The 14th Taiwan-Japan joint workshop for young scholars in applied mathematics

Abstracts

Venue: room 516, Nakano Campus, Meiji University

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Feb. 29	
10:00-13:00	Free discussion

Feb.27 room 516, Meiji University

9:50-10:00	Opening (Registraion starts from 9:30)		
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10:10--10:20	Jing-En Huang (National Taiwan Normal University, B4)	2	Multi-Camera Multi-People Tracking on Basketball Matches Based on Deep Learning Models
10:20--10:30	Yuki Kimura (Musashino University, B4)	3	Traveling front on a 1- and 2-dimentional growth-diffusinon-chemotaxis model
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11:15--11:30	You-jun Li (National Taiwan Normal University, M1)	7	3D Point Clouds Semantic Segmentation Using Visual-Language Models
11:30--11:45	Sosuke Hiraoka (Future University Hakodate, M1)	8	Mathematical modeling of Proneural Wave on growing domain
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Feb. 28 room 516, Meiji University

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Feb. 29

10:00-13:00	Free discussion

Topological Data Analysis of An Epicentre Distribution

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The object of my work is to describe an epicentre distribution using Topological Data Analysis (TDA). This work provides the information about the shape of data of an epicentre distribution and the effectiveness of a random walk fractal model called Lévi Dust for it. I implemented a clustering method called K-Medoids method on the time series diagrams consisting of each year's diagram to detect the anomaly years of earthquakes. In terms of the data I used, it is the epicentre distribution of Nagano and Gifu prefecture in Japan from 2000 to 2020. The results reveal that Lévi Dust could be used as a feature of machine learning methods for analysing epicentre distributions and those years were divided into two groups broadly, which means a few of the years may be anomaly. So, in my presentation, I briefly talk on the way of analysing and the results.

Multi-Camera Multi-People Tracking on Basketball Matches Based on Deep Learning Models

Jing-En Huang (National Taiwan Normal University)

Abstract:

This talk explores the challenges in multi-people tracking in basketball matches using a system of four overlapping-view cameras, highlighting the difficulties in identifying and tracking players who are closely clustered, move rapidly, and are often obscured in camera views. The study delves into integrating data from multiple cameras with overlapping views to ensure consistent tracking across different angles. In sports analysis, the tracking system developed from this study can provide detailed player metrics, movement patterns, and team strategies, offering valuable insights for coaches and analysts. Furthermore, this system can be utilized in the realm of broadcast technology to automate player highlighting and generate comprehensive game summaries, thereby significantly enhancing the viewer experience.

Traveling front on a 1- and 2-dimentional growth-diffusinon-chemotaxis model

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Abstract

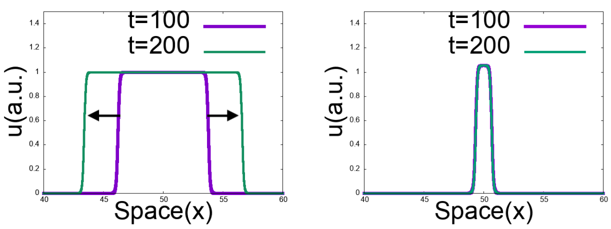
Increased attention has been focused on chemotactic aggregation. Various mathematical model has been proposed. In this study, numerical experiments on the following model[1] are carried out.

$$\begin{cases} \dfrac{\partial u}{\partial t} = \epsilon^2 \Delta u - \epsilon k \nabla \cdot (u \nabla \chi(v, \theta)) + f(u), \\ \dfrac{\partial v}{\partial t} = \Delta v + u - \gamma v. \end{cases}$$

Here, $u(x,t)$ and $v(x,t)$ represent the population density of the organism and the concentration of the chemo-attractant, respectively. k is a positive constant and is called the advection coefficient. ϵ is a very small value, and γ is the decomposition rate. $f(u)$ is a bistable growth term, given as $f(u) = u(1-u)(u-a)$ with $0 < a < 1/2$. $\chi(v)$ represents the chemotactic sensitivity as a function dependent on v and θ given by

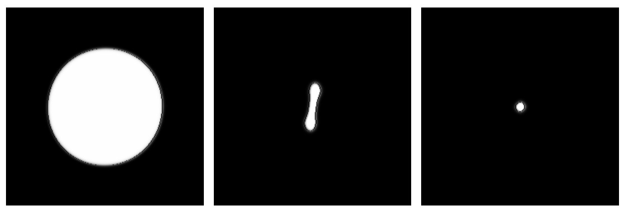
$$\chi(v) = \frac{\theta v^2}{\theta^2 + v^2},$$

where $\theta > 0$. In the one-dimensional domain, for small values of the advection coefficient k, the front of pulse propagates with constant velocity as shown in Fig. 1(a). On the other hand for large values of k, the front is pinned as shown in Fig. 1(b). In two dimension, various patterns appear for the initial conditions having circular pattern. For the small k, the front with circular shape is propagating as shown in Fig. 2(a). For intermediate values of k, radial asymmetry patterns appears as shown in Fig. 2(b). For large k, radial symmetry patterns appear as shown in Fig. 2(c). To make clear the mechanism of the pattern formation, we would like to discuss our 1- and 2-D numerical results in this conference.



(a) propagating (b) Pinned

Figure 1



(a) Propagating (b) RA (c) RS

Figure 2

References

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Exploring Parameter Estimation Techniques for HIV Modeling: From Simulation Data to Real-world Applications

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This presentation is divided into three main parts. First, we will share relevant information about the latest developments in AIDS. Second, we will introduce and build HIV models and generate artificial data. We will then estimate the model's parameters using the least squares method. At the same time, we will perform a simple statistical analysis to compare estimated values with valid values to evaluate the accuracy of the process. We hope to explore better methods further and apply them to actual data. We use these data and the HIV model to estimate possible parameter ranges for the HIV model. Our future goal is to verify the accuracy of the parameter estimation results obtained by the least squares method, and we hope to apply this method to the simulation of actual data.

