investigate the stability of spot solutions localized on the spheroidal surface. This is a joint work with Dr. Hiroshi Ishii (Research Institute of Electronic Science, Hokkaido University).

# Data analysis using a mathematical model of body circulation describing Glucose, Insulin, and C-peptide kinetics

**NODA Yuma*, Junyong Eom, UEDA Yuki†, UCHIUMI Shinya†, NAGAYAMA Masaharu†, NAKAOKA Shinji¶, SUITO Hiroshi‖, KATAGIRI Hideki****

**Graduate School of Science,**
**Hokkaido University**

**Abstract**

We propose a mathematical model of the body circulation that describes the dynamics of glucose, insulin, and C-peptide concentrations and analyze the data using real data in order to understand the pathogenesis of diabetes mellitus. The objective of this study is to propose an indicator of the early stage of pre-diabetes using the mathematical model. As a mathematical model of glucose-insulin metabolism in diabetogenesis, Sorensen's mathematical model[1] linking each compartment in the blood circulation is known. We propose an ordinary differential equation (ODE) system model describing glucose, insulin, and C-peptide concentrations in nine organs: heart, brain, pancreas, liver, kidney, upper and lower limbs, small intestine, and other digestive organs.

In order to identify candidate indicators of the early stage of diabetes mellitus, we analyzed the time series data of oral glucose tolerance test on mice fed a high-fat diet and a normal diet. Here, the number of weeks of loading the two diets is referred to as the number of experimental weeks, and the parameters of the mathematical model are estimated for the glucose tolerance test data at 0, 1, 4, and 7 weeks of the experimental period. Clustering of the data by the 2-hour uptake and 2-hour secretion of glucose, insulin, and C-peptide in each organ during each experimental week showed that mice fed a high-fat diet and those fed a normal diet were completely divided into two groups when the experimental week was 7. Pancreatic insulin secretion, liver insulin uptake, cardiac insulin uptake, and skeletal muscle insulin uptake were estimated to be important factors that differentiate the two diets. Since glucose metabolic rate is considered to be less different between the two diets than insulin metabolic rate, we defined liver insulin sensitivity and skeletal muscle insulin sensitivity as indices of insulin effect on glucose uptake in the liver and skeletal muscle, which are insulin dependent in glucose metabolic rate. We examined changes in liver and insulin sensitivity over time and found that liver and insulin sensitivity tended to decrease in mice fed a high-fat diet. This suggests that insulin sensitivity is an early indicator of the effects of a high-fat diet.

## References

[1] J. T. Sorensen, A Physiologic Model of Glucose Metabolism in Man and Its Use to Design and Assess Improved Insulin Therapies for Diabetes, Thesis of Massachusetts Institute of Technology, 1985.

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† Research Institute for Electronic Science, Hokkaido University

¶ Faculty of Advanced Life Science, Hokkaido University

‖Advanced Institute for Materials Research, Tohoku University.

**Tohoku University Graduate School of Medicine

# Reaction-Diffusion Modeling for Self-Motion of a Rigid Body

***<u>MOTOHASHI Natsume</u>, KITAHATA Hiroyuki, NAKATA Satoshi, SAKAKIBARA Koya, TAKASAO Keisuke, MONOBE Harunori, NAKAMURA Ken-Ichi, FUJINO Takuya, NAGAYAMA Masaharu**

**Department of Mathematics, Graduate School of Science, Hokkaido University**

### Abstract

We propose a model using the volume-conserving Allen-Cahn equation for a self-propelled system consisting of a rigid body where a surface tension gradient induces motion. We introduce the mechanism to represent the shape of an object in motion to the previous model [1]. We can realize it by introducing a function defined on a rotational coordinate whose origin is the barycenter of the object to double-well potential. Furthermore, we derive a model using the interface equation by taking the singular limits. This poster shows the models and numerical results for them.

