

# FMfI2023 Booklet

## Forum "Math-for-Industry" 2023 -MfI2.0-

Institute of Mathematics for Industry,  
Kyushu University, Fukuoka, Japan

Nishijin Plaza  
8.29-9.1 2023

A Satellite Meeting of the 10th International Congress  
on Industrial and Applied Mathematics (ICIAM 2023)

### Confirmed speakers

Yusuke Aikawa (The University of Tokyo, JPN)

Yuko Araki (Tohoku University, JPN)

Jose Alberto Cuminato (Universidade de São Paulo, BGR)

Maria J Esteban (Université Paris-Dauphine, FRA)

Naoki Hamada (KLab Inc., JPN)

Ichiro Hasuo (National Institute of Informatics, JPN)

Yasuaki Hiraoka (Kyoto University, JPN)

Jae-Hun Jung (Pohang University of Science and Technology, KOR)

Nataša Krejić (University of Novi Sad, SRB)

Sven Leyffer (Argonne National Laboratory, USA)

Kaname Matsue (Kyushu University, JPN)

Mark McGuinness (Victoria University at Wellington, NZL)

Busayamas Pimpunchat (King Mongkut's Institute of  
Technology Ladkrabang, THA)

Konrad Polthier (Free University of Berlin, DEU)

Daisuke Sakurai (Kyushu University, JPN)

Jun Sese (Humanome Lab., Inc., JPN)

Kana Shimizu (Waseda University, JPN)

Amit Singer (Princeton University, USA)

Tomohiro Tachi (The University of Tokyo, JPN)

Yoshikazu Terada (Osaka University, JPN)

Satoru Tokuda (Kyushu University, JPN)

Hiroe Tsubaki (The Institute of Statistical Mathematics, JPN)

Hiroaki Yamada (Fujitsu Laboratory Ltd., JPN)

### Organising Committee

Kenji Kajiwara (Kyushu University), Chair

Zainal Aziz (Universiti Teknologi Malaysia)

Phillip Broadbridge (La Trobe University)

Kim Chuan Toh (National University of Singapore)

Yasuhide Fukumoto (Kyushu University)

Soon-Sun Kwon (Ajou University)

Konrad Polthier (Free University of Berlin)

Osamu Saeki (Kyushu University)

Wil Schilders (Eindhoven University of Technology)

Stephen Taylor (University of Auckland)

Masato Wakayama (NTT/Kyushu University)



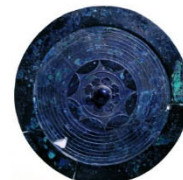


## Forum "Math-for-Industry" 2023 – MfI 2.0 –

Institute of Mathematics for Industry, Kyushu University, Fukuoka, Japan

**Nishijin Plaza, August 29 – September 1, 2023**

A Satellite Meeting of the 10th International Congress on Industrial and Applied Mathematics (ICIAM 2023)



## Forum "Math-for-Industry" 2023 –MfI2.0–:

The fifteenth installment of the FMfI series initiated by Kyushu University under the auspices of the Asia Pacific Consortium of Mathematics for Industry (APCMfI)

**Kyushu University Nishijin Plaza**

2-16-23 Nishijin, Sawara-ku, Fukuoka 814-0002, JAPAN

**29 August - 1 September 2023**

<https://apcmfi.org/fmfi2023/index.html>

### Sponsors



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**Foreword:**

It is our pleasure to welcome you to the fifteenth installment of the Forum "Math-for-Industry" (FMfI) conference series, which will be held in Fukuoka, Japan, under the auspices of the Asia Pacific Consortium of Mathematics for Industry (APCMfI). The FMfI series was initiated by Kyushu University and has since grown to become a premier conference for exploring the interface of industrial and applied mathematics to solve challenges with and for industry.

This year, the FMfI2023 is planned to be a satellite conference of the 10th International Congress of Industrial and Applied Mathematics (ICIAM2023), held on August 20-25, 2023, in Tokyo, Japan. The theme of this year's forum, "MfI2.0", highlights the ongoing evolution of the field of mathematics for industry. As industries become increasingly reliant on data-driven decision-making and automation, the importance of practical applications of mathematics in industry continues to grow. The FMfI series has been at the forefront of this development, promoting collaboration between mathematicians, researchers, and industry professionals.

