# The 10th Japan-Taiwan Joint Workshop for Young Scholars in Applied Mathematics

## Program & Abstract

**February 27 – March 1, 2019**

**at Ryukoku University**

**Lecture Room 101, Building 8, Seta Campus**

## February 27 (Wednesday)

8:50–9:00 **Opening**

9:00-10:00 **Session 1** Chair: Shih-Hsin Chen (National Taiwan University)

- 9:00–9:15 Yusaku Shimoji (Meiji University, M2)
- 9:15–9:30 Po-Yu Lin (National Taiwan University, M2)
- 9:30–9:45 Ching-Lun Lu (National Cheng Kung University, M2)
- 9:45–10:00 Kana Mizuno (Shimane University, M2)

10:10-11:10 **Session 2** Chair: Shun-Chieh Wang (National Taiwan University)

- 10:10–10:25 Yuka Fukase (Meiji University, M2)
- 10:25–10:40 Takanori Kawase (Ryukoku University, M2)
- 10:40–10:55 Kazuki Ikeda (Meiji University, M2)
- 10:55–11:10 Yi-Ting Chen (National Chiao Tung University, M2)

11:20-12:20 **Session 3** Chair: Wei-Chen Chang (National Taiwan University)

- 11:20–11:35 Shota Yamakawa (Ryukoku University, M2)
- 11:35–11:50 Yuta Shimazaki (Meiji University, M2)
- 11:50–12:05 Po-Hsin Cheng (National Cheng Kung University, M2)
- 12:05–12:20 Hiroto Kawata (Meiji University, M1)
- 12:20–12:35 Yuma Watabe (Hiroshima University, M1)

12:35–12:45 **Group photo**

12:45–13:40 **Lunch**

13:40-14:55 **Session 4** Chair: Takahiro Hiraga (Hiroshima University)

- 13:40–13:55 Chengen Lee (National Taiwan University, M2)
- 13:55–14:10 Liu Yang (Northeast Normal University / Shimane University, M2)
- 14:10–14:25 Yi-Juan Du (National Chiao Tung University, M1)
- 14:25–14:40 Hiroaki Ishiyama (Ryukoku University, M2)
- 14:40–14:55 Le Nguyen Thuy Van (National Central University, M1)

15:15-16:30 **Session 5** Chair: Lorenzo Contento (Meiji University)

- 15:15–15:30 Wataru Makita (Ryukoku University, M1)
- 15:30–15:45 Kuan-Jhan Lin (National Taiwan University, M1)

15:45–16:00 Daichi Inoue (Meiji University, M1)

16:00–16:15 Fei-Hung Huang (National University of Tainan, M1)

16:15–16:30 Naoto Ichikawa (Shimane University, M1)

16:50-18:00 **Session 6** Chair: Chueh-Hsin Chang (Tunghai University)

16:50–17:00 Hiromu Gion (Shimane University, B4)

17:00–17:10 Yu-Kai Lin (National Central University, B3)

17:10–17:20 Miu Nodagashira (Ryukoku University, B4)

17:20–17:30 Pei-Shan Fang (National Cheng Kung University, B4)

17:30–17:40 Kaito Fujihara (Shimane University, B4)

17:40–17:50 Ming-Hsiu Lu (National Central University, B4)

17:50–18:00 Ryu Fujiwara (Meiji University, B4)

18:10–18:40 **Parallel discussion**

## February 28 (Thursday)

8:50–9:00 **Announcements**

9:00-10:00 **Session 7** Chair: Yung-Hsiang Huang (National Taiwan University)

9:00–9:15 Riku Kanai (Meiji University, M2)

9:15–9:30 Hiroki Komoto (Ryukoku University, M2)

9:30–9:45 Bing-Ze Lu (National Cheng Kung University, M2)

9:45–10:00 Yuki Yagasaki (Meiji University, M2)

10:10-11:10 **Session 8** Chair: Shunsuke Kobayashi (Meiji University)

10:10–10:25 Wen-Hao Yang (National Taiwan University, M2)

10:25–10:40 Yu-Yu Weng (National Tsing Hua University, M1)

10:40–10:55 Akira Machishaku (Ryukoku University, M2)

10:55–11:10 Mana Futamura (Meiji University, M1)

11:20-12:20 **Session 9** Chair: Huai-Hua Lu (National Taiwan University)

11:20–11:35 Eigo Fukada (Shimane University, M1)

11:35–11:50 Yuhei Sasai (Meiji University, M1)

11:50–12:05 Tomohiro Nakahara (Hiroshima University, M1)

12:05–12:20 Yuyuan Yuan (National Taiwan University, M1)

12:30–13:30 **Lunch**

13:30-14:30 **Session 10** Chair: Ryo Ito (Meiji University)

13:30–13:50 Wei-Chen Chang (National Taiwan University, D4)

13:50–14:10 Shunsuke Kobayashi (Meiji University, D2)

14:10–14:30 Huai-Hua Lu (National Taiwan University, D4)

14:50-16:10 **Session 11** Chair: Yan-Yu Chen (Tamkang University)

14:50–15:10 Yung-Hsiang Huang (National Taiwan University, D4)

15:10–15:30 Takahiro Hiraga (Hiroshima University, D1)

15:30–15:50 Shih-Hsin Chen (National Taiwan University, D4)

15:50–16:10 Shun-Chieh Wang (National Taiwan University, D1)

16:30-17:10 **Session 12** Chair: Yasufumi Yamada (Hiroshima University)

16:30–16:50 Ryo Ito (Meiji University, PD)

16:50–17:10 Lorenzo Contento (Meiji University, PD)

18:00–20:00 **Awards Ceremony and Party**

## March 1st (Friday)

9:30–18:00 **Free Discussion**

This workshop is sponsored by a project of Ryukoku Joint Research Center for Science and Technology, “Mathematical studies on emergence of localized patterns, propagations, cross-diffusion and non-local effect” (S. Yotsutani), and partially supported by Meiji University, Ryukoku Center for Mathematical Sciences, Mathematical Society of the Republic of China, Taiwan (TMS), National Center for Theoretical Science, Taiwan (NCTS), Ministry of Science and Technology, Taiwan (MOST), JST Presto, ”Multiphase shape optimization in phononic crystal design ” (E. Ginder), JSPS KAKENHI Grant-in-Aid for Scientific Research (B) Grant Number 16KT0022 (H. Ninomiya), 18H01139 (Y. Morita), Grant-in-Aid for Scientific Research (C) Grant Number 15K04972 (S. Yotsutani), Grant-in-Aid for Young Scientists (B) Grant Number 16K17629 (T. Kawakami), Grant-in-Aid for challenging Exploratory Research Grant Number 16K13778 (H. Ninomiya).

Organizers:
Tatsuki Kawakami (Ryukoku University)
Yoshihisa Morita (Ryukoku University)
Shoji Yotsutani (Ryukoku University)
Kota Ikeda (Meiji University)
Hirokazu Ninomiya (Meiji University)
Yuichi Togashi (Hiroshima University)
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Yung-Fu Fang (National Cheng Kung University, NCKU)
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Dong-Ho Tsai (National Tsing Hua University, NTHU)
Ming-Chih Lai (National Chiao Tung University, NCTU)
Chang-Hong Wu (National University of Tainan, NUTN)
Chueh-Hsin Chang (Tunghai University, THU)
Yan-Yu Chen (Tamkang University, TKU)

# Numerical computation of magnetic fluid instabilities in a Hele-Shaw cell with time-dependent gap by the method of fundamental solutions

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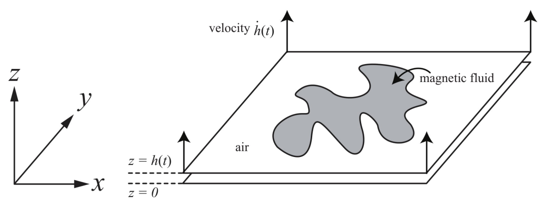
The purpose of my talk is to track the boundary of magnetic fluid in the Hele-Shaw cell numerically. The model equations which describe the motion of magnetic fluid under the condition of external energy supply due to the upper plate of the Hele-Shaw cell in the presence of a normal magnetic field is formulated as follows:

$$\begin{cases} \triangle p = 12\eta \dfrac{h_t(t)}{h(t)^3} \quad \text{in } \Omega(t), \\ p = \sigma k - 3\eta \dfrac{\dot{h}(t)}{h(t)^3} \|\boldsymbol{x}\|^2 \quad \text{on } \partial\Omega(t), \\ V = -\dfrac{h(t)^2}{12\eta} \left( \nabla p - \dfrac{2M}{h(t)} \nabla \varphi_m \right) \cdot \boldsymbol{n} \quad \text{on } \partial\Omega(t). \end{cases}$$

Here $p$ is an unknown pressure function, $h(t)$ is a time-dependent gap between two parallel plates in the $z$-direction and $\varphi_m$ is the value of magnetostatic field potential created by the magnetic fluid on the boundary of the Hele-Shaw cell. We apply the method of fundamental solutions (MFS) to simulate the magnetic fluid instabilities, since the MFS is known as the fast and mesh-free numerical solver for potential problems such as Laplace equations, Poisson equations, etc.