Shape and stability of stationary solutions for the 1D Gray-Scott model

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We are interested in spatial patterns of the following the 1D Gray-Scott model (P. Gray and S.K. Scott, Science, **38**, (1983), Science, **39**, (1984)):

$$
\text{(TP)}\begin{cases} u_t = d_1 u_{xx} - uv^2 + F\cdot(1-u) & \text{in } (0,1)\times(0,\infty),\\ v_t = d_2 v_{xx} + uv^2 - v\cdot(F+k) & \text{in } (0,1)\times(0,\infty),\\ u_x(0,t)=u_x(1,t)=0, \quad v_x(0,t)=v_x(1,t)=0 & \text{in } (0,\infty),\\ u(x,0)=u_0(x), \quad v(x,0)=v_0(x) & \text{in } (0,1), \end{cases}
$$

where $u=u(x,t),\ v=v(x,t)$ are unknown functions, and $d_1,\ d_2,\ F,\ k$ are positive constants. This model represents the autocatalytic chemical reaction U + 2V $\to$ 3V, V $\to$ P. J.E. Pearson (Science, **261**, (1994)) showed various spational-temporal patterns by calculating this model numerically. D. Ueyama(Hokkaido Math. J., **28**, (1999)) studied the self-replicating patterns that is observed in the model from a global bifurcational view point, and they showed a mechanism that pulses are replicated. However, it is not clear that the shape of stationary solutions for each diffusion rate concerning self-replicating pattern. Thus, we investigate the following stationary problem:

$$
\text{(SP)}\begin{cases} 0 = d_1 u_{xx} - uv^2 + F\cdot(1-u) & \text{in } (0,1),\\ 0 = d_2 v_{xx} + uv^2 - v\cdot(F+k) & \text{in } (0,1),\\ u_x(0)=u_x(1)=0, \quad v_x(0)=v_x(1)=0, \end{cases}
$$

where $u=u(x)$ and $v=v(x)$ are unknown functions.

In this study, we have the following questions.

- What shape are the solutions of (SP)?
- What shape of solution will be stable?

We aim to answer these questions by investigating the global bifurcation structure of solutions of (SP). In this talk, we report numerical results of the structure of solution of (SP) with $F=0.022, k=0.051$ and $d_1=2d_2$.

This is the joint work with Tatsuki Mori (Musashino University).

Mathematical Modeling and Simulation of Droplet Motion

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Liquid droplets are familiar to our daily lives–raindrops, condensation on windows, and morning dew on leaves may come to mind. Yet, droplets are also widely used in industrial applications, ranging from cooling processes to the growth of nanowires. Therefore, understanding their shape properties is important. This research focuses on the mathematical modeling and analysis of scalar liquid droplets, and on developing approximation methods for use in numerical calculations. Since the droplet's boundary changes with variations of its shape, our model equation is a free boundary problem with a prescribed contact angle condition. This type of boundary condition imparts a significant challenge to the mathematical analysis, and to the development of numerical methods. We will consider droplets in a situation similar to that shown in the figure below. More precisely, our model equation becomes a volume-constrained gradient flow of an energy functional with obstacle, written $u_t = \Delta u + \lambda(u)$ in $\{u > 0\}$. In this talk, we will show how to overcome the difficulty of the free boundary condition by regularizing the delta and Heaviside functions within the energy functional, derive an approximation of the original free boundary problem, and show results of our numerical methods.

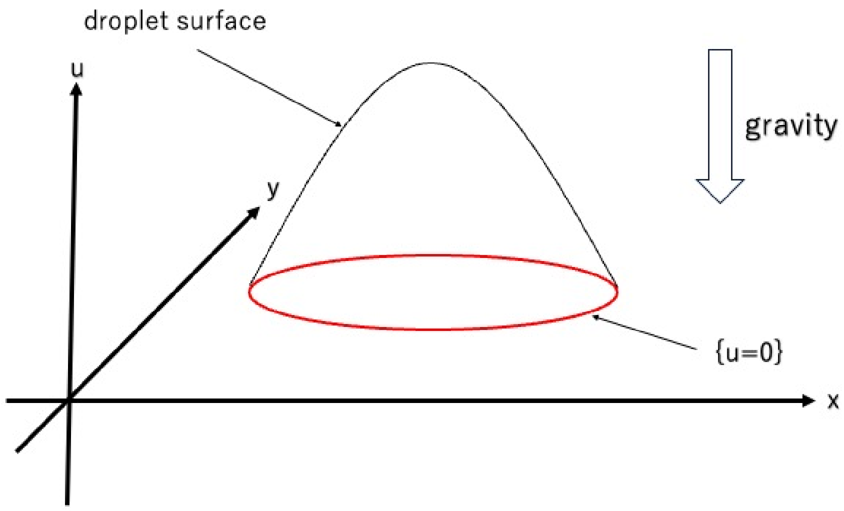

Fig.1　A scalar droplet

3D Point Clouds Semantic Segmentation Using Visual-Language Models

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In recent years, Visual-Language models have become a popular method for image classification and semantic segmentation. Through Contrastive Language-Image Pre-training method, these models demonstrate superior image segmentation capabilities and strong generalization. In this talk, we aim to leverage the segmentation capabilities of 2D visual-language models for the task of 3D point cloud segmentation. To this end, we employ a 3D-2D-3D approach to convert 3D point clouds into 2D images, perform semantic segmentation using visual-language models, and then project the results back into 3D point clouds. We will also discuss experimental results and further applications.

Mathematical modeling of Proneural Wave on growing domain

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Drosophila is a model organism that has been well studied because of its ease of genetic manipulation. In the visual center of Drosophila larvae, the propagation of differentiation from undifferentiated cells (NE) to differentiated cells (NB) has been observed to occur continuously like a wave, and this phenomenon is called Pronerual Wave(hereinafter, this is called ”PW”) [1]. For clarification of the gene network, complementary studies between mathematical models and biological experiments have been conducted. Regarding the mathematical models of PW, spatially discretized model [2] and continuous model which retains the spatially discretized structures like size and shape of cells have been proposed [3].

A previous study has also been reported that the loss of Fat-Hippo signaling function which regulates cell growth and cell division caused the delay of NB differentiation and detectes in NE morphology [4]. However, how Fat-Hippo signaling and other signaling regulating PW interact with each other is an open question. Therefore, we aim to clarify how the Fat-Hippo signaling affects other networks by incorporating the effect of domain growth into the mathematical model.

In our presentation, we show reaction-diffusion system on domain that grows in only one direction and numerical simulation of the mathematical model of PW incorporating the effects.

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A previous study on fractional calculus

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The concept of fractional calculus was not realized overnight but has evolved and been refined over a long period. It challenges our traditional understanding of calculus by introducing the concept of fractional orders of differentiation and integration. This means that compared to traditional integer-order calculus, fractional calculus offers a more nuanced and comprehensive perspective when dealing with dynamic systems and nonlinear problems. In this representation, I'll briefly introduce the story behind the fractional calculus. It must carefully be defined, and fit with the original calculus when the order approaches to integers. Also, I'll show some propositions and protrait my future goal.