The program for this year's forum includes a series of invited talks ranging from emerging mathematical ideas in MfI to large-scale academia-industry collaborated projects. Our esteemed speakers will share their knowledge and expertise on a variety of topics related to the application of mathematics in industry, and we hope that this will inspire and encourage new collaborations and innovative solutions. In particular, we have invited speakers from the International Council for Industrial and Applied Mathematics (ICIAM), the European Consortium for Mathematics in Industry (ECMI), and the Society of Industrial and Applied Mathematics (SIAM), by which we expect to strengthen the relationship with the international communities.

In addition, we are excited to host a poster session for early career researchers, providing an opportunity for them to share their research and ideas with a wider audience. We hope that this session will foster the next generation of mathematicians who will continue to push the boundaries of mathematics for industry.

We are thrilled to host FMfI 2023 in Fukuoka, Japan, and we look forward to welcoming you to this exciting and informative conference. We hope that you will find this conference to be a valuable opportunity to share your knowledge and learn from others, and we wish you a productive and enjoyable experience at FMfI 2023. Also, Fukuoka is famous and popular for its fine local special foods, such as fresh fish, ramen (soup noodles), and yakitori (grilled chicken). We hope that you enjoy much of Fukuoka as well!









Chair of FMfI2023 Organizing Committee





## Forums History

Forum "Math-for-Industry" (FMfI) 2023 is the fifteenth installment of the FMfI series initiated by Kyushu University under the auspices of the Asia Pacific Consortium of Mathematics for Industry (APCMfI). aims and locations of past Forums are listed below.

FMI2008 16 - 17 September 2008	Tokyo, Japan	Math for Industry	
FMI 2009 9 - 13 November, 2009	Fukuoka, Japan	Casimir Force, Casimir Operators and the Riemann Hypothesis -- Mathematics for Innovation in Industry and Science--	
FMI2010 21 - 23 October, 2010	Fukuoka, Japan	Information security, Visualization, and Inverse problems, on the basis of optimization techniques	
FMI 2011 24 - 28 October, 2011	Honolulu, U.S.A.	"TSUNAMI - Mathematical Modelling" Using Mathematics for Natural Disaster Prediction, Recovery and Provision for the Future	
FMI 2012 22 - 26 October, 2012	Fukuoka, Japan	Information Recovery and Discovery	
FMI 2013 4 - 8 November, 2013	Fukuoka, Japan	The Impact of Applications on Mathematics	
FMI2014 27 - 31 October 2014	Fukuoka, Japan	Applications + Practical Conceptualization + Mathematics = fruitful Innovation	
FMI 2015 26 - 30 October 2015	Fukuoka, Japan	The Role and Importance of Mathematics in Innovation	
FMfI 2016 21 - 23 November 2016	Brisbane, Australia	Agriculture as a metaphor for creativity in all human endeavors	
FMfI 2017 23 - 26 October 2017	Honolulu, U.S.A.	Responding to the Challenges of Climate Change: Exploiting, Harnessing and Enhancing the Opportunities of Clean Energy	
FMfI 2018 17 - 21 November 2018	Shanghai, China	Big Data Analysis, AI, Fintech, Math in Finances and Economics	
FMfI 2019 18 - 21 November 2019	Auckland, New Zealand	Mathematics for the Primary Industries and the Environment	
FMfI 2021 13 - 16 December 2021	Hanoi, Vietnam	Mathematics for Digital Economy	
FMfI 2022 21 - 24 November 2022	Melbourne, Australia	Mathematics of Public Health and Sustainability	
FMfI 2023 29 August - 1 September 2023	Fukuoka, Japan	MfI2.0 Restart to form the upwinding spiral	