## References

[1] K. Sakakibara & S. Yazaki, A charge simulation method for the computation of Hele-Shaw problems, RIMS Kôkyûroku **1957**, (2015) 116-133

[2] S. Yazaki, A numerical scheme for the Hele-Shaw flow with a time-dependent gap by a curvature adjusted method, Advanced Studies in Pure Mathematics **64**, (2015) 253-261

[3] A. Tatulchenkov & A. Cebers, Magnetic fluid labyrinthine instability in Hele-Shaw cell with time dependent gap, Physics of fluids **20**, (2008)

# On Numerical Experiments for Extended Kalman Filtering

Po-Hsin Cheng
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In this talk, numerical simulations of Kalman filtering for two given examples illustrate that signals cannot be tracking provided the target system is undetectable. This is the main drawback for applying the extended Kalman filtering to a nonlinear problem. To overcome the drawback, a regularization strategy based on dimension lifting is developed. Numerical experiments conclude the efficiency of the regularization strategy.

# Isogeometric analysis and splines

Ching-Lun Lu
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This is my study on the CAD(Computer aide design) and FEM(Finite element method). I will introduce the relation between computer graphic and CAD. The important part is NURBS(Non-Uniform Rational Bezier Splines), which is used widely in CAD and computer graphics.

Spline is a function defined by piecewise polynomials. I study some linear problems using NURBS, and it is the concept of isogeometric analysis.

# A Model for Dynamic Pattern Formation in Cuttlefish

Kana Mizuno (1), Eigo Fukada (2), Mayuko Iwamoto (3)
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Body pattern of cephalopods changes instantaneously [1], and the time scale is fast compared with Turing pattern formation. A purpose of this study is to understand the mechanism of pattern formation in cuttlefish. By capturing the characteristics of cuttlefish's skin structure [2], we build a mathematical model which is described by self-driven springs and dampers with FitzHugh-Nagumo model. In this presentation, we will show the simulation results of the non-uniform patterns with our model.

## References

[1] R. Nakajima, Y. Ikeda, A catalog of the chromatic, postural, and locomotor behaviors of the pharaoh cuttlefish (Sepia pharaonis) from Okinawa Island, Japan, Marine Biodiversity Volume 47(2017), 735-753.

[2] L. F. Deravi, et al., The structure-function relationships of a natural nanoscale photonic device in cuttlefish chromatophores, J. R. Soc. Interface Volume 11(2014), 20130942.

# Travelling Waves in A Rabies Propagation Model

Yuka Fukase
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Rabies is an infectious viral disease transmitted from animals to humans. If a bite from a rabid animal goes untreated and rabies develops, it is almost always fatal. Today, this disease occurs in more than 150 countries and territories. Therefore, it is important to study how the distribution of the disease propagates. Macdonald [1] studied the spread of rabies in the northeastern part of France in the 1970's, according to that regions of an epidemic phase and a silent phase appear alternately in the process of spreading the disease. As one of mathematical models expressing such propagation of rabies, we introduce a two-component reaction-diffusion system motivated by Murray et al. [2]. This model constructed by a density of susceptible $S(x,t)$ and the one of infectious $I(x,t)$ to explain the propagation of rabies, where $S$ and $I$ are functions of space $x$ and time $t$. Then, our model is as follows:

$$\begin{cases} S_t = \varepsilon \left(1 - \dfrac{S}{K}\right) S - \beta S I, \\ \\ I_t = d I_{xx} + \beta S I - \gamma I. \end{cases}$$

Here, $\varepsilon$ is the birth rate, $\beta$ is the contact rate, $\gamma$ is the removal rate, $K$ is a carrying capacity and $d$ is a diffusion coefficient, all being positive constants. In this presentation, we will discus the travelling wave solution of this model.

# References

[1] Macdonald, D. W. *Rabies and Wildlife A biologist's perspective.*, Oxford University Press (1980).

[2] Murray, J. D., Stanley, E. A. and Brown, D. L. (1986). *On the Spatial Spread of Rabies among Foxes.* The Royal Society, B 229, 111-150

[3] Ai, S., Du, Y. and Peng, R. (2017). *Traveling waves for a generalized Holling-Tanner predator-prey model.* J. Differential Equations, 263 (11), 7782-7814

# A new method in ecology: Estimating a relationship by Time series data

Takanori Kawase (1), Kazutaka Kawatsu (2), Daisuke Kyogoku (2), Michio Kondoh (2)
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**Introduction.**
In order to understand the structure of ecosystem, interspecific interactions should be investigated through the methods in population ecology. However, interspecific interaction changes its direction and strength along with time. In addition, interspecific interactions defined based on individual-level behavioral observation may be not always a driver of population dynamics. Thus, it is difficult to quantify the interaction for population ecology. Recently, a statistical method, Empirical Dynamic Modeling (EDM), which is based on theory of non-linear dynamical systems, has been developed for estimating temporally-changing interactions from time-series data. We used one of the EDM methods, Convergent Cross Mapping (CCM), which can estimate causal-effect relationships between potentially-interacting multiple time series, by distinguishing causality from correlation. In addition, it can estimate the timing when the causality happened. We used this method for evaluating whether behaviorally-defined interactions (i.e., resource competition and reproductive interference) really the cause of population dynamics.

**Method.**
We experimentally co-grew two species bean weevils (*Callosobruchus maculatus* [C.m hereafter] and *Callosobruhus chinensis* [C.c hereafter]) and evaluated whether two types of interspecific interactions were the causes of their population dynamics from the time series data. There are two interspecific interactions occurring at the different life stage of the weevils: (1) resource competition in the larval stage and (2) reproductive interference in the adult stage. In addition, the interference as the driver of population is reported from previous observation reports that C.c affects C.m only. The estimated causality can be discuss based on its lifecycle. We counted the number of living adults of each species every week to generate time series data. In order to detect the causality for different life stages, we used CCM to the time series with no time delay to three weeks delay.

**Result and Discussion.**
Competitive exclusion occurred in the experiment; C.m excluded C.c CCM analysis detected bio-directional causality between C.m population and C.c population, implying that population dynamics of these species influences each other. Likewise, these causalities were estimated in every timing of the life stage. Based on the timing of life stages with specific time delay (no delay to three weeks delay), our results suggest that (1) the reproductive interference as the driver of population can occur from C.m to C.c. and that (2) resource competition is contest type in both species. Although the behavioral observation cannot argue how interspecific interactions affect population dynamics, the application of EDM enabled us to detect the causality of interspecific interactions.

## References

[1] K. Kawatsu and S. Kishi, Identifying critical interactions in complex competition dynamics between bean beetles, *Oikos*, 127 (4), 553–560 (2018).

# The propagation of reaction-diffusion equation in growing region

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Reaction-diffusion equations are usually considered in a fixed domain. However, the domain often varies or grows in biological phenomena, such as animal coat patterns and phyllotactic patterns in shoot apex. In this talk we study distributions of chemical substances that are diffusing and reacting with one another in a growing domain and are investigate the effect of the growth of domain. Especially, we treat the heat equation and the Fisher-KPP equation in a growing domain.

## References

[1] D. G. Aronson and Weunberger, Multidimensional nonlinear diffusion arising in population genetics, Adv. Math. 30(1978), 949-1032.