Analysis of Wealth Distribution in Japan via the Affine Wealth Model

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The widening economic inequality in developed countries, including the United States and Japan, is extended, which is a worldwide serious social issue. The yard-sale model extremely simplifies the mechanics of the economy into transactions of wealth between pairs of individuals[1]. Later, three social elements, wealth redistribution, wealth-attained advantage and debt, were added as parameters to the yard-sale model, which is called the affine wealth model and given by Eq.(1). Here, wealth redistribution means the flow of wealth from the rich to the poor. As shown in [2], the affine wealth model fits well with economic data of the United States. This result implies that the economic situation can be examined from parameter transitions. On the other hand, there is no research for Japanese economy situation. Thus, our aim in this study is to show that the wealth distribution of the affine wealth model agrees with real Japanese economic data by parameter fitting [Fig.1]. In this study, we use data on redistributed income for 1996 and 2021 and household assets for 2014 and 2019. Finally, we analyze Japanese wealth inequality based on the parameters.

$$\frac{d}{d\bar{w}}\left[\left(\bar{B}+\frac{\bar{w}^2}{2}\bar{A}\right)\bar{P}\right]=\chi(1+\Delta-\bar{w})\bar{P}-\zeta\left\{\frac{2}{1+\Delta}\left(\bar{B}-\frac{\bar{w}^2}{2}\bar{A}\right)+(1-2\bar{L})\bar{w}\right\}\bar{P}$$
$$\bar{A}(\bar{w}):=\int_{\bar{w}}^{\infty}d\bar{x}\,\bar{P}(\bar{x}),\quad \bar{L}(\bar{w}):=\frac{1}{1+\Delta}\int_0^{\bar{w}}d\bar{x}\,\bar{P}(\bar{x})\bar{x},\quad \bar{B}(\bar{w}):=\int_0^{\bar{w}}d\bar{x}\,\bar{P}(\bar{x})\frac{\bar{x}^2}{2} \tag{1}$$

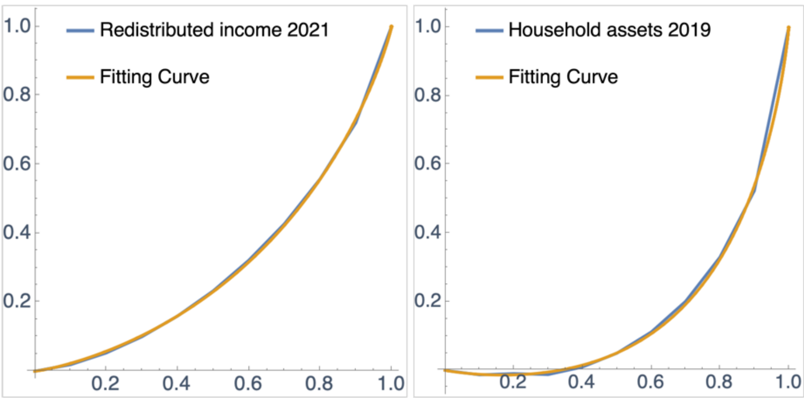

Figure 1: Lorenz curve fit of Japanese economic data.

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Inverse Scattering Problem for Piecewise Constant Coefficients using Deep Learning Algorithm

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Abstract

In this talk, we are interested in determining the piecewise constant coefficients of the inhomogeneous medium from the acoustic wave scattering with sound-soft obstacles. The main idea is to use deep learning algorithms to set the far-field pattern of the scattering field and the piecewise constant coefficients of the inhomogeneous medium to train a model. Through this model, we can obtain the coefficients of the inhomogeneous medium in any far-field pattern of the scattering field.

Mathematical analysis of time-fractional diffusion equation with a nonlinear boundary condition

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We consider the following a time-fractional diffusion equation with a nonlinear boundary condition.

$$(P) \qquad \begin{cases} {}_0^cD_t^\alpha u = \Delta u & \text{in } \mathbb{R}^N_+ \times (0,\infty), \\ u(x,0) = \psi(x) & \text{in } \mathbb{R}^N_+, \\ -\partial_{x_N} u = u^p(x,t) & \text{on } \partial\mathbb{R}^N_+ \times (0,\infty), \end{cases}$$

where $N > 4$, $p > 1$, $\alpha \in (0,1)$ and $\psi(x) \in L^1(\mathbb{R}^N_+) \cap L^\infty(\mathbb{R}^N_+)$. Here ${}_0^cD_t^\alpha$ is a Caputo derivative. Also, we rewrote initial-boundary problem (P) into

$$u(x,t) = \int_{\mathbb{R}^N_+} \{Z(x-y,t) + Z(x-y_*,t)\}\psi(y)ds$$
$$+ \int_0^t \int_{\partial\mathbb{R}^N_+} \{Y(x-y,t-s) + Y(x-y_*,t-s)\}u^p(y,s)d\sigma_y ds.$$

In this talk, we introduce properties of fundemental solutions of (P) and we show the existence of global-in-time solutions of (P) in case of $p > 1 + 1/N$. Here $Z(x,t)$ and $Y(x,t)$ is fundamental solutions of (P). Due to properties of fundamenrtal solutions, it is necessary to separate the calculations with attention to integrability.

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Few-shot learning for identifying abnormal vocal signals by YAMNet and transfer learning.

Chien-Feng Chen (National Cheng Kung University)

Abstract

In recent years, AI technology has become an essential tool in medicine. However, the accuracy and precision of AI technology in medical audio recognition are still in the development stage, especially in cases where data collection is insufficient, such as patients with rare diseases. Therefore, we hope to use few-shot learning combined with deep learning technology to identify abnormal audio signals of diseases. The data used in this study comes from recordings of patients at the National Cheng Kung University Hospital. Each patient's recording is 100 seconds long and is used as one piece of data. Currently, we have collected recordings from 14 patients and 14 people with normal voices, with an equal distribution of 14 males and 14 females. We used the Google open-source model YAMNet (Yet another Audio Mobilenet Network) and trained it using transfer learning. We first processed the audio to increase the amount of data. Each piece of data was divided into windows of 0.975 seconds, with a sliding window sampling method and a 99% overlap between each window. This allowed us to train a model with higher accuracy using data from fewer patients. During the experiment, we found that for a third of patient recordings, the first half of the audio was more difficult to distinguish by the human ear and required the assistance of the model for identification. It is best to record audio in a low-noise environment to ensure the accuracy of the results. This study will help us further improve the application of AI technology in medical audio recognition and provide a certain reference basis for the future medical field.

A motion model of spherical microorganisms under free boundary conditions

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Fluid flow around microorganisms can be described by the Stokes equation since the Reynolds number is small. Therefore, the equation can be solved analytically by appropriately setting the continuity equation and boundary conditions, but on the other hand, the complexity of the solution is lost. This point can be resolved by considering the complexity of the boundary conditions. In the case of complex boundaries with deformations and movements, free boundary conditions are generally applied, where the boundary is treated as an unknown function. Free boundary conditions are force balance and kinematic condition. If $(\sigma_{rr}, \sigma_{r\theta})$ is the stress vector of microorganisms, (u_r, u_θ) is the velocity vector, p is the pressure, μ is the viscosity, $E(\boldsymbol{u})$ is the deformation velocity tensor, $\boldsymbol{n}$ is the normal vector, $\boldsymbol{t}$ is the tangent vector and η is the shape of microorganisms, the force balance is

$$\sigma_{rr} = p - 2\mu E(\boldsymbol{u})\boldsymbol{n} \cdot \boldsymbol{n}, \qquad \sigma_{r\theta} = -2\mu E(\boldsymbol{u})\boldsymbol{n} \cdot \boldsymbol{t}, \tag{1}$$

and the kinematic condition is

$$u_r = \frac{\partial \eta}{\partial t} + \frac{u_\theta}{r}\frac{\partial \eta}{\partial \theta}. \tag{2}$$

The problem is that these are nonlinear and thus difficult to handle. Therefore, Lighthill and Blake developed the Squirimer model of spherical microorganisms' model. In this model, the shape of the boundary is given in advance by the flow velocity, thus avoiding nonlinearity. There have been many studies on the Squirmer model. Nonetheless, to the author's knowledge, there are no studies that address the nonlinearity of free boundary conditions.