FMfI2023 Program at a glance				
	Aug. 29	Aug. 30	Aug. 31	Sep. 1
9:00 - 9:30	Registration			
9:30 - 10:00	Opening Kenji Kajiwara Philip Broadbridge Wil Schilders Motoko Kotani			
10:00 - 10:30	①Neil Budko	⑩Amit Singer	⑲Kana Shimizu	㉓Sven Leyffer
chair	W. Schilders	R. Oishi-Tomiyasu	K. Nuida	H. Waki
10:30 - 11:00	②Ichiro Hasuo	⑪Busayamas Pimpunchat	㉔Yusuke Aikawa	㉔Yuko Araki
chair	W. Schilders	S. Taylor	K. Nuida	M. Y. Hirose
11:00 - 11:30				
11:30 - 12:00	③José Alberto Cuminato	⑫Konrad Polthier	㉑Hiroe Tsubaki	㉕Philip Broadbridge
chair	O. Saeki	H. Ochiai	S. Kurata	H. Nguyen
12:00 - 12:30	④Mark McGuinness	⑬Tomohiro Tachi	㉒Masayo Y. Hirose	㉖Kaname Matsue
chair	O. Saeki	H. Ochiai	S. Kurata	H. Nguyen
12:30 - 14:00				
14:00 - 14:30	⑤Yasuaki Hiraoka	⑭Hiroaki Yamada	Poster session	㉗Stephen Taylor
chair	S. Kaji	N. Kamiyama		㉘Nor Haniza Sarmin
14:30 - 15:00	⑥Jae-Hun Jung	⑮Satoru Tokuda		P. Broadbridge
chair	S. Kaji	N. Kamiyama		
15:00 - 15:30	⑦Daisuke Sakurai	⑯Yoshikazu Terada		Closing
chair	S. Kaji	N. Kamiyama		Philip Broadbridge
15:30 - 16:00				
16:00 - 16:30	⑧Maria J Esteban	⑰Naoki Hamada		
chair	Y. Fukumoto	Y. Mizoguchi		
16:30 - 17:00	⑨Alfio Quarteroni	⑱Jun Sese		
chair	Y. Fukumoto	Y. Mizoguchi		
17:00 - 17:30				
18:30 -		Banquet		

⑧ : Online talk

## TIME TABLE

Monday 28 August 2023	
14:00 - 15:00	<b>IMI International Advisory Board Meeting</b> Participants: IMI International advisory board members
15:30 - 16:30	<b>Asia Pacific Consortium of Mathematics for Industry Board Meeting</b> Participants: APCMfI council members
16:30 - 17:30	<b>Asia Pacific Consortium of Mathematics for Industry General Meeting</b> Participants: All APCMfI members
17:30 - 18:00	<b>IJMI Editorial board meeting</b> Participants: IJMI Editorial Board Members
Tuesday 29 August 2023	
9:00 - 9:30	<b>Registration:</b> Please register for FMfI2023 at the reception counter, and confirm receipt of the forum materials and your name tag. If you wish to participate in the banquet, please pay in Japanese yen. Also, if necessary, please check in your baggage.
9:30 - 10:00	<b>Opening ceremony</b> Congratulatory speech: <ul style="list-style-type: none"> <li>• Kenji Kajiwara (Kyushu University, JPN)</li> <li>• Philip Broadbridge (La Trobe University, AUS)</li> <li>• Wil Schilders (Eindhoven University of Technology, NLD)</li> <li>• Motoko Kotani (Tohoku University, JPN)</li> </ul>
10:00 - 10:30 Chair	① <b>Neil Budko</b> Wil Schilders
10:30 - 11:00 Chair	② <b>Ichiro Hasuo</b> Wil Schilders
11:30 - 12:00 Chair	③ <b>José Alberto Cuminato</b> Osamu Saeki
12:00 - 12:30 Chair	④ <b>Mark McGuinness</b> Osamu Saeki

12:30 - 14:00 Lunch	Before lunch Group Photo	
14:00 - 14:30 Chair	⑤ <b>Yasuaki Hiraoka</b> Shizuo Kaji	
14:30 - 15:00 Chair	⑥ <b>Jae-Hun Jung</b> Shizuo Kaji	
15:00 - 15:30 Chair	⑦ <b>Daisuke Sakurai</b> Shizuo Kaji	
16:00 - 16:30 Chair	⑧ <b>Maria J Esteban</b> (online talk) Yasuhide Fukumoto	
16:30 - 17:00 Chair	⑨ <b>Alfio Quarteroni</b> (online talk) Yasuhide Fukumoto	
Wednesday 30 August 2023		
10:00 - 10:30 Chair	⑩ <b>Amit Singer</b> (online talk) Ryoko Oishi-Tomiyasu	
10:30 - 11:00 Chair	⑪ <b>Busayamas Pimpunchat</b> Stephen Taylor	
11:30 - 12:00 Chair	⑫ <b>Konrad Polthier</b> Hiroyuki Ochiai	
12:00 - 12:30 Chair	⑬ <b>Tomohiro Tachi</b> (online talk) Hiroyuki Ochiai	
14:00 - 14:30 Chair	⑭ <b>Hiroaki Yamada</b> Naoyuki Kamiyama	
14:30 - 15:00 Chair	⑮ <b>Satoru Tokuda</b> Naoyuki Kamiyama	
15:00 - 15:30 Chair	⑯ <b>Yoshikazu Terada</b> Naoyuki Kamiyama	
16:00 - 16:30 Chair	⑰ <b>Naoki Hamada</b> Yoshihiro Mizoguchi	
16:30 - 17:00 Chair	⑱ <b>Jun Sese</b> Yoshihiro Mizoguchi	