[2] A. Kolmogorov, I. Petrovskii, and N. Piscounov. A study of the diffusion equation with increase in the amount of substance, and its application to a biological problem. In V. M. Tikhomirov, editor, Selected Works of A. N. Kolmogorov I, pages 248-270. Kluwer 1991

# Spectral methods for modified Poisson-Boltzmann equation on different geometries

Yi-Ting Chen
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To investigate the structure of the electrical double layer (EDL) in electrolyte solutions, we visit modified Poisson-Boltzmann (MPB) equation over different geometries, and verify a theoretical prediction numerically by using Chebyshev and Fourier spectral method. The advantage of our approach is that the grid points are clustered close to the domain boundary so that we can capture the behavior of the boundary layer accurately.

# Solution structure of stationary solutions of a limiting SKT cross-diffusion equation

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We consider the following stationary limiting equation

$$(S^1_\infty)\begin{cases} \displaystyle\int_0^1 \frac{\tau}{v}\left(a_1 - b_1\frac{\tau}{v} - c_1 v\right)dx = 0 & \text{in } (0,1), \\ d_2 v_{xx} + v\left(a_2 - b_2\frac{\tau}{v} - c_2 v\right) = 0 & \text{in } (0,1), \\ v_x(0) = 0, \quad v_x(1) = 0, & \\ v(x) > 0, \quad v_x(x) > 0 & \text{in } (0,1) \end{cases}$$

for a stationary cross-diffusion equation. Here, $v(x)$ is an unknown function, and $\tau$ is an unknown constant. The constants $d_2,\ a_i,\ b_i,\ c_i,\ (i = 1,\ 2)$ are all positive. We remark that the important quantities involving the constants $a_i,\ b_i,\ c_i,\ (i = 1,\ 2)$,are $A := a_1/a_2,\ B := b_1/b_2,\ C := c_1/c_2$. It seems natural to consider the following two cases separately: "weak competition" case $C \leq B$ and "strong competition" case $B < C$.

Shigesada-Kawasaki-Teramoto [1] proposed the original cross-diffusion equation. Lou-Ni [2, 3] derived the stationary limiting equation $(S^1_\infty)$ to investigate the effect of cross-diffusion. Lou-Ni-Yotsutani [4] showed theorems about existence, non-existence of non-constant steady state solutions, the shape of the solution, and clarified the structure of solutions of $(S^1_\infty)$ for all cases $C \leq B$ and $B < C$.

We have precisely investigated the solution structure and the stability in the case $B < C$ . In this talk, we report our numerical results on the solution structure and the stability of $(S^1_\infty)$ for the case $C \leq B$.

This is a joint work with Y.Lou, T.Mori, W.-M.Ni and S.Yotsutani.

## References

[1] N.Shigesada, K.Kawasaki, and E.Teramoto, *Spatial segregation of interacting species*, J.Theoret Biology **79** (1979), 83-99.

[2] Y.Lou and W.-M.Ni, *Diffusion, self-diffusion and cross-diffusion*, J.Differential Equations **131** (1996), 79-131.

[3] Y.Lou and W.-M.Ni, *Diffusion vs cross-diffusion: An elliptic approach*, J.Differential Equations **154** (1999), 159-190.

[4] Y.Lou, W.-M.Ni and S.Yotsutani, *On a limiting system in the Lotka-Volterra competision with cross-diffusion*, Discrete Contin. Dyn. Syst. A **10** (2004), 435-458.

[5] T.Mori, T.Suzuki and S.Yotsutani, *Numerical Approach to Existence and Stability of Stationary Solutions to a SKT Cross-diffusion Equation*, Mathematical Models and Methods in Applied Sciences,**28**(2018), 2191-2210.

# The Analysis of Economic Structure in September 2008

Yuta Shimazaki, Kazuyuki Nakamura
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Several financial crises have broken out in these 20 years. Though they have large impact on our society, it is impossible to prevent damage from them because there are many factors to cause the financial crises. Therefore, financial crises are major problem and are treated by various approaches to solve the problem.

In this research, we analyze the exchange rates to clarify the structure of the financial crises. Used exchange rates are USD/JPY, EUR/USD, USD/CHF, and GBP/USD from September 1 to September 30 in 2008, where bankruptcy of Lehman Brothers happened on September 15. We divide September into 4 period and minimum time interval is one hour. We use two analyzing methods, regime switching model [1] and relative noise contribution [2].

As the results, the stability of all exchange rates was decided by own characteristics in all periods. For example, Table 1 shows the indices how much an exchange rate is affected by other exchange rates in September 29. The indices are the average of parameters from regime switching model by other exchange rates. The result shows regime change is not determined by other exchange rates, that is, interactions among exchange rate do not relate to stability. However, there is a relationship between affairs and stability. Therefore, the factors affecting stability of the exchange rates seems to be external factors like government's economic policy. These investigations imply that traders consider external factor to be more important than other rates when financial crises happens.

| Rates \ Explanatory variables | Intersept | USD/JPY | EUR/USD | GBP/USD | USD/CHF |
|---|---|---|---|---|---|
| USD/JPY | 109.992 | | 18.807 | -15.907 | 3.926 |
| EUR/USD | 2.695 | -0.073 | | -0.0085 | -0.243 |
| GBP/USD | 2.033 | -0.053 | 0.869 | | -0.551 |
| USD/CHF | 451.056 | -10.861 | -68.948 | 3.882 | |

Table 1: The indices of other rates effects in September 29

# References

[1] F. X. Diebold, J.-H. Lee, and G. C. Weinbach, "Regime Switching with Time-Varying Transition Probabilities", in Nonstationary Time Series Analysis and Cointegration, Oxford University Press, pp. 283-302 1994.

[2] G. Kitagawa: Introduction to Time Series Modeling, CRC Press, 2010.

# On Numerical Experiments for Extended Kalman Filtering

Po-Hsin Cheng
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In this talk, numerical simulations of Kalman filtering for two given examples illustrate that signals cannot be tracking provided the target system is undetectable. This is the main drawback for applying the extended Kalman filtering to a nonlinear problem. To overcome the drawback, a regularization strategy based on dimension lifting is developed. Numerical experiments conclude the efficiency of the regularization strategy.

# Automatic drum transcription by RNN considering phase information

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Automatic drum transcription (ADT) is the task of retrieving symbolic representation of drum instruments from monaural drum solo recordings. In recent years, recurrent neural network (RNN) based approach have achieved the highest evaluation accuracies and various architectures have been discussed by many researchers. In the conventional RNN implementations, power spectrum in the frequency domain have been used as the input feature. However, for the purpose of improving the evaluation accuracy, we propose a new RNN architecture with phase information added to the input layer. As a result of the evaluation experiment, by adding the phase information to the input, the accuracy of estimating activations of the drum instruments considerably increased and the effectiveness of phase information is demonstrated.

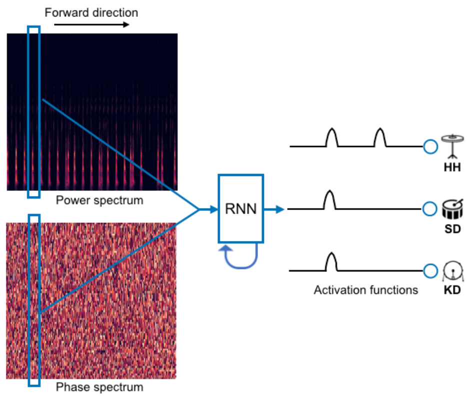


Figure 1: Our RNN architecture using power and phase spectrum of hi-hat (HH), snare drum (SD) and kick drum (KD) as input and estimating their activations.

| | Previous | Proposed |
|---|---|---|
| HH | 0.304 | 0.205 |
| SD | 0.130 | 0.0676 |
| KD | 0.107 | 0.0360 |

Figure 2: Comparison of RMSE.

## References

[1] Richard Vogl, Matthias Dorfer, and Peter Knees, “Recurrent neural networks for drum transcription”, Proc 17th ISMIR. (2016).

[2] Juan P.Bello, Chris Duxbury, Mike Davies, and Mark Sandler, “On the Use of Phase and Energy for Musical Onset Detection in the Complex Domain”, IEEE Signal Procrssing Letters, Vol.11, No. 6. (2004).

# Practical investigation of acoustic navigation employed by bats

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Bats can avoid obstacles and other individuals using a ultrasonic sensing (echolocation). Their sensing system is a very simple design which consists of 1 transmitter, 2 receivers and small brain. Although, it is not well understood how do bats realize advanced navigation with such a simple sensing system. In a previous study, navigation strategies employed by bats have been investigated by scientist of the animal behavior. In order to understand the behavioral principle quantitatively, it is require to evaluate the usefulness to the real environment.