In this study, the goal is to construct a model of the movement of spherical microorganisms under free boundary conditions and to compare the analytical and numerical solutions with the Squirmer model. The analytical comparison shows that the propulsive distances are consistent under the linear approximation. Numerical comparison suggests that the numerical solutions are similar when the spherical microorganisms are subjected to small deformations and not so similar when they are subjected to large deformations.

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Non-monotone travelling wave solutions for the n-species Lotka–Volterra competitive system with diffusion

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This talk is about the n-species Lotka–Volterra competitive system with diffusion. It is fundamental to research the traveling wave solutions to understand the dynamical system. We successfully show the existence of non-monotone pulse-front travelling waves connecting two equilibria $(0, 0, \cdots, 0)$ and $(1, 0, \cdots, 0)$. These waves play an important role in ecology and may motivate us to explore other interesting phenomena in the Lotka–Volterra system. Our approach to prove the existence of traveling waves is based on a method by applying Schauder's fixed point theorem with the help of suitable upper-lower solutions. One of our main breakthroughs is the construction of such appropriate upper-lower-solutions for the competition system. We also apply the idea of shrinking rectangles to the derivation of the asymptotic behavior of the right-hand tail. Moreover, by proving the non-existence of traveling wave solutions with speed less than the critical value s^*, we characterize the minimal speed s^* of the traveling waves for this model.

Pulsating Traveling Wave of the Mitchell-Schaeffer Model

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2024/2/10

Abstract

This study investigates the pulsating traveling wave of the Mitchell-Schaeffer model. The Mitchell-Schaeffer model is a mathematical model that describes the dynamics of cardiac action potentials. Numerical simulation of this model with periodic boundary condition shows a pulsating traveling wave solution, which is a time-periodic deformation of a pulse-type traveling wave solution by pulse-to-pulse strong interaction. We investigate the singular limit problem of the modified Mitchell-Schaeffer model and present a pulsating traveling wave numerically. This is based on a joint work with H.Ninomiya.

Name : Yu–Hsuan Tai
School : National Taiwan University

Title : Simulation and Application of Variational Inference

Abstract:

Variational inference is a method used in Bayesian inference to approximate complex posterior distributions.
This presentation will focus on key concepts such as the variational family, evidence lower bound (ELBO), and the optimization parameter process.
Finally, we will demonstrate the results and simple applications of variational inference using a Gaussian mixture model.

Presence of Dirac points in the diamond crystal

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The purpose of this research is to describe the branching of energy functions of crystals in quantum mechanics by means of a geometric method. Especially, we focus on Dirac points in the diamond crystal. A wave vector $\mathbf{k}$ is a Dirac point if the energy function is expressed as a 3-dimensional cone in a neighbourhood of $\mathbf{k}$ by a transformation of variables. In order to construct energy functions in the tight-binding model, we use a method of a base graph due to Sunada. The base graph of the diamond crystal is considered as a 3-dimensional version of the base graph of the graphene, which has 2-dimensional honeycomb structure. In general, we show that the branching of energy functions of crystals appears at singular points of orbifolds. By using this method, we detect Dirac points of the diamond crystal.

A Refinement Method for Blow-up Solutions to the Energy-Subcritical Semilinear Heat Equation

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We consider the semilinear heat equation

$$u_t = \Delta u + u^p,\ p > 1,\ x \in \mathbb{R}^d,\ d = 1, 2.$$

Based on the scaling invariance of the problem, we develop a refinement method whose numerical solutions are in agreement with theoretical results. The main findings of the results are presented using MATLAB.

Spatio-temporal Dynamics on Bioconvection of Euglena under Periodic Light Illumination

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Euglena, which is photosynthetic microorganisms, forms spatiotemporal patterns called bioconvection under light illumination from the bottom. The convection pattern originates from negative phototaxis of *Euglena*, which is directional swimming toward away from a light source. In this study, we investigated how the bioconvection pattern of *Euglena* responds periodic change in the light intensity. Here, the light intensity was alternated 2500 lux and 0 lux with 20 s in the period, namely square wave light illumination. The ratio of bright period was varied from 0.05 to 0.95. As control, the bioconvection under the constant light whose intensity was set to the average of periodic one is also observed. The results showed that pattern formation was slower under periodic light than under steady light (Fig. 1). Next, we observed the effect of periodic light on the individual movement of the *Euglena*. Our observation indicated that suddenly increase in the light intensity induced rotation of *Euglena* in the place. This is due to the unique light responsiveness of *Euglena*, in which tumbling occurs with increasing light intensity. From these results, we propose a mechanism for pattern formation of bioconvection in *Euglena* under periodic light.

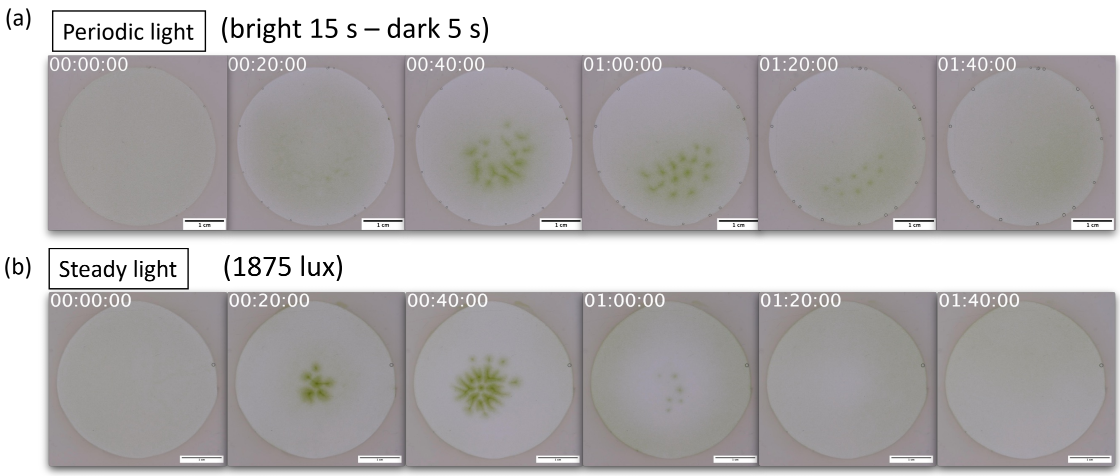

Figure 1. Time series of images of bioconvection under (a) periodic and (b) steady light.