18:30 -	<b>Banquet</b>
<b>Thursday 31 August 2023</b>	
10:00 - 10:30 Chair	⑲ <b>Kana Shimizu</b> Koji Nuida
10:30 - 11:00 Chair	⑳ <b>Yusuke Aikawa</b> Koji Nuida
11:30 - 12:00 Chair	㉑ <b>Hiroe Tsubaki</b> Sumito Kurata
12:00 - 12:30 Chair	㉒ <b>Masayo Y. Hirose</b> Sumito Kurata
14:00 - 18:00 Chair	<b>Poster session</b>
<b>Friday 1 September 2023</b>	
10:00 - 10:30 Chair	㉓ <b>Sven Leyffer</b> (online talk) Hayato Waki
10:30 - 11:00 Chair	㉔ <b>Yuko Araki</b> Masayo Y. Hirose
11:30 - 12:00 Chair	㉕ <b>Philip Broadbridge</b> Dinh Hoa Nguyen
12:00 - 12:30 Chair	㉖ <b>Kaname Matsue</b> Dinh Hoa Nguyen
14:00 - 14:30 Chair	㉗ <b>Stephen Taylor</b> Philip Broadbridge
14:30 - 15:00 Chair	㉘ <b>Nor Haniza Sarmin</b> Philip Broadbridge
15:00 - 15:30	<b>Closing</b> • Philip Broadbridge <b>Poster Prize-Giving</b> 



## Presentation Abstract



### Usage Guide

Information on speakers is listed in order of presentation number.

- (0) Time
- (1) **Name**
- (2) Affiliation
- (3) **Lecture title**
- (4) Abstract
- (5) Keywords represents.



- ①
- (0) Aug.29, 10:00 - 10:30
- (1) **Neil Budko**
- (2) Delft University of Technology
- (3) **ECMI: Cooperating, Promoting and Teaching Industrial Mathematics in Europe**
- (4) The European Consortium for Mathematics in Industry (ECMI), established in 1987, is actively engaged in promoting the role of mathematics in industry, teaching new generations of applied mathematicians to work directly with industry, and helping the members of academia to acquire European and industrial funding. In this talk the structure and activities of ECMI will be described, including: nodes, study groups, special interest groups, modeling weeks, bi-annual conference, prizes, and publications. Current research directions and initiatives at various ECMI nodes will be presented.



- ②
- (0) Aug.29, 10:30 - 11:00
- (1) **Ichiro Hasuo**
- (2) National Institute of Informatics
- (3) **Proving Safety of Automated Driving Vehicles**
- (4) I will introduce our recent work on using mathematical logic to rigorously prove the safety of automated driving vehicles. The main challenge in such formal verification attempts for real-world systems is the absence of target system models. We follow the methodology called RSS (responsibility-sensitive safety, Shalev-Shwartz et al., 2017) that tells what to model (and what not to model) in a both technically and socially sensible way. Our logical formalization and extension of RSS allows us to handle complex driving scenarios in a compositional manner. Overall, the work suggests the potential of mathematical logic as a social infrastructure for establishing trust in novel ICT.



- ③
- (0) Aug.29, 11:30 - 12:00
- (1) **José Alberto Cuminato and Débora de Oliveira Medeiros**
- (2) Institute of Mathematics and Computer Sciences, University of São Paulo - USP
- (3) **A Lagrangian-finite difference scheme for viscoelastic fluid flows**
- (4) We present new numerical schemes based on writing the upper-convected time derivative of the polymeric tensor in terms of the Generalized Lie Derivative (GLD) on a Lagrangian framework and then discretizing it by finite differences. The viscoelastic models are rewritten considering the GLD with the method of characteristics. The polymeric tensor derivatives are approximated by methods of first or second order in time, combined with linear, or quadratic, spatial interpolations in order to improve the stability of the scheme, in preparation for the study of the High Weissenberg Number Problem. This is a joint work with Cassio Oishi and Hirofumi Notsu.