Especially, during the echolocating flight of Japanese horseshoe bats, it is confirmed that bats obtain the echoes including frequency beat which was occured by interferece of the emmitted pulse and doppler shiftted echoes.
We hypothesized that bats are using such a frequency beat and proposed useful object localization method for agent moving condition. By using 1 transmitter and 2 receivers with the proposed method, we evaluated localization accuracy in the real environment.
Finally, we will introduce the drone equipped with 1 trasmitter and 2 receivers which was constructed as a tool for verifying bats behavior optimized for 3D navigation.

# Deep Neural Network Based Multi-modality and Multi-organ Automatic Segmentation for Brain Radiosurgery

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Tumor and critical organ delineation is the most critical step in automatic stereotactic radiosurgery (SRS) treatment planning workflow for brain metastases. Recent progress in Convolutional Neural Networks(CNN) has made it feasible to produce voxel-wise predictions of volumetric images and provide a powerful tool for automatic segmentation. The present study aims to develop a CNN algorithm for tumor and multi-organ segmentation on multi-modality imaging including contrast-enhanced computed tomography (CTc) and contrast-enhanced T1-weighted magnetic resonance imaging (MRI-T1c). Our dataset are acquired from one brain metastases cohort (n=95) treated with SRS using CyberKnife system. Each data included volume mask for brain tumors, brain stem, optic chiasm, bilateral eyes and optic nerves with associated CTc and MRI-T1c. We develop a workflow to organize the raw data, perform image preprocessing including data augmentation and registration, construct CNN models, train and test the models then visualize the results. The results of DICE scores for tumors and multi-organs around 0.5 and 0.8 in the testing set for CTc and MRI-T1c images, respectively.

# Stability of an epidemic model with boosting of immunity

Liu Yang (1,2), Yukihiko Nakata (2)
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We formulate an epidemic model with waning and boosting of immunity by delay differential equations, following the idea by Aron [1, 2]. In the model, recovered individuals may be reinfected because the immune system does not confer long-lasting immunity against a pathogen, thus the immunity wanes. On the other hand, it is also reported that the natural immunity is enhanced by the continued exposure to infection which is called boosting effect. Our main purpose is to explore the effect of the boosting of immunity on the disease transmission dynamics using an epidemic model. We also compare the transmission dynamics with and without boosting effect by numerical simulations.

## References

[1] J. L. Aron, "Dynamics of acquired immunity boosted by exposure to infection", Math. Biosci. 64, 249–259 (1983).

[2] J. L. Aron, "Acquired immunity dependent upon exposure in an SIRS epidemic model", Math. Biosci. 88, 37–47 (1988).

# Analysis of continuous data assimilation algorithm for Lorenz 63 model with nonlinear nudging

Yi-Juan Du
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Data assimilation is an important issue because it can process data from different sources through a series of processing and adjustment, and finally can be comprehensively applied. Especially for dynamic systems with sensitivity to initial value and chaos, such as Lorenz 63 model, we will use the nonlinear nudging techniques to predict on this model. In this talk, we will present the analysis of continuous data assimilation algorithm for this model based on nonlinear nudging and numerical experiments will be demonstrated, too.

# Nakayama Algebra and Algebraic Stability of Persisitent Homology

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Topological Data Analysis (TDA) is method of analyzing data from the geometric characteristics of data. It is applied to machine learning, material science, data analysis and so on. Persistent Homology is the most important mathematical idea in TDA [1]. By Persistent Homology, we can visualble the geometric characteristics of data using Persistence Diagram. Here we introduce an important theorem on Persistent Homology.

**Theorem 1** *(Algebraic Stability Theorem, [2]) $M$ and $N$ are p.f.d persistent homology, if $f : M \to N(\delta)$ is $\delta$-interleaving morphism then $\mathcal{B}(M)$ and $\mathcal{B}(N)$ are $\delta$ matching. In particular,*

$$d_{\mathcal{B}}(\mathcal{B}(M), \mathcal{B}(N)) \leq d_I(M, N).$$

From this theorem, for example $M$ is true data, $N$ is observation data, if there is not much noise, we can analyze $M$ from $N$. Therefore, there is no influence on the essential analysis result.

In this talk, We got the result which Algebraic Stability Theorem of Persistent Homology is established on Nakayama Algebra, so I will report it.

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# Dynamics of the Spruce budworm–bird interaction with the effect of insecticide

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We study the dynamics of the spruce budworm system with the effect of bird predation and insecticide. If the growth rate is large enough, we shall show the globally asymptotical stability of equilibrium. The existence of limit cycle of dynamical system is also shown under certain conditions. Moreover, if insecticide is applied many times or the maximum budworm mortality rate due to the action of the insecticide is very high, then the uniqueness of limit cycle is shown. In real life, in addition to birds, the number of budworm also depends on many factors such as the state of the forest and the effectiveness of insecticide in different life stages of the budworms. Thus, we would like to study the model for the dynamics of the budworm-bird-forest interaction in the future.

# Bifurcation of sticky circle packing

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Let $H = \{x + \sqrt{-1}y : y > 0\}$ be a upper half-plane. Let $D(w, r) = \{\zeta : |\zeta - w| \leq r\}$ be a disk with the center $w$ and the radius $r > 0$. A sticky circle packing $\Lambda(r, \theta)$ for a given pair of parameters $r > 0$ and $\theta$, is the family of disks $\{D_{j,k} = D(j\theta - k + \sqrt{-1}y_j, r) : j, k \in \mathbf{Z}, j \geq 0\}$ such that $y_j = \min\{y \geq 0 : P_j(y)\}$, where $P_j(y)$ is the condition that the family of disks $\{D(s\theta - k + \sqrt{-1}y_s, r) : k \in \mathbf{Z}, s = 0, 1, \ldots, j-1\}$ and $\{D(j\theta - k + \sqrt{-1}y, r) : k \in \mathbf{Z}\}$ do not overlap.

A fraction $\frac{a}{m}$ is called a (local) parastichy index of the disk $D_{j,k}$ if it is tangent to the disk $D_{j+m,k+a}$. The fraction $\frac{a}{m}$ is called a parastichy index of the packing $\Lambda(r, \theta)$ if it is a parastichy index of $D_{j,k}$ for sufficiently large $j$. The fraction $\frac{a}{m}$ is called a semi-parastichy index of $\Lambda(r, \theta)$ if it is a parastichy index of $D_{j,k}$ for infinitely many $j$.

Let $S(\frac{a}{m})$ be the set of $(r, \theta)$ such that the packing $\Lambda(r, \theta)$ has a parastichy index $\frac{a}{m}$. Let $S(\frac{a}{m}; \frac{b}{n})$ be the set of $(r, \theta) \in S(\frac{a}{m})$ such that the packing $\Lambda(r, \theta)$ has a semi-parastichy index $\frac{b}{n} \neq \frac{a}{m}$. Let $S(\frac{a}{m}; \emptyset)$ be the set of $(r, \theta) \in S(\frac{a}{m})$ such that the packing $\Lambda(r, \theta)$ has no semi-parastichy index $\frac{b}{n} \neq \frac{a}{m}$.

Any packing $\Lambda(r, \theta)$ has a parastichy index, so $H = \bigcup_{a/m} S(\frac{a}{m})$. For distinct regions $S(\frac{a}{m})$, $S(\frac{b}{n})$, we have $S(\frac{a}{m}) \cap S(\frac{b}{n}) \neq \emptyset$ if and only if $mb - na = \pm 1$. The region $S(\frac{a}{m})$ is connected, simply-connected, and has a boundary point $\frac{a}{m}$ on the real axis.

In this talk, we observe that

$$S(\frac{a}{m}) = \bigcup_{mb-na=\pm 1} S(\frac{a}{m}; \frac{b}{n}) \cup S(\frac{a}{m}, \emptyset)$$

for the case $a = 1$. We shall present the bifurcation diagram for the semi-parastichy indices in the $(r, \theta)$-parameter space.