Traveling Waves Induced by Precipitation and Re-dissolution Reactions

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Aluminum ion reacts to hydroxide ion and produces a precipitate, which re-dissolves under high pH condition. Therefore, traveling a precipitate band is observed by adding a high pH solution onto a gel including aluminum ion. It is known that defects are induced on the precipitate band and spiral waves are formed [1]. The detail mechanism of defect formation and propagation is not yet known. In this study, in order to clarify the mechanism of defect formation and propagation on the precipitate bands, gel free system was newly adopted. In this system, aqueous solutions of aluminum chloride and sodium hydroxide were put into a narrow space, where convection was prevented, and made contact (Figure 1). Because of gel free condition, high concentration of aluminum solution could be prepared. As the results, no defects were observed with aluminum ion solution lower than 0.2 M. Additionally, the traveling speed decreased with the increase in the aluminum ion concentration and approached to zero higher than 0.8 M.

According to experimental results, the amount of defect precipitation increased with increasing concentration. Hence, the precipitates may have an inhibitory effect on ion diffusion. In other words, this precipitate may have a property that makes it difficult to re-dissolve, preventing the reaction.

A mathematical model has already been proposed for this phenomenon [2]. However, in this model, the production of defects did not originated from element process of the chemical reactions. Therefore, according our observation, we also aim to create a mathematical model that capture the essence of the phenomenon.

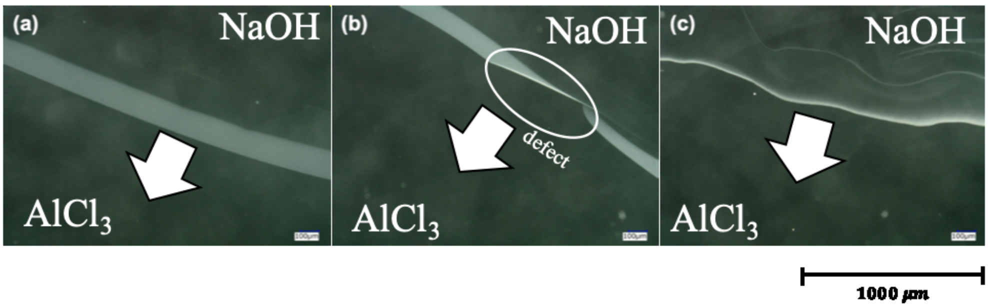

Figure 1: Snapshot of the precipitation bands.
Aluminum ion concentration was (a)0.1 M, (b)0.3 M, and (c)0.4 M

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A numerical analysis approach to algorithms for continuous optimization problems

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Some algorithms for continuous optimization problems can be regarded as numerical methods for solving their underlying ordinary differential equations. For example, the steepest descent method can be interpreted as an explicit Euler method applied to the gradient flow. In 2022, Ushiyama, Sato and Matsuo [1] constructed an efficient optimization method based on certain numerical method with extremely wide stability domain. In this talk, we introduce their analysis method and show some numerical examples for convex and non-convex optimization problems.

First, let us consider an unconstrained optimization problem as follows:

$$\min_{x \in \mathbb{R}^d} f(x)$$

where f is differential and L-smooth. This optimization problem can be solved using the steepest descent method:

$$x_{k+1} = x_k - h_k \nabla f(x_k) \quad (k = 1, 2, \cdots).$$

From the numerical perspective, the steepest descent method can be regarded as the explicit Euler method for the gradient flow $\dot{x} = -\nabla f(x)$. Numerical analysis for ordinary differential equations deals with step size conditions for the sake of stability [2]. The largest step size h_k is determined by the set which is called "stability domain". The domain with such a feature can be realized by Chebyshev polynomials. It is possible to propose a method that allows for the use of a larger step size than the steepest descent by using Chebyshev polynomials .

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On the Role of Asymmetric Dispersal Rates in a Multi-Strain SIR Model in Patchy Environment

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This talk explores the impact of dispersal rates in a multi-strain SIR model within a patchy environment, focusing on the competitive dynamics among strains. Our study investigates the competitive relationship among strains and establishes a connection between epidemic models and the ecological theory. Building upon the work of [1], we prove that there exists an evolutionarily stable dispersal rate, which determines the victorious strain under suitable conditions. Additionally, we have established the existence and stability results of the coexistence equilibrium.

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A finite difference method and its error estimate for a system of nonlinear Klein-Gordon equations

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We consider the following of nonlinear Klein-Gordon equations with periodic boundary condition :

$$\begin{cases} u_{tt} - u_{xx} + \alpha u + \beta v^{2p} u = 0 & 0 < x < 1, \quad t \in \mathbb{R}^+, \\ v_{tt} - v_{xx} + \gamma v + \beta p v^{2p-1} u^2 = 0 & 0 < x < 1, \quad t \in \mathbb{R}^+, \\ u(0,t) = u(1,t), \quad v(0,t) = v(1,t), & t \in \mathbb{R}^+, \end{cases} \tag{1}$$

where $u = u(x,t)$ and $v = v(x,t)$ are real valued unknown functions and $p \in \mathbb{N}$, α, β, γ are positive constants. In fact, (1) has the following energy conservation property:

$$\frac{dE}{dt}(t) = \frac{d}{dt} \int_0^1 \{ (u_t)^2 + (u_x)^2 + \left(\alpha u^2\right) + \left(\beta v^{2p} u^2\right) + (v_t)^2 + (v_x)^2 + \left(\gamma v^2\right) \} dx = 0.$$

Take a positive constant τ and a positive integer M and set $x_j = jh, h = 1/M$. Then, our scheme to find $u_j^n \approx u(x_j, t_n)$ and $v_j^n \approx v(x_j, t_n)$ read as

$$\begin{cases} \left(u_j^n\right)_{t\bar{t}} - \dfrac{1}{2}\left(u_j^{n+1} + u_j^{n-1}\right)_{x\bar{x}} + \dfrac{\alpha}{2}\left(u_j^{n+1} + u_j^{n-1}\right) + \beta \left(v_j^{n+1}\right)^{2p} \left(\dfrac{u_j^{n+1} + u_j^{n-1}}{2}\right) = 0 \\ \left(v_j^n\right)_{t\bar{t}} - \dfrac{1}{2}\left(v_j^{n+1} + v_j^{n-1}\right)_{x\bar{x}} + \dfrac{\gamma}{2}\left(v_j^{n-1} + v_j^{n-1}\right) \\ \quad +\beta \left(u_j^{n-1}\right)^2 \left(\sum_{i=1}^{p} \left(v_j^{n+1}\right)^{p-i} \left(v_j^{n-1}\right)^{i-1}\right) \left(\frac{\left(v_j^{n+1}\right)^p + \left(v_j^{n-1}\right)^p}{2}\right) = 0 \end{cases}$$

where $(u_j^n)_{t\bar{t}} = \frac{u_j^{n+1} - 2u_j^n + u_j^{n-1}}{\tau^2}$ and $(u_j^n)_{x\bar{x}} = \frac{u_{j+1}^n - 2u_j^n + u_{j-1}^n}{h^2}$. We define a discrete counter part E^n of $E(t_n)$ and show that $E^n = E^{n-1}$ when our scheme has a solution (u_j^n, v_j^n) under the periodic boundary condition. Moreover, we prove that the our scheme converges to the exact solution of (1) as the discretization parameters tend to zero. Several numerical examples that confirm the validity of our theoretical results are also offered.