- ④
- (0) Aug.29, 12:00 - 12:30
- (1) **Mark McGuinness**
- (2) Victoria University of Wellington
- (3) **Real Time Moisture Measurement using Microwaves**
- (4) An important factor when delivering bauxite ore to an alumina factory is the moisture content in the shipment. A microwave analyzer can be mounted across a conveyor belt to measure phase shift, attenuation, and ore depth to infer moisture content in real time using a linear calibration.

The moisture content is a important because it affects the weight of the ore, with direct impact on the true value of the ore. Accurate and reliable continuous moisture measurement is important to both buyer and seller.

Our study is informed by data provided to a European Study Group with Industry that was collected from a number of shipments to a factory in Ireland. We use Maxwell's differential equations to develop a four-layer model of microwave propagation that captures the effects of reflections at multiple interfaces between ore and air. These reflections cause interference effects in phase shifts and attenuation as the ore depth varies on the conveyor belt.

Our model explains the strongly nonlinear dependence of attenuation data on ore depth, and improves understanding of and confidence in the real-time measurement of ore moisture content using microwaves.



⑤

(0) Aug.29, 14:00 - 14:30

(1) **Yasuaki Hiraoka**

(2) Kyoto University

(3) **Persistent homology from viewpoints of representation, probability, and application**

(4) Topological data analysis (TDA) has emerged in this century and shed new light on data science. A particularly important tool in TDA is persistent homology, which can provide useful information about “shape of data” in a multi-scale way. Much of the development of theoretical research on persistent homology has been motivated by applications. This talk will survey the progress of persistent homology from the perspective of both mathematical and applied research.



⑥

(0) Aug.29, 14:30 - 15:00

(1) **Jae-Hun Jung**

(2) POSTECH

(3) **Topological data analysis of time-series data**

(4) Time-series data are found in a wide range of industrial applications. We consider topological data analysis (TDA) as an effective method for identifying inherent cyclic structures in the data. We illustrate some applications of TDA to music and periodic signals using the extracted cyclic patterns.



⑦

(0) Aug.29, 15:00 - 15:30

(1) **Daisuke Sakurai**

(2) Kyushu University, JPN

(3) **Maps and Their Topological Singularities in Visualization**

(4) Computation of topology and singularity has become a recognized tool for understanding scalar field data over a volumetric continuum. In the real world, however, volumetric data are rarely scalar, requiring analysis of vector-valued fields. It is thus interesting to consider how computational topology for scalar fields, which are functions, can be generalized for maps. In this talk, the speaker shares his experience on this topic, especially for visualization. Data are treated as PL-maps for the simplicity of topological analysis, and algorithms are studied in a variety of concepts relating to Reeb graphs and Morse theory. Indeed, one key is the generalization of Reeb graphs and the analysis of their structure for understanding data. In particular, the talk sheds lights on how Reeb spaces and singular fibers appear in the context of computation, and recent work on benchmarking multiobjective optimization solvers.



⑧

(0) Aug.29, 16:00 - 16:30

(1) **Maria J ESTEBAN**

(2) Université Paris-Dauphine, FRA

(3) **A new European initiative to facilitate the interaction of industry and academic mathematicians**

(4) In September 2022 was officially launched the OpenDesk of EU-MATHS-IN. In this talk I will present this one-stop-shop for tailor-made solutions for industry, commerce, public administration and startups and comment on its functioning since its launching.



⑨

(0) Aug.29, 16:30 - 17:00

(1) **Alfio Quarteroni**

(2) Politecnico di Milano, Milan, and EPFL, Lausanne, ITA

(3) **Physics-based and data-driven mathematical models for the simulation of the heart function**

(4) This presentation will focus on an integrated numerical model to simulate the cardiac function. Physics-based models will represent the backbone of our approach, however their synergistic use with data driven models will be addressed as well.

Applications to several problems of clinical relevance will be discussed.



⑩

(0) Aug.30, 10:00 - 10:30

(1) **Amit Singer**

(2) Princeton University

(3) **Computational Mathematics for Cryo-Electron Microscopy**

(4) Single-particle cryo electron microscopy (cryo-EM) is an increasingly popular technique for elucidating the three-dimensional structure of proteins and other biologically significant complexes at near-atomic resolution. It is an imaging method that does not require crystallization and can capture molecules in their native states. In single-particle cryo-EM, the three-dimensional molecular structure needs to be determined from many noisy two-dimensional tomographic projections of individual molecules, whose orientations and positions are unknown. The high level of noise and the unknown pose parameters are two key elements that make reconstruction a challenging computational problem. Even more challenging is the inference of structural variability and flexible motions when the individual molecules being imaged are in different conformational states. The talk will overview the underlying mathematical theory, computational methods, and notable challenges for structure determination by single-particle cryo-EM.