# The synchronization analysis of Kuramoto model for the identical oscillators

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In this talk, I will introduce the concept of synchronization and the Kuramoto model. Furthermore, I investigate the synchronization behavior of the solution mathematically. My talk will consist of two parts: Part I is analysis of Kuramoto model and the stationary solution of N identical oscillators. Part II is analysis of the non-stationary solution of N identical oscillators and future works.

# Three-Variable Model of the Photosensitive Belousov-Zhabotinsky Reaction

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Various pattern dynamics, found in physiology, ecology and so on, have been captured by the theory based on reaction diffusion systems. The Belousov-Zhabotinsky (BZ) reaction is one of the model reactions used to study nonlinear oscillation phenomena, which occur in vivo. The BZ reaction is brought about by mixing appropriate amount of oxidant, reductant, acid and metal catalyst. In the process of oxidizing the reductant, concentrations of the reaction intermediates oscillate periodically. Accordingly, the oxidation-reduction potential also oscillates. Although the BZ reaction is a complex process involving more than 100 elementary reactions, the main part of reaction is summarized as the Oregonator model [1], which is the kinetic model of the BZ reaction. The Oregonator model describes the mechanism and dynamics of the oscillation of the BZ reaction. On the other hand, the BZ reaction is known to be stimulated by light irradiation. In fact, it can be realized by using photosensitive metal catalyst. Several reaction models have been proposed with stimulations by light irradiation. However, since most of previous models contains more than four variables, these are not so easy to analyze.

Our strategy is reducing the previous four-variable model [2] by nondimensionalization and the fast-slow method to obtain a simpler model. The results of simulations guarantee the validity of the simplified model. In addition, plural period-doubling bifurcations, which have not been known in the basic BZ reaction, are found by bifurcation analysis in this research.

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# Why marriages are so difficult: a mathematical aspect

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Most couples generally plan enduring relationships. Nevertheless, the high divorce rates massively reported show a resounding failure in their implementation. The phenomenon of couple disruption is considered epidemic in the world. It is interesting to understand why so many couples end in divorce while some others do not (but may complaint why their sustained effort cannot rouse their feeling very much) since the social change induced by marriage deeply affects the social structure and the well-being of their members. Our aim is to offer a consistent explanation for the facts of marriage by modifying a feeling-effort dynamical system proposed by Rey (2010 PLoS ONE), where the optimal control modeling brings a mathematical approach to the analysis of marriage and close relationships.

# A Self-organized Model for Safety Autonomous Driving Cars

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The Japanese government aims to realize a perfect autonomous driving car which does not require a driver completely by 2020. A purpose of this study is to build a simple model with prediction [1], as a first step for understanding the behavior of perfect autonomous driving cars. We modified the previous model, Social Force Model (SF model) [2], which describes pedestrian motion by the equation of motion that calculates the physical and the psychological forces by other individuals and obstacles. In this presentation, we will discuss safety with this model compared to the previous model by numerical simulations.

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# An epidemic model with treatment capacity

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Treatment is an important method to decrease the spread of diseases such as measles, tuberculosis and flu. In the present work, we propose an epidemic model with a limited resource for treatment in order to understand the effect of the treatment capacity, which modifies [1].

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## Optimization problems in signal and audio denoising

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Total variation based filtering, derived by Rudin, Osher, and Fatemi at first in 1992, has nowadays been widely applied in signal denoising and further in image denoising problem, such as signal smoothing, fingerprint enhancement, and so on.

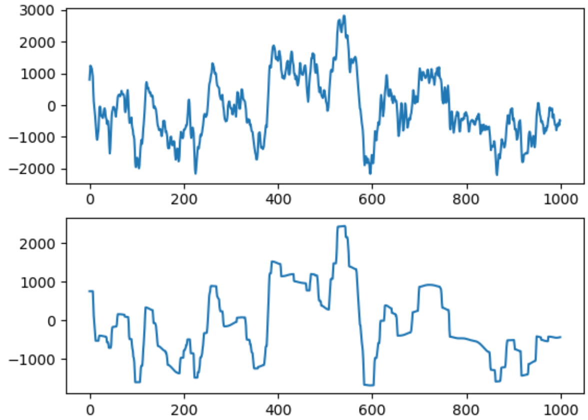


Figure 3: Signal denoising (above: the original signal; below: the smoothing signal)

This filter (in 1-dimension, for instance) can be implemented through several recursive (or non-recursive) approaches so as to reduce the objective function, which is given by

$$J(x) = \frac{1}{2}\sum_{k=1}^{N} |y_k - x_k|^2 + \lambda \sum_{k=1}^{N-1} |x_{k+1} - x_k|,$$

where $\lambda$ is the reciprocal of Lagrange multiplier, and $\{y_k\}_{k=1}^N$ is the observed signal consisting of the original signal $\{x_k\}_{k=1}^N$, combined with a normal random variable $n \sim N(0, \sigma^2)$, and is defined by $y_k = x_k + n$ for each $k = 1, \cdots, N$.

However in audio, a special kind of signals, does not play a good result based on the above approach when solving the denoising problem. We will focus on the main idea of the total variation filtering in the beginning of this talk, as well as try out to revise the model by taking frequency into consideration, followed by accessing the particular signal denoising problem as our future work.

# Closed geodesics on the beading regular icosahedra

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A planar graph is called 3-regular if each vertex is incident to three edges. A typical example of a 3-regular graph is a honeycomb graph consisting of hexagons. A 3-regular finite planar graph $G$ defines a beading polyhedron, which gives rise to a knot or link of strings $K$. In each bead, there pass through two (segments of) strings. In this task, we assume positive crossing of strings in each bead. A connected component of string is called a beading geodesic.

If $G$ consists only of pentagons and hexagons, then the Euler formula shows that there are exactly twelve pentagons. Such $G$ is called corner-transitive if for any pair of vertices $v_1, v_2$ of pentagons, there exists a graph automorphism $\varphi : G \to G$ that maps $v_1$ to $v_2$. A beading regular icosahedron is defined as a beading polyhedron of a corner-transitive 3-regular finite planar graph consisting of pentagons and hexagons.

The family of beading regular icosahedra is indexed by a pair of integers $(p, q)$. On the other hand, it is known that the family of closed geodesic on the regular icosahedron is also indexed by a pair of integers $(p, q)$. There exists a natural correspondence between the beading regluar icosahedron of type $(p, q)$ and the closed geodesic on the regular icosahedron of type $(p, q)$.

# Schauder's estimates for general elliptic equations

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Let $\Omega$ be an open set in $\mathbb{R}^n$, with smooth boundary and

$$W^{k,p}(\Omega) = \{u \in W^k(\Omega); D^\alpha u \in L^p(\Omega) forall |\alpha| \leq k\}.$$

We define the operator $L$ by

$$Lu = D_i(a^{ij}(x)D_j u + b^i(x)u) + c^i(x)D_i u + d(x)u$$

whose coefficients $a^i j$, $b^i$, $c^i$, $d(i,j = 1, ..., n)$ are assumed to be measurable functions on $\Omega$. Assume the operator L satisfies the condition (1): $\forall x \in \Omega, \xi \in \mathbb{R}^n$ and some constant $\lambda > 0$ and $\Lambda$ and $v \geq 0$

$$\begin{cases} a^{ij}(x)\xi_i\xi_j \geq \lambda|\xi|^2 \\ \Sigma|a^{ij}(x)|^2 \leq \Lambda^2 \\ \lambda^{-2}\Sigma(|b^i(x)|^2 + |c^i(x)|^2) + \lambda^{-1}|d(x)| \leq v^2. \end{cases} \tag{1}$$

In this talk, I will introduce the Schauder interior estimates of $L$: Suppose that $f^i \in L^q(\Omega), i = 1, ..., g \in L^{q/2}(\Omega)$ for some $q > n$. If $u \in W^{1,2}(\Omega)$ and satisfies $Lu = g + D_i f^i$ in $\Omega$, for any ball $B_{2R}(y) \in \Omega$ and $\Omega' \subset\subset \Omega$ and $p > 1$ and $R > 0$,

$$\begin{cases} sup_{B_{R(y)}} u(-u) \lesssim R^{-n/p}\|u^+(u^-)\|_{L^p(B_{2R(y)})} + k(R) \\ \|u\|_{C^\alpha(\overline{\Omega'})} \lesssim \|u\|_{L^2(\Omega)} + \lambda^{-1}(\|f\|_q + \|g\|_{q/2}) \\ |u|_{1,\alpha;\Omega'} \lesssim |u|_{0;\Omega} + |g|_{0;\Omega} + |f|_{0,\alpha;\Omega} \end{cases}$$

which play an essential role in the esistence and regularity theory of second order linear elliptic equations. What's more, the inequalities are also useful to discuss about the Dirichlet problem for continuous boundary values.