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Global solver for Geman-McClure robust rotation estimation with outlier rejection

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Abstract

Rotation estimation with outlier rejection is a fundamental problem with many applications in computer vision, pattern recognition, and robotics. However, it is difficult to guarantee global optimality of estimation results due to the non-convexity of $\mathrm{SO}(n)$. In addition, outlier rejection often introduces other non-convexity to the optimization problem. In this talk, we propose a fast solver for robust rotation estimation via Geman-McClure cost function with convex linear relaxation. We will discuss the optimality of the proposed method in theoretical part, and show our results against other state-of-the-art techniques in point cloud registration.

Onset of intragroup conflict in a generalized model of social balance

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Dynamically changing interpersonal relationships lie at the core of the emergence of in-group structures, such as polarity or conflict. We explore these dynamics in a simple continuous dynamical model based on Heider's balance theory. Previous theoretical findings include a rigorous proof of the emergence of in-group harmony or bipolar conflict (global minima) and the identification of local minima called *jammed states*, along with their corresponding energy spectrum in terms of structural complexity. However, some unrealistic scenarios constrain our capacity to contextualize and directly apply these results to real-world social behaviors. To address these challenges, we first introduce a unified dynamical model and find that group size can be critical to the onset of in-group bipolar conflict. Using random matrix statistics, we then characterize pathways to jammed states—a topic that has gained little attention to date most likely because jammed states have previously been discussed only in stochastic models. In a surprising twist, we also show that perturbing our dynamical model can yield an *increased* number of jammed states, giving rise to the novel notion of "noise-induced jammed states." We finally address possible real-world implications as well as suggest potential contributions to the existing literature in related fields such as anthropology and archaeology.

Title: Bernstein-von-Mises theorem, Bayesian method, in EIT inverse Problems
Speaker: YU CHEN XIAO
This talk investigates the application of Bayesian inference in Electrical Impedance Tomography (EIT), including methods for selecting prior models and parameter estimation. By integrating prior knowledge with observed data, this approach offers a wide and flexible framework for estimating conductivity distributions. Furthermore, we validate the results of the Bernstein-von Mises theorem in Bayesian inference, which provides useful insights into the asymptotic behavior of posterior distributions. We demonstrate the effectiveness and reliability of Bayesian methods in EIT inverse problems through numerical simulations: as the number of observations (N) increases, Bayesian methods become increasingly accurate, and the projection of the posterior distribution approaches a Gaussian distribution (Bernstein-von Mises theorem). Finally, we compare our results with those obtained using Ensemble Kalman filter methods. These research findings are significant for optimizing EIT system design and improving imaging accuracy.

Mode-switching of Self-propelled Camphor Disks depending on the Number Density

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Camphor disk is one of a typical self-propelled particle sliding on a water surface. It is known that the camphor particles show three types of motions depending on the number density, which are continuous motion, oscillatory motion, and stop [1]. As the first step to analyze this complex phenomenon, a single particle system was investigated, where the surface area of water phase (A) and the diameter of particles (ϕ) were varied to control number density and the same transitions were observed [2]. Additionally, a mathematical model has been suggested, and the mechanism of oscillatory motion has been clarified. As the next step, the mathematical model is required to be applied to the multi particles system. Here, in order to clarify the effect of number of camphor disk N, we observed the behaviors of two camphor particles, namely, $N = 2$ system. Our experimental observation indicates that continuous motion (Fig.1) changed to oscillatory motion with overcoming a critical value of $N\phi/A$. This means that the bifurcation from continuousness to oscillation is controlled by supply rate of camphor molecule from disks to the water surface. Furthermore, the amplitude of oscillatory motion linearly decreased with the increase in $1/L$, where L is the diameter of water surface. It indicates that the transition from oscillatory motion to stop is controlled not only by supply rate but by freely movement distance. Now we have been in the way to examine the oscillatory mechanism with those results.

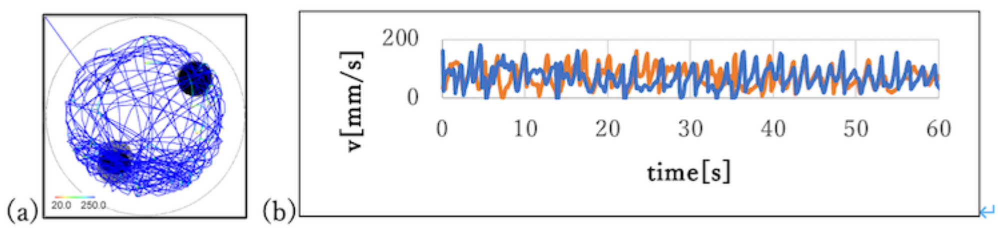

Figure 1. (a) Trajectory of continuous motion of camphor disks and (b) speed profiles.

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Cluster Formation of Self-propelled BZ Droplets

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It is known that an aqueous droplet of bromine solution spontaneously moves into an oil phase containing a surfactant, monoolein (MO). The bromine reacts to MO and produces bromo-monoolein (BrMO), which induces gradient of interfacial tension resulting in self-propelled motion. While a droplet exhibits random movement, multiple droplets leads cluster formation.

In this study, to control the internal chemical condition of droplet, the Belousoh-Zhabotinsky (BZ) reaction was introduced into the droplet. We monitored the formation and collapse of clusters with change in the concentration of sulfuric acid, the oxidant in the BZ. The findings indicate that the concentration of sulfuric acid does not significantly impact the timing of cluster formation and collapse. Clusters form rapidly and collapse over an extended period. Moreover, droplets were observed to engage in a rotational movement during cluster formation.

Based on these observations, we propose the following mechanism for cluster formation and collapse:

1. When multiple droplets are present, the region between the droplets harbors the highest concentration of BrMO. This induces a flow that brings droplets closer together, resulting in cluster formation.

2. The formed cluster depletes the surrounding MO while in rotation.

3. After a certain time, the MO concentration around the cluster stabilizes, the attractive interaction vanishes, and the inherent random movement of the droplets prevails, leading to the probabilistic dissolution of the cluster.