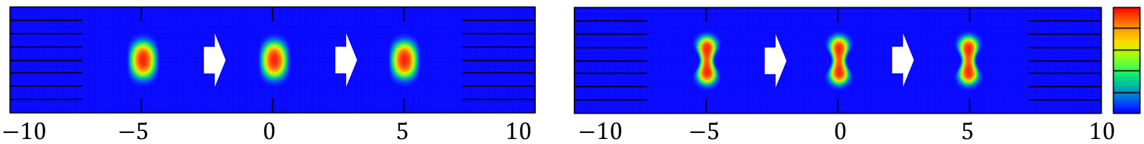


**Fig.1** Short-axis-directed translational solutions of elliptical and dumbbell-shaped objects from the model using the volume-conserving Allen-Cahn equation.

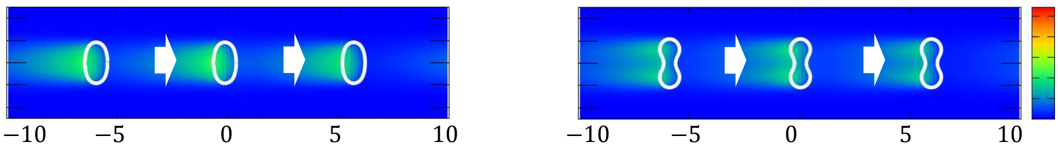


**Fig.2** Short-axis-directed translational solutions of elliptical and dumbbell-like-shaped objects from the model using the interface equation.

[1] M. Nagayama, H. Monobe, K. Sakakibara, K.-I. Nakamura, Y. Kobayashi, and H. Kitahata, *On the reaction-diffusion type modeling of the self-propelled object motion*, Sci. Rep. 13, 12633 (2023)

# Guaranteed bounds of eigenvalues for Laplacian on planar curved domains

**UCHIUMI Shinya**

**Research Center of Mathematics for Social Creativity,**
**Research Institute for Electronic Science, Hokkaido University,**
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**Abstract**

We consider the eigenvalue problem of the Laplacian with the homogeneous Dirichlet boundary condition, or homogeneous Neumann condition, in planar curved domains. Based on the framework by Liu (2015), we show guaranteed bounds of the eigenvalues, where the lower and upper bounds are explicitly computable. We use the curved finite element space by Zlamal (1973). The constant that appears in the theorem by Liu is estimated by using the argument by Ciarlet and Raviart (1972).

# A quantum algorithm for dynamic mode decomposition: Toward operator-theoretic analysis of dynamical systems on quantum computers

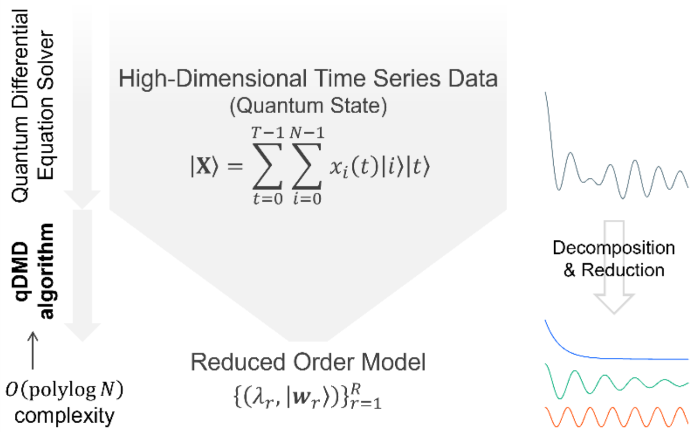
**MIZUNO Yuta**

**Global Research and Development Center for Business by Quantum-AI Technology, National Institute of Advanced Industrial Science and Technology**
**Research Institute for Electronic Science, Hokkaido University**
**E-mail: yuta.mizuno@aist.go.jp**

## Abstract

In this poster, we present the quantum dynamic mode decomposition (qDMD) algorithm that we proposed recently [*Phys. Rev. Research* **6**, 043031 (2024)]. Quantum computers can solve $N$-dimensional liner differential equations with a computational complexity of $O(\mathrm{poly}\log N)$. The output of such a simulation is a quantum state in which time-series data are encoded in the probability amplitudes. Our qDMD algorithm analyzes this encoded time series data and decomposes it into several modes corresponding to exponential decay or growth, as well as sinusoidal oscillations. In other words, the qDMD algorithm effectively computes dominant eigenvalues and eigenvectors of the coefficient matrix associated with the linear differential equation. The computational complexity of the qDMD algorithm is also $O(\mathrm{poly}\log N)$, representing an exponential improvement over classical counterpart.