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# Machine Learning and Image Classification

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Recently, Machine Learning (ML) has become the focus of attention [1] because it would be expected to enrich our life. By finding hidden features in a lot of data, ML can make a decision without human 's consideration. Supervised Machine Learning (SML) has already got many achievements in various field. However, it is difficult to collect enough labeled data for SML, so we are required to catch a structure of data by the limited information. A purpose of this research is to establish the way to classify unlabeled data. In this presentation, we will talk about image classification using the K-means clustering.

## References

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# Point cloud watermarking technology

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Recently, due to the development of 3D scanning and modeling technologies, 3D model data has been widely used in various fields. Such as architecture, medicine, and manufacturing, etc. Therefore, anti-counterfeiting, copy-proof, and integrity inspection technologies are required. 3D model data is roughly divided into parametric surface, point cloud, and polygon mesh. In practice, point cloud and polygon grid are more common. Point cloud is the data obtained through 3D scanner, which will be a set of coordinate points in three-dimensional space. Polygon mesh is usually created by software or reconstructed by point clouds. The data format is also a set of coordinate points in three-dimensional space and contains the connection between points. The watermarking technology of polygon mesh has be developed mature, and this paper expects to study the watermarking technology on point cloud. Because the process of reconstructing a polygon mesh from a point cloud often depends on the quality of the original point cloud quality, especially when the object has a complex surface, there is no way to convert the point cloud and the polygon mesh well, which will greatly increase the distortion caused by the watermarking.

# Localization of graph Laplacian eigenvectors on scale free networks

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Eludicating characteristics of large scale free networks leads to revealing structures of substantial amount of networks. Among those aspects, diffusion on a network is depicted by the eigenvectors of its graph Laplacian, and especially in a large scale free network, the elements of each eigenvector tend to have relatively large values only on the nodes whose degrees are close. However, it is still unsolved why the localization can be observed in scale free networks in general. Here we analyze the root of localization by introducing an $L^p$ graphon, which is a representation of limit objects of sparse graphs, and is defined by a $p$-integrable function on $[0,1]^2$. In this sense, a continuum limit of the graph Laplacian is described by an $L^p$ graphon.

In this research, the continuum limit of the graph Laplacian generates a closed linear operator $L$ densely-defined on $L^2(0,1)$. Our aim is to determine the spectra of $L$ and obtain the resolvent estimates. Moreover, we state that the singularity of the "eigenfunctions" of $L$ implies the origin of the localization of the graph Laplacian eigenvectors on large scale free networks in a formal way.

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# A variational approach to the inverse imaging of composite elastic materials

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We have constructed a variational method for analyzing inverse problems whose solutions describe the interior of composite elastic materials. In particular, given an outward surface velocity along the boundary of the composite, we have designed a cost functional which measures the difference between data obtained from our model equations. Using Lagrangian functionals, we are then able to obtain the gradient of the cost functional and investigate its gradient flow. Numerical methods, based on the method of discretization of time and the finite element method, were also constructed. These methods were then used within level set equations to investigate numerical solutions of the inverse problems. Our results show that the gradient flow is able to extract the interior composition of the elastic bodies using only the boundary velocity's information. In addition to showing numerical solutions of the inverse problems, we will show imaging results involving real surface acoustic wave data. This research is joint with E. Ginder (Meiji University), O. Wright (Hokkaido University) and P. Otsuka (Hokkaido University).

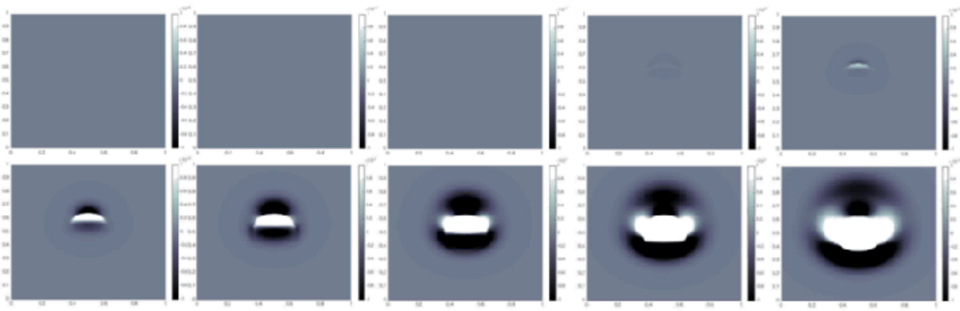

Figure 4: Simulation of elastic wave propagation though a glass slab with a steel inclusion. Magnitude shows the difference between the simulations, with and without the inclusion.

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# Convergent cross mapping and skew prodect mapping

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Convergent Cross Mapping (CCM), proposed by Sugihara et al. in 2012([1]), is a procedure which detects the causality between two kinds of data $X$ and $Y$ . Roughly speaking, in their terminology, $X$ causes $Y$ means that the information of $X$ is used to decide that of $Y$ . More precisely, $X$ causes $Y$, if the correlation coefficient between the predicted value of $Y$ using $X$ and the real value of $Y$ increases according to the amount of data $X$ and $Y$ . This method became one of the basic methods to determine the causality in the field of ecology.

Nevertheless, from mathematical point of view, there are several unclear points in their method; for instance:

1. The definition of the causality.
2. The increase of the correlation coefficient according to the amount of data is a necessary and/or a sufficient condition for the causal- ity? What is a threshold value of the increase constant to obtain the causality?
3. What is the mechanism to explain this kind of phenomena?
4. What kind of properties are obtained concerning the correlation coefficient in case the causality exists and/or not exists?

In this talk, we consider a simple dynamical system and use it to show how the idea of the convergent cross mapping may work in a mathematically clear way. The system we study is of skew-product type given as follows:

$$\begin{cases} x(t+1) = x(t) + \omega_1 \pmod 1 \\ y(t+1) = y(t) + \omega_2 + kx(t) \pmod 1 \ \ \omega_1 = 5, \omega_2 = \pi \end{cases}$$

Although we cannot answer the above questions even to such a simple sys- tem, we shall discuss some results concerning them.

## References

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# Algorithms of Brian Segmentation from T1/T2 MRI Image

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Nowadays, according to the advanced medicine progress, clinicians highly depend on the medical imaging technique which allows them to visualize the representations of the interior patient body, such as computed tomography (CT) and magnetic resonance imaging (MRI). However, these medical images are outputted to the two-dimensional pictures which may not provide the sufficient information for doing three-dimensional computation research. Due to the previous reason, we would like to collect these images from the brain MRI via the machine learning algorithms to obtain the segmentation and reconstruction of the brain imaging. During this research work, there's some noise after processing. Therefore, we plan to develop a suitable algorithm including the variation method, with the concept of kernel method in machine learning in order to get the better results. Finally, we would like to represent an algorithm, which may work on most image to generate high-quality imaging for the object.

# Analysis of a mathematical model for interfacial behaviors under drying processes

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Recently, many studies have been conducted on interface behaviors of fluids under various conditions, including several mathematical studies on drying processes of nonvolatile particles and volatile solvents. The mathematical models are proposed in previous articles and reduced from the equations of motion of fluid. In those models, viscosities and densities in fluids are supposed to be constant, although these elements are actually varied with concentrations of the solvents and particles [1]. Thus, we apply the lubrication approximation to the Navier-Stokes equation and derive the following partial differential equations under the periodic boundary condition, taking account of the change in viscosities and densities of the fluid;

$$\begin{cases} \dfrac{\partial h}{\partial t} = -\dfrac{\partial K}{\partial x} - \dfrac{\rho}{\rho_l}\alpha(1-\phi) - \dfrac{D}{\rho_l}\dfrac{\partial}{\partial x}\left(h\dfrac{\partial \rho}{\partial x}\right), & 0 < x < L, t > 0, \\ h\dfrac{\partial \phi}{\partial t} = -\dfrac{\partial \phi}{\partial x}K + \dfrac{\rho}{\rho_l}D\dfrac{\partial}{\partial x}\left(h\dfrac{\partial \phi}{\partial x}\right) + \phi\dfrac{\rho}{\rho_l}\alpha(1-\phi), & 0 < x < L, t > 0, \\ K = \dfrac{1}{\mu}\left(\dfrac{5}{24}gh^4\dfrac{\partial \rho}{\partial x} - \dfrac{1}{3}h^3\dfrac{\partial}{\partial x}\left(\rho g h - \gamma\dfrac{\partial^2 h}{\partial x^2}\right)\right), & \\ \rho = (\rho_g - \rho_l)\phi + \rho_l, \quad \mu = (\mu_g - \mu_l)\phi + \mu_l. & \end{cases} \tag{2}$$

The function $h(x,t)$ is the height of the fluid and $\phi(x,t)$ is the volume fraction of nonvolatile particles in the fluid. All parameters in (2) are nonnegative.