This research elucidates the mechanism behind cluster formation in self-propelled BZ droplets. In the future work, we intend to conduct experiments with varying concentrations of bromine and MO.

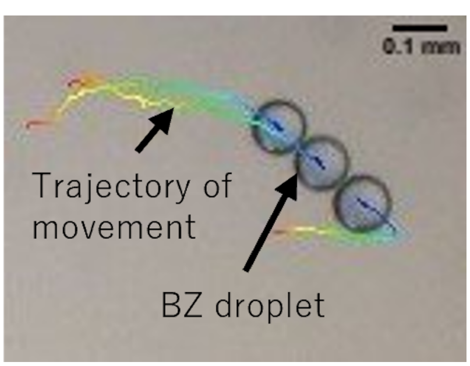

Figure 1. Cluster formation of self-propelled BZ droplets and trajectory of movement.

Comparsion of CNNs and Capsule Networks for CAPTCHA recognition

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Abstract

In this talk, we give a brief introduction to CNNs and Capsule Networks first. Then we compare their accuracy in predicting CAPTCHA under various conditions. In particular, we focus on the differences between the two algorithms for certain specific letter recognitions. Finally, we discuss possible applications to medical images.

Numerical simulation of breaking ball

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Abstract

The author started playing baseball in elementary school and wondered why a breaking ball bends as he acquired skills. As an undergraduate student, he performed numerical simulations of air flow around a cylinder in two-dimensional space using FreeFEM++ software, so he decided to perform numerical simulations in three-dimensional space, which is closer to reality. Because of the three-dimensional space, in addition to the direction of rotation, the axis of rotation must also be considered. Therefore, we collected data on ball speeds and rotation rates of professional baseball players, rotation efficiency, which represents the effect of rotation on the trajectory of the ball, and the direction of rotation, which is represented as a clock, as measured by a measuring device called PITCHING2.0. The horizontal tilt angle of the axis of rotation was defined as the azimuth angle, and the vertical tilt angle as the elevation angle, which were calculated using the rotational efficiency and direction of rotation, respectively. The axis of rotation with a clean backspin in the direction of travel was taken as the initial state, and the axis of rotation was rotated using the rotation matrix in the vertical and horizontal directions, in that order. This enabled us to simulate a wide variety of changeable pitches. However, a problem arose with the computational mesh. In the case of this study, the Reynolds number, which represents the effect of fluid viscosity, is large, approximately 1.5×10^5, so a fine computational mesh is required. However, if the mesh was made too fine, the calculation stopped in the middle. Therefore, the size of the mesh and the computational domain were adjusted so that the computation would continue to the end, but because the mesh was not fine enough, it was not clear whether the numerical calculations were being performed correctly. However, the effect of the rotation and the change in trajectory due to the inclination of the axis were observed. It was confirmed that aerodynamic drag increases as the ratio of gyro spins, which are rotations perpendicular to the direction of travel, increases. It was also confirmed that aerodynamic drag increased as the number of rotations of the gyro spin increased. Based on these results, we reproduced the straight pitches of nine pitchers and the breaking pitches of six pitchers. We were able to confirm that the trajectory of the ball changed depending on the tilt of the axis of rotation and the number of revolutions, as the horizontal change changed with the vertical tilt of the axis of rotation and the vertical change with the horizontal tilt of the axis of rotation. However, there were some differences from the actual trajectory of the ball, and we would like to deepen our understanding of numerical calculation methods for high-Reynolds-number phenomena in the future.

Relativistic Euler Equations

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In this talk, we discuss the relativistic Euler equation. We first review the basic knowledge of special relativity, the Euler systems and shock waves. Then, we focus on the problem of normal shock waves for the Euler equations and the relativistic Euler equations. We obtain similar results for supersonic flows.

An inhomogeneous boundary value problem for the Lane--Emden equation on a cone

Sho Katayama (University of Tokyo)

This talk is concerned with a boundary value problem for the Lane–Emden equation

$$-\Delta u = u^p \quad \text{in} \quad \Omega, \quad u > 0 \quad \text{in} \quad \Omega, \quad u = \kappa\mu(x) \quad \text{in} \quad \Omega. \tag{P}$$

Here $p > 1$, $\kappa > 0$, and $\Omega = \{r\theta \in \mathbb{R}^N : \ r > 0, \theta \in A\}$, $A \subset S^{N-1}$, is an infinite cone. Under a suitable assumptions on a nonnegative non-zero function μ on $\partial\Omega$ and the exponent p, we give a complete classification of the existence and non-existence of solutions to problem (P). We also obtain a result on the existence of multiple solutions to problem (P) via bifurcation theory.

Self-similar solutions of the relativistic Euler system with spherical symmetry

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The relativistic Euler system is an important model in astrophysics, plasma physics, and nuclear physics. In our works, we consider the spherical piston problem in relativistic fluid dynamics. Based on the assumption of self-similarity, the problem can be transformed into an initial value problem of the ODE system with appropriate boundary conditions. In this presentation, I will introduce the self-similarity phenomenon and discuss the self-similar solutions of the spherical piston problem with relativistic effects.

Well-posedness Problem Of The General KdV Equation

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In this talk, we will address the local well-posedness issue of the initial boundary value problem for the general KdV equation in one dimension.

As is well known, the initial value problem of the KdV equation can be addressed through the inverse scattering method. However, the subsequent challenge lies in handling the initial boundary value problem of the KdV equation. A fundamental question arises: how to address the linear KdV equation on a half-line or, more generally, on an interval? A. Fokas proposed a method to address such issues, which is now known as the unified transform method or Fokas method.

First, I will use the unified transform method to derive the solution formula to the initial boundary value problem of the linear KdV equation. Then, utilizing the contraction mapping theorem, we obtain the solution for the nonlinear equation.

Quenching for axisymmetric hypersurfaces under forced mean curvature flows

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In my talk, we consider the motion of axisymmetric hypersurfaces $\{\Gamma_t\}_{t\geq 0}$ evolved by forced mean curvature flows in the periodic setting. We establish conditions that quenching occurs or does not occur in terms of the initial data and forcing term. I will explain mainly about an a priori estimate and how it used.

A General Semi-parametric Distribution Model with Latent Group-specific Indices

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This study introduces a groupwise semi-parametric distribution model to identify subgroups characterized by heterogeneous indices. We propose a novel method that combines the pseudo sum of integrated least squares and pairwise fusion penalties for the estimation of subgrouping partition and index coefficients. A semi-parametric information criteria is utilized to aid in selecting the number of clusters. A classification rule is further constructed for assigning group membership to new observations lacking response variable information. Under mild conditions, we establish the consistency of our estimated group structure and the asymptotic equivalence between our proposed estimator and the oracle estimator for group-specific regression coefficients. In terms of implementation, we modify the alternative direction method of multipliers algorithm to emphasize its favorable convergence characteristics and incorporate warm-start initial values. An effective divide-and-conquer strategy is also introduced to manage numerous observations efficiently, reducing computational demands while fitting the pairwise fusion penalized distribution model. The applicability of our methodology is illustrated through comprehensive simulation studies and empirical data analyses.