The time evolution of any finite (and possibly nonlinear) dynamical system can be described by the Perron–Frobenius operator (acting on probability density functions over the state space) or the Koopman operator (acting on observable functions). These operators are infinite-dimensional and linear, and their spectral decompositions provide valuable insights into the temporal behavior of the system. This operator-theoretic perspective is particularly appealing because it allows one to apply linear algebraic techniques even to nonlinear dynamical systems. However, the numerical implementation of such analyses is challenging, as it often involves solving linear algebra problems in exponentially large-dimensional spaces. We anticipate that the so-called "curse of dimensionality" in operator-theoretic dynamical systems analysis can be mitigated by leveraging the qDMD algorithm. In this poster, we discuss the potential of the qDMD algorithm as a tool for enabling efficient operator-theoretic analysis of dynamical systems.



# Complexity of attractor-ruin for globally coupled map by using optimal transport distance

**WADA Koji**

**Graduate School of Science,**
**Hokkaido University**

## Abstract

In this presentation, we show the results of the complexity of attractor ruin for a globally coupled map. The globally coupled map (GCM) is a discrete dynamical system, and here we consider a model in which the logistic map is globally coupled. An attractor-ruin is a set in which the attractor is destabilized by a change in parameters, which is characterized by a Milnor attractor. Intermittent phenomena called chaotic itinerancy, in which orbits transition between attractor ruin, have been observed in various complex systems, and their onset mechanisms and statistical properties have attracted attention. In this study, the instability of orbits of GCM is analyzed from the viewpoint of clustering by using the optimal transport distance, and the complexity of attractor ruins is numerically evaluated by applying this method. As a result, it was found that the complexity is high in the parameter region called the partially ordered phase, where chaotic itinerancy occurs.

# Lower gradient estimates for viscosity solutions to first-order Hamilton-Jacobi equations depending on the unknown function

**HIROSE Kazuya**

**Graduate School of Science,**
**Hokkaido University**

**Abstract**

In this poster, I wish to present a result on the lower bounds for gradients of viscosity solutions to Hamilton--Jacobi equations, where the convex Hamiltonian depends on the unknown function. We obtain several gradient estimates using different methods. First, we utilize the equivalence between viscosity solutions and Barron—Jensen solutions, and study the properties of the inf-convolution. This method is based on [Ley, 2001]. Second, we examine the contact Hamiltonian system to understand how initial gradients propagate along its solutions. This method is based on [Hamamuki-H., 2023].

# Global well-posedness of multi-component nonlinear Schrödinger systems with general Sobolev critical nonlinearities

**TSUHARA Shun**

**Graduate School of Science,**
**Hokkaido University**

**Abstract**

We consider a multi-component nonlinear Schrödinger system with Sobolev critical nonlinearity. The system is a generalization of the nonlinear Schrödinger equation with the Hamiltonian structure, and it encompasses several physical models, including the Manakov model and phenomena such as Raman amplification. In the Sobolev critical setting, the linear dispersion and nonlinear focusing effects are in balance, so that standard energy methods are not sufficient to prove the global existence of solutions. For the single component case, pioneering works by Bourgain, Kenig–Merle, and others have led to a deep understanding of the global dynamics using the concentration-compactness and rigidity argument. Inspired by these approaches, we extend the concentration-compactness framework to our system and construct the ground state solution. Furthermore, under the assumptions of gauge invariance and mass resonance, we prove the global well-posedness of the system below the ground state.