⑪

(0) Aug.30, 10:30 - 11:00

(1) **Busayamas Pimpunchat**

(2) King Mongkut's Institute of Technology Ladkrabang, Thailand

(3) **The role of AI in society and communities for sustainable progress**

(4) The presented research emphasizes the potential of AI to contribute significantly to greater social good. This technology addresses the world's most pressing challenges. A more resilient and sustainable future can be built by using AI as a powerful tool. By focusing on flood protection, agricultural yields, and social security, we showcase the diverse applications of AI in these domains. In the realm of flood protection, AI algorithms are employed to identify high-risk areas, facilitating improved flood protection systems. This approach aids in minimizing casualties and injuries caused by flooding events. AI techniques also play a vital role in forecasting agricultural yields. By leveraging data-driven insights, farmers can make informed decisions regarding planting and harvesting, leading to enhanced food security. Furthermore, our discussion highlights the application of AI in estimating compensation and determining contribution rates for the Social Security Fund. Such analyses enable governments to establish appropriate rates, ensuring the long-term sustainability of social security systems.



⑫

(0) Aug.30, 11:30 - 12:00

(1) **Konrad Polthier**

(2) Free University of Berlin

(3) **Vibrations of Geometric Shapes**

(4) The vibrations of musical strings are well understood by Fourier analysis while the vibrations of geometric shapes exhibit surprising properties triggered by careful choices of differential geometric energies. We will review solved problems and introduce novel approaches with applications in biology, computer graphics and crystallography.



⑬

(0) Aug.30, 12:00 - 12:30

(1) **Tomohiro Tachi**

(2) The University of Tokyo

(3) **Computationally Designing Macroscopic Behaviors of Origami**

(4) Origami, the traditional art of folding sheets of paper, is attracting the attention of scientists and engineers as an approach to obtaining programmable metamaterials with shape-morphing abilities and mechanical properties. To control and design such exotic behaviors of origami, we are developing a novel framework to handle the macroscopic behaviors of origami through computation. The talk shows our recent works on self-organized wrinkling behaviors, conservative systems of origami tessellations, and STEAM collaboration.



⑭

(0) Aug.30, 14:00 - 14:30

(1) **Hiroaki Yamada**

(2) Converging Technologies Laboratory, Fujitsu Ltd.

(3) **Advancing Social Simulation by Fusing with Machine Learning**

(4) Social simulation is a simulation that reproduces various social phenomena. Social simulation has the advantage of visualizing future and past events that are difficult to observe directly and analyzing counterfactual events. In the fields of logistics, traffic management, and pedestrian management, there has been a lot of social simulation research to visualize the whole perspective of large-scale complex social systems and to analyze policies that are difficult to experiment with. In recent years, there has been growing interest in machine learning, such as deep learning, in the social simulation domain, due to the desire to deal with a large amount of accumulated social data and to link social simulation with the real world (digital twin). Specifically, it is expected that machine learning can be helped to build simulation models using large-scale social data and to analyze massive data generated from simulations. In this presentation, we introduce our research which tries to integrate social simulation and machine learning in order to meet recent expectations.



⑮

(0) Aug.30, 14:30 - 15:00

(1) **Satoru Tokuda**

(2) Research Institute for Information Technology, Kyushu University

(3) **Scaling relations between observed data and Occam's razor in Bayesian model selection**

(4) We show how observed data scale Occam's razor in Bayesian model selection, a guiding principle that models should be simple enough to describe the data. This work is motivated by mathematical modelling for understanding physical phenomena.



⑯

(0) Aug.30, 15:00 - 15:30

(1) **Yoshikazu Terada**

(2) Graduate School of Engineering Science, Osaka University / Center for Advanced Integrated Intelligence Research, RIKEN

(3) **A statistical theory of clustering**

(4) With recent advances in computer and measurement technologies, large and complex datasets have become common in various application fields. The importance of unsupervised learning has been recognized. Clustering, one of the most important tasks in unsupervised learning, aims to discover hidden groups for a given set of data points. However, the theoretical properties of clustering methods have received less attention. In this talk, we will discuss the minimal requirements that clustering methods should satisfy from a theoretical standpoint. We will explain the theoretical properties of several clustering methods and present our recent works related to this topic.