Barchan movement by the sand supply using crest line model

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In desert areas, dunes often approach the city, and they cover roads and railways. It causes tremendous damage. The elucidation of the basic mechanism and the prediction of the movement of barchan by mathematical model can be useful for disaster prevention. Barchans, dealt with in this research, are croissant-shaped dunes observed in desert fields with little sand and a constant seasonal wind direction. Barchans have a part called horns on the leeward side, and sand flows out from them. Barchan exists in a group, so the exhaled sand is supplied to another barchan on the downwind side. When considering the movement mechanism of barchan, it is important to take into account the interaction between barchans due to such a flow of sand. As previous research, using a cell model that calculates the movement of sand for each grid of the field, if one supplies the same amount of sand as the flowed out sand from the barchan to a point apart from the center axis on the windward side, the peak of barchan moves laterally and finally reaches the source of sand keeping the shape of the parabolic shape[1]. However, in the cell model, it is not possible to consider the dynamics of barchan movement or to obtain a mathematical solution to it.

Therefore, we tried to reproduce the barchan movement by supplying sand with the crest line model[2], which is a minimal model that can be analyzed mathematically. As a result, with the crest line model, it also reproduces the barchan's top approaching the source of sand smoothly while maintaining its shape, just like the cell model. This result can be applied to the mathematical solution of the barchan movement by sand supply and the consideration of the collision between the barchans.

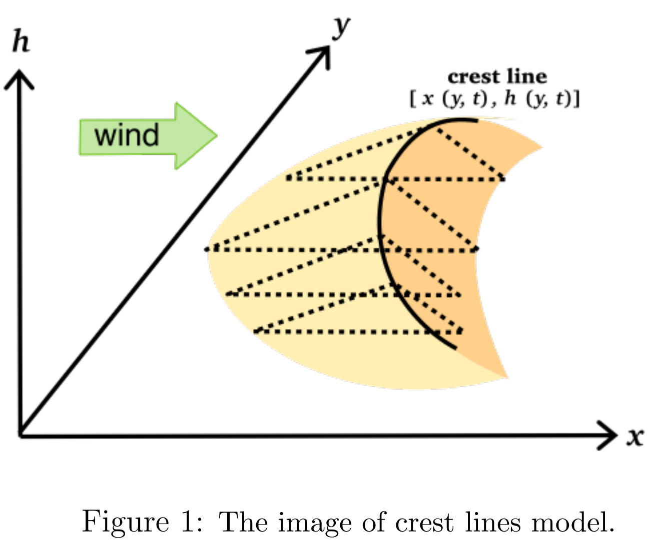

Figure 1: The image of crest lines model.

Reference

[1]A. Kastuki, et al., Simulation of barchan dynamics with inter-dune sand streams, New Journal of Physics (2011)
[2]L. Guignier, et al., Sand dunes as migrating strings, Physical Review E (2013)

Hexahedral Mesh Generating for Complex Models.

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The Hexahedral mesh is an evolving technique within the Finite Element Modeling (FEM) framework, offering a streamlined alternative to the traditional tetrahedral mesh by utilizing fewer nodes and elements for equivalent spatial discretizations. This presentation will explore various methodologies for hexahedral mesh generation, primarily focusing on a transition from tetrahedral to hexahedral meshes-termed as the "remeshing" process.

A notable approach, the "Frame-Field Guided" method, will be highlighted for its strong reliance on the geometric characteristics of the modeled objects, ensuring the preservation of essential geometric features. Despite its promising capabilities, this technique is in its nascent stages, with successful application limited to a subset of standard datasets.

Furthermore, the presentation will discuss the adaptation of a cutting-edge open-source tool for constructing a hexahedral mesh representation of a brain model. Although the outcomes are yet to reach perfection, they lay a solid foundation for future advancements in this domain.

In summary, we will evaluate the advantages and challenges of the "Frame-Field Guided" hexahedral mesh generation method and illustrate its practical application through a case study involving a brain model. The discussion aims to shed light on the current state and future directions of hexahedral meshing in FEM applications.

Reconstructing underlying network from observed 2-mode clustering pattern using nonlocal monostable equation with sign-changing kernel

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Estimating a network structure from observed patterns is a common challenge in many scientific situations. The process of determining network topology can be time-consuming, especially when dealing with complex systems. In this study, we focus on understanding the underlying network structure of the clustering pattern on an unknown network. We consider a nonlocal reaction-diffusion process on the network, which is mathematically modelled by the nonlocal reaction-diffusion equations (NRD). NRD consists of the nonlocal diffusion term and the local reaction term. The network topology in this context is equivalent to the graphon, the realization of the adjacency matrix of the network as a function. The graphon plays a role as an integral kernel of the nonlocal diffusion operator in NRD.

Suppose that we observe a scalar value on each node, with node sets divided into two-mode clusters as a result of an activator-inhibitor process on the network, such as the nonlocal FitzHugh-Nagumo model (NFHN). The scalar-valued distribution might be the observation of the activator variables. It is known that NFHN has heterogeneous steady states corresponding to two-mode clustering. With a significant difference in the diffusion coefficients of the activator and inhibitor, NFHN is adiabatically reduced to a scalar-valued equation, reduced nonlocal Fitzhugh Nagumo equation (rNFHN) [Carletti et al., Phys. Rev. E, 2020]. The nonlinearity of rNFHN is monostable with certain sets of parameters. Despite the reaction term's monostability, rNFHN exhibits two-mode clustering due to the coexistence of positive and negative spectra in the resulting nonlocality. Such nonlocality originated from the huge difference in the time scales of the diffusion of activators and inhibitors.

The aim of our research is to estimate the underlying network topology of observed two-mode clustering on an unknown network. Precisely, we construct the method to estimate the underlying unknown network topology of the original NFHN from some steady states of rNFHN. The method is divided into three steps. In the first step, we model the multi-edged nonlocal diffusion operator that represents the nonlocality of rNFHN from the given clustering pattern. This operator may have both positive and negative spectra. In the second step, we compute the nonlocal diffusion operator of NFHN, which realizes the clustering with rNFHN. NFHN's nonlocality is the solution to a certain operator-valued equation, which depicts the relationship between the nonlocality of rNFHN and NFHN. We rigorously prove the existence of the solution using Banach's fixed-point theorem. The final step involves computing the candidate network topology for NFHN. This work contributes to a better understanding of complex reaction-diffusion processes on networks and provides a valuable approach to uncovering hidden network structures from observed patterns.