Our aim in this study is to examine the behavior of the solution and the existence of stationary solutions with spatial pattern. It can be shown by numerical simulations that $h$ converges to a constant stationary solution as $t \to \infty$ in many cases. Moreover, we analyze the linear stability of steady states. When $\alpha = 0$ and $D > 0$, any constant stationary solutions are linearly stable. On the other hand, when $\alpha = D = 0$, (2) exhibits nonconstant steady states. Then, we confirm the existence of a stationary solution in a rigorous way and obtain the following results; If $\alpha > 0$ or $D > 0$, (2) has only constant stationary solutions. On the other hand, if $\alpha = 0$ and $D = 0$, there exists a nonconstant stationary solution $(h, \phi)$, where $\phi$ can be given arbitrarily.

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# Predicting Time Steps in Molecular Simulations

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Time scale limitation has been and remains a challenging problem in molecular simulations. Large systems such as proteins are still narrowed in scale of nano-second with the help of super computers. The limit of time may contribute to insufficient result and improper inference while the simulation is already time-consuming. A machine learning method: time series prediction is implemented to solve this problem. Since features (Total force, numbers of Hydrogen bond, etc.) of protein have strong time dependence during simulation, this relationship can be used to obtain a different data by shifting original data with time. Taking these two data, we may train the machine to catch up structure of systems and achieve predicting these features in the next time step.

# Determination of Wave Propagation Direction for a Class of Biological Bistable Models

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Biological invasion is an important ecological phenomenon, and thus it is important to determine the propagation direction in the associated biological model. However, there are very few analytical results on the determination of propagation direction in the bistable biological system. In this study, we give a complete characterization of propagation direction in a class bistable biological system.

# Mathematical Model for Quadrupedal Walking and its Dynamical Pattern

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Depending on walking speeds, various walking patterns are observed in quadruped animals. Mathematical models realizing the typical patterns of quadrupedal walk, Walk, Pace, Trot and Bound, have been proposed in [1] and [2]. In this research based on the model by Tero et al. (2013)[1], we study the following reduced dynamical model:

$$\begin{cases} \dot{\rho} &= -\alpha\rho - \beta(\sin\phi - \sin\psi), \\ \dot{\phi} &= \omega - (g+\rho)\cos\phi, \\ \dot{\psi} &= \omega - (g-\rho)\cos\psi, \end{cases}$$

where $\rho$ and $(\phi, \psi)$ are related to a physical state of the body and the motion of the legs respectively. The parameters $\alpha$, $\beta$, $g$ are assumed to be positive. Applying numerical methods to this model, we identify parameter regions where the three walking patterns take place. Moreover, we show some dynamical structure of the model equation.

This is a joint work with Prof. Y. Morita (Ryukoku University). We thank Dr. M. Akiyama (Hokkaido University) for letting us know the work ([1]) and his variable comments.

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# Synchronization of Metronomes

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The living beings exhibit the rhythms. Synchronization phenomena play important roles in rhythms. I studied the method of homogeniation following to [1] and applied to the synchronization phenomena of two metronomes on an experimental and theoretical sides. I derived the phase equations by the averaging method and checked whether a synchronization phenomenon really happens to the two metronomes experimentaly.

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# FitzHugh-Nagumo Neuron Network for understanding the mechanism of Dynamic Pattern Formation in Cuttlefish

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Cuttlefishes and squids can change own body patterns to fit the surrounding environments in the situations of camouflage and communication with others, which are controlled by contraction of muscles around pigment cells with neural system [1], but it is unclear that how visual information is reflected in their body patterns. A purpose of this research is to understand the mechanism of pattern formation in cuttlefish by focusing on the neural system connecting pigment cells and muscles. In this presentation, we will build a neuron network model using discrete FitzHugh-Nagumo model and discuss simulation results with the model.

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# Stationary solutions of gap gene expression patterns in the *Drosophila* embryo

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Gap genes are involved in segment determination during the early development of the fruit fly, *Drosophila melanogaster*, and establish discrete expression patterns about 10-20 nuclei along the anterior-posterior axis. They regulate other genes and essentially determine the position of segments which develop the head, chest, and abdomen of *Drosophila* approximately 70 minutes before cellularization.

In a previous research [1], gap gene dynamics is represented by a reaction diffusion system given by

$$\frac{\partial v^a(x,t)}{\partial t} = \zeta(t) R^a g\left(u^a\right) - \lambda^a v^a(x,t) + D^a \frac{\partial^2 v^a(x,t)}{\partial x^2}, \tag{3}$$

where $v^a(x,t)$ denotes the relative concentration of gap gene $a$ corresponding to fluorescence intensity from 0 to 255. The first term on the right–hand side in (3) expresses the production rate of protein $a$ given by a sigmoid function $g(u) = \frac{1}{2}(\frac{u}{\sqrt{u^2+1}} + 1)$ or a step function $g(u) = 1$ $(u > 0)$ and $0$ $(u \leq 0)$. The doubling of nuclei and shutdown of transcription during mitosis is given by a transcriptional delay function $\zeta(t)$. The total regulatory input from gene $b$ to $a$ is defined by $u^a = \sum_b T^{b\to a} v^b + h^a$, where $T^{b\to a}$ is a regulatory weight from gene $b$ to $a$. The second and third terms describe protein dacay and diffusion of protein $a$, respectively.

Numerical results imply that (3) can reproduce gap gene expression patterns. However, the diffusive coefficient of Hunchback is about twenty five times larger than that of Giant and Knirps, and about six times larger than that of *Krüppel* in numerical simulations of [1]. Then we apply the Stokes–Einstein relation [2] to the proteins. As a result, diffusive coefficients are computed by the Stokes–Einstein relation and not so different among the proteins. This is our first result.

Secondly, we obtain various kinds of stationary solutions in (3) for a step function $g(u)$ by solving linear ordinary differential equations. Moreover, we show that some stationary solutions in (3) correspond to the result of numerical simulations.

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# The role of cytoplasmic protein on cell polarity formation of asymmetric cell division

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Asymmetric cell division is an elegant development process to create cell diversity. In this process, a mother cell creates polarity in both membrane and cytosol by distributing her substrates and components asymmetrically before cell division. Thus, the polarity formation in asymmetric cell division is a complex process created by harmonization of upstream and downstream polarities between the membrane and cytosol. MEX-5/6 is a well-investigated down-stream cytoplasmic protein which is deeply involved in the polarity of up-stream transmembrane protein PARs in *C. elegans* embryos. However, the interplay between the upstream PARs and downstream MEX-5/6 polarities has been poorly understood, and the contribution of downstream polarity to the robust formation of the upstream polarity remains largely unknown. In this study, we have explored the underlying mechanism of MEX-5/6 polarity formation and the interplay of MEX-5/6 polarity with PAR polarity by developing a high-dimensional mathematical model that reflects cell geometry. We found that MEX-5/6 polarity and PAR polarity have a significant mutual effect on both the establishment and maintenance phases with respect to the symmetric breaking, the length scale of polarity domain, and the temporal dynamics of polarity formation. We also found that MEX-5/6 is significantly involved in PAR polarity via flow dynamics. Our study suggests that the polarity of MEX-5/6 plays a critical role in the polarity of PARs, and the collaboration between the downstream polarity of cytoplasmic protein and the upstream polarity of transmembrane protein is indispensable for creating robust cell polarity in asymmetric cell division.