⑰

(0) Aug.30, 16:00 - 16:30

(1) **Naoki Hamada**

(2) KLab Inc.

(3) **Two-Parameter Extension of Regularization Path for Elastic Net**

(4) Elastic net is one of the most successful methods in sparse modeling because its two regularization terms achieve sparseness and robustness simultaneously. However, its regularization path varies only one regularization factor while the other is fixed. This talk gives a two-parameter extension of the regularization path and a method for its approximate computation. This is a joint work with Yusuke Mizota, Shunsuke Ichiki and Kenichi Hayashi.



⑱

(0) Aug.30, 16:30 - 17:00

(1) **Jun Sese**

(2) Humanome Lab., Inc.

(3) **Health forecast machine learning model with 25 million measurement data**

(4) We are conducting health measurement research that measures the daily lives of people with IoT devices, analyzes them and returns the results to subjects. Here, we introduce a machine learning method to predict health conditions based on over 25 million data points and questionnaire results.



⑲

(0) Aug.31, 10:00 - 10:30

(1) **Kana Shimizu**

(2) Waseda University

(3) **Secure string search using a succinct data structure**

(4) The secure multi-party computation (SMPC) enables computing a function among mutually untrusted parties. We introduce an efficient SMPC protocol for a database search using a succinct data structure and show the application to genome sequence search.



⑳

(0) Aug.31, 10:30 - 11:00

(1) **Yusuke Aikawa**

(2) The University of Tokyo

(3) **Expander Families for Post-Quantum Cryptography**

(4) The security of public key cryptography is supported by computational hardness of problems derived from mathematics. For example, the integer factoring problem is a basis for the security of RSA cryptography. However, in 1994, Shor proposed an efficient quantum algorithm solving these problems, for example factoring and discrete logarithm problem (DLP). This means that emergence of large-scale quantum computers will break public key cryptography in use today. So, we need cryptography that are resistant to cryptanalysis by quantum computers. Such cryptographic primitives are called post-quantum cryptography, PQC for short. In order to construct PQC, it is necessary to introduce mathematical computational assumptions that are different from factoring and DLP.

In this talk, the speaker will talk about constructing a candidate of PQC from random walks on expander graphs, including our recent results. In particular, isogeny graphs of abelian varieties and Cayley graph expanders will be discussed.



②①

(0) Aug.31, 11:30 - 12:00

(1) **Hiroe Tsubaki**

(2) The Institute of Statistical Mathematics, Research Organization of Information and Systems

(3) **Statistical Science for Society**~ **Process and Professionals for Progress** ~

(4) Statistical science, which was born as a Grammar of Science, generated the process of customer value generation in industry mainly in the field of quality management. After a brief review of its history, I will discuss how these knowledge management processes should be utilized current social issues that cannot be solved without integrating knowledge from diverse fields, how to incorporate new technologies such as statistical machine learning into the processes, and how to foster professionals who possess necessary knowledge of mathematical scientific methods and competencies of utilizing them.



②②

(0) Aug.31, 12:00 - 12:30

(1) **Masayo Y. Hirose**

(2) Institute of Mathematics for Industry, Kyushu University

(3) **Poverty Mapping in Japan based on Area Level Model Approach using Japanese Official Microdata**

(4) It has been considered a social problem related to poverty in Japan, especially for a decade. To address such a big issue, making a reliable document to understand some poverty situations for small domains may be essential. In this study, we map the poverty rate of a small demographic domain for each prefecture, which was constructed using official Japanese microdata. We also modified one statistical estimating method under the area-level model to analyze the data obtained using a complex sampling design. This is joint work with Dr. Mayumi Oka at the Institute of Statistical Mathematics.



②③

(0) Sep.1, 10:00 - 10:30

(1) **Sven Leyffer**

(2) Argonne National Laboratory

(3) **Topological Design Problems and Integer Optimization**

(4) Topological design problems arise in many important engineering and scientific applications, such as additive manufacturing and the design of cloaking devices. We formulate these problems as massive mixed-integer PDE-constrained optimization (MIPDECO) problems. We show that despite their seemingly hopeless complexity, MIPDECOs can be solved efficiently (at a cost comparable to a single continuous PDE-constrained optimization solve). We discuss two classes of such methods for solving MIPDECOs that do not require exhaustive tree-searches: rounding techniques, and trust-region methods. Surprisingly, both methods converge asymptotically under mesh refinement to a globally optimal integer solution under a convexity assumption. We illustrate these solution techniques with examples from topology optimization.