# Topological Data Analysis on Medical Imaging

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One of the most important problems in data science is how to extract information from high-dimensional and complicated data. Topological data analysis (TDA), an emerging topic in applied mathematics, provides a powerful tool to analyze data by computing the corresponding topological features. In this talk, we will discuss the background and some useful techniques in TDA. In applications, we will talk about how to use TDA to solve the problems in medical imaging with machine learning tools.

# A new approximation to Lennard-Jones Potential

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Lennard-Jones potential is an important and well-known potential to interpret the nano-bio interaction. Its Fourier transform will help us not only to derive a new model in mathematics but to reduce computed time in molecular dynamics simulation. However, the original Lennard-Jones potential has no transformation. Thus, we supply an approximated potential being close to original one and having precise Fourier transform. In this talk, I will show some properties and its applications of the new approximated potential.

# The existence of rotating wave of a flame/smoldering-front evolution equation

Shunsuke Kobayashi[1], Yasuhide Uegata[2] and Shigetoshi Yazaki[3]

Behavior of the solution to the so-called Kuramoto-Sivashinsky equation ([1, 5, 7]) for Jordan curves which is a model equation of smoldering combustion of a sheet of paper ([2, 3, 4, 6]) is mathematically analyzed. It is revealed that the equation possesses rich structures such as instability, spreading and rotating of flame/smoldering front or spinning burned region. In particular, the existence of a rotating wave solution bifurcating from a trivial solution (an expanding circle) is analyzed by using local bifurcation theory. We also give some numerical examples in which the rotating waves are visualized.

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# Slower diffuser phenomenon in a parabolic-elliptic predator-prey system of 3-species

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The phenomenon that slower diffuser prevails has been disscussed for many years. In 1998, Dockery et. al consider n-species competition model in a Neumann boundary domain. They found that among the positive solutions with different diffusion rates, the solution with the smallest one will finally survive and others will be extinct.

In 2017, King-Yeung Lam and Yuan Lou then transformed the competition model into a continuous form. They also proved the similar consequence, that is, the slower diffuser prevails.

We then want to know the phenomenon in the predator-prey system. Thus, the following is the predator-prey type model with Neumann boundary we considered and we have some partial results:

$$\begin{cases} u_t = d_1 \Delta u + u[m(x) - u - v - w] \\ v_t = d_2 \Delta v + v[m(x) - u - v - w] \\ 0 = \Delta w - w + u + v \end{cases} \tag{4}$$

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# On the Effects of Trap Potentials for Nonlinear Schrödinger Systems

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It's known that the multispecies Bose-Einstein condensates (BEC) in hyperfine spin states can be well characterized by some kind of coupled nonlinear Schrödinger systems with potentials. In this talk, we study some effects of trap potentials on the corresponding ground state energies and eigenvalues. This is a joint work with Tai-Chia Lin.

# A mathematical model of a navigation system using interaural intensity differences inspired by echolocating bats

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It is well known that many species of bats use echolocation when they fly in the air [1]. They get the information of surroundings by emitting ultrasonic waves from their mouth or nose and listening to echoes by their two ears. The amount of information in such process seems to be much less than the information in vision in which we get time sequence of 2 dimensional images. Despite of this, bats can not only fly in the completely dark cave but also hunt flying insects [2]. Our goal is to understand how such high performance of bats is achieved using echolocation.

In this study, we focus on the obstacle avoidance flight of bats. We, at first, discuss how bats detect the position of obstacles using information of echoes, and propose a mathematical model for the realtime flight path planning.

We show that the "ratio" between the acoustic pressures on the left and right ears delivers sufficient information to detect the orientation of obstacle. Combined with time interval between emitting ultrasonic sound and receiving its echoes, bats can detect the position of obstacle. The actual bats emit ultrasound pulses in the direction of flight and the direction of the nearest obstacle [3]. We show that the double (and triple) pulse emission is a good strategy to detect the obstacle.

Our mathematical model of navigation system is proposed by defining a risk function which include short time memory. Combined with double pulse emission strategy, in silico bat can safely fly in the room with several obstacles. In a real world, there are so many echoes other than the direct echo, for example, echoes from walls, ground and corners, thus bats must make a choice of echoes. Inspired by this fact, we further propose an information reduction strategy, in which only a small number of selected information is used to calculate the risk function. In silico bat also can safely fly in the room with obstacles even if the information reduction is drastic. We are testing our strategy by making autonomous vehicles.

Such a mathematical and engineering approach will provide new perspective regarding robust acoustic sensing employed by bats.

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# On synchronization analysis of non all-to-all Kuramoto oscillators

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**Abstract**

Synchronization is an universal phenomenon in real world, and Kuramoto model is a model to describe this phenomenon. In this talk, I will introduce the non all-to-all Kuramoto model and investigate theories of phase and frequency synchronization. Some numerical experiments and future works will be also presented in my talk.

# Traveling wave solutions of a 4-Species competition-diffusion model with weak competition

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In this presentation, we will first review some results of the traveling wave solutions of the Lotka-Volterra competition-diffusion model of 3-species $(u, v, w)$.

$$\begin{cases} u_{\xi\xi} + su_\xi + u(1 - u - cv - \epsilon_1 w) = 0 \\ dv_{\xi\xi} + sv_\xi + v(a - bu - v - \epsilon_2 w) = 0 \\ d_3 w_{\xi\xi} + sw_\xi + w(r_3 - C_{31}u - C_{32}v - C_{33}w) = 0 \\ (u, v, w)(-\infty) = (0, a, 0)\ ,\ (u, v, w)(+\infty) = (1, 0, 0) \end{cases}$$

In particular, the competitions between $u$ and $w$ and between $v$ and $w$ are small real values $\epsilon_1$ and $\epsilon_2$. Second part, we generalized the weak competition problem to 4-Species model:

$$\begin{cases} u_{\xi\xi} + su_\xi + u(1 - u - cv - \epsilon_1 w - \epsilon_2 p) = 0 \\ dv_{\xi\xi} + sv_\xi + v(a - bu - v - \epsilon_3 w - \epsilon_4 p) = 0 \\ d_3 w_{\xi\xi} + sw_\xi + w(r_3 - C_{31}u - C_{32}v - C_{33}w - \epsilon_5 p) = 0 \\ d_4 p_{\xi\xi} + sp_\xi + p(r_4 - C_{41}u - C_{42}v - \epsilon_6 w - C_{44}p) = 0 \\ (u, v, w, p)(-\infty) = (0, a, 0, 0)\ ,\ (u, v, w, p)(+\infty) = (1, 0, 0, 0) \end{cases}$$

Our aim is to find the nontrivial solutions of $(u, v, w, p)$, where the profile of $(u, v)$ are monotonicity profile, and $(w, p)$ are pulses. This talk will focus on the perturbation argument.

# Determining the optimal coefficient of the spatially periodic Fisher-KPP equation that minimizes the spreading speed

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Propagation phenomena appear in various fields of natural science, including population genetics, epidemiology, ecology and so on. The spatially periodic Fisher-KPP equation is among the classical models that describe propagation phenomena. From the viewpoint of ecology, this equation describes the expansion of the territory of invading alien species in a given habitat. The periodic coefficients of the equation represent an environment in which favorable zones and less favorable zones appear alternately in a periodic manner. The aim of this work is to analyze the influence of periodic environment on the invasion speed. In this talk, we discuss the problem of finding optimal periodic coefficient that minimizes the "spreading speed" under certain condition. The term "spreading speed" refers to the asymptotic speed of the propagating front of a solution with compactly supported initial data. From the ecological point of view, the spreading speed describes the invasion speed of alien species. Hence the problem means seeking the best disposition of environment to prevent the invasion of alien species. In order to solve this problem, we introduce a condition under which equality holds in an inequality about the spreading speed derived by Nadin.

# Patterns and waves in a prey-predator system with Allee effect

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In reaction-diffusion systems, the presence of two travelling fronts connecting the same rest states has been linked to the appearance of complex spatio-temporal patterns. This may occur either due to front instability, such as in FitzHugh-Nagumo-like system with NIB bifurcations, or due to stable front interactions such as merging, breathing and reflection, as it is the case in some three-species competition-diffusion systems. In this presentation, we will show how the three-species competition-diffusion system can be substituted by a prey-predator (two-species) system with Allee effect preserving the existence of two stable fronts. We will give some preliminary results about travelling waves and their interaction in such system.