②④

(0) Sep.1, 10:30 - 11:00

(1) **Yuko Araki**

(2) Tohoku University

(3) **Statistical modeling of time-varying physical quantities for tactile evaluation of automotive materials**

(4) In the automotive manufacturing industry, there has been significant progress in automating the production process. When it comes to material selection, some companies evaluate multiple materials using a pressure needle, and based on the results, humans choose the materials that provide a comfortable tactile experience. In this study, we developed a statistical model to investigate how the time-varying physical quantities observed on the surface of each material impact the sensory evaluation through touch. Our proposed model predicts a group based on a set of functions, taking into account quantities that vary over time as a function of time. This approach enables a more precise and quantitative assessment of the tactile properties of materials. Additionally, by utilizing the Karhunen-Loeve expansion of the set of time functions, we uncover the waveform characteristics of the physical quantities over time.





②⑤

(0) Sep.1, 11:30 - 12:00

(1) **Philip Broadbridge**

(2) La Trobe University, Australia and IMI-Kyushu University, Japan

(3) **Reaction-diffusion models for fish populations with realistic mobility**

(4) Nonlinear reaction-diffusion equations, with Fisher logistic growth and constant diffusion coefficient, have been used in fisheries research to estimate sustainable harvesting rates and critical domain sizes of no-take areas. However, constant diffusivity in a population density corresponds to standard Brownian motion of individuals, with a normal distribution for displacement over a fixed time interval. For available good data sets on mobile fish populations, the distribution is certainly not normal. The data can be fitted with a long-tailed Lévy distribution that corresponds to diffusion by fractional Laplacian. Optimal foraging theory shows that an order-0.5 Lévy process is optimal for sparse populations.

We have developed exact solutions for realistic Fisher-Kolmogorov-Petrovski-Piscounov models with diffusion by fractional Laplacian. These have also been extended to hyperbolic diffusion models with a Cattaneo-type delay between gradient and flux, as an individual will persist with overcrowding for some time before emigrating. It is then shown how to modify critical domain sizes of protected areas.



②⑥

(0) Sep.1, 12:00 - 12:30

(1) **Kaname Matsue**

(2) Institute of Mathematics for Industry / International Institute for Carbon-Neutral Energy Research, Kyushu University, JPN

(3) **Nonlinear dynamics of hydrodynamically unstable premixed flames with physicochemical interactions**

(4) Dynamics of hydrodynamically unstable premixed flames are studied. The nonlinear hydrodynamic model and the Sivashinsky equation are considered to extract intrinsic nature of nonlinear flame morphology through numerics and the bifurcation theory. This talk is based on the joint works with Prof. Moshe Matalon (UIUC).



②⑦

(0) Sep.1, 14:00 - 14:30

(1) **Stephen Taylor**

(2) University of Auckland

(3) **Dairy Farm Modelling**

(4) Milk production is a major global industry and it is New Zealand's largest export earner.

We use mathematical modelling to analyze common issues faced by dairy farmers in NZ and abroad, including how long cows should be grazing in a particular field before being rotated to another, and the effects of urination and defecation on soil and waterways.



②⑧

(0) Sep.1, 14:00 - 14:30

(1) **Nor Haniza Sarmin**

(2) Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia

(3) **DNA Splicing : Emerging Technologies in Recombinant DNA Using Formal Language Theory**

(4) The diversity of mathematical applications in various scientific concepts has led to significant advancements in understanding complex biological processes. One area where this interdisciplinary collaboration thrives is DNA splicing, a basic biological process in manipulating genetic information and simulated by the technique of recombinant DNA molecules that relies on restriction enzymes. This presentation explores the idea of DNA splicing in various concepts. Firstly, the fundamental mathematical framework behind DNA splicing is presented. Also, the interplay between mathematical models and wet lab experiments is shared to validate the theoretical findings. The emergence of DNA splicing in computer science where some computational models such as graphical user interface (GUI) is also discussed. Finally, the graphical approach to studying DNA splicing is presented to emphasize the role of visual representation in comprehending complex biological processes.



## Poster Session Poster Outline



### Usage Guide

Information on the Poster is listed in alphabetical order by the Author's family name.

- (0) Name
- (1) Affiliation
- (2) Poster title
- (3) Abstract
- (4) Presenter's Short Bio

poster image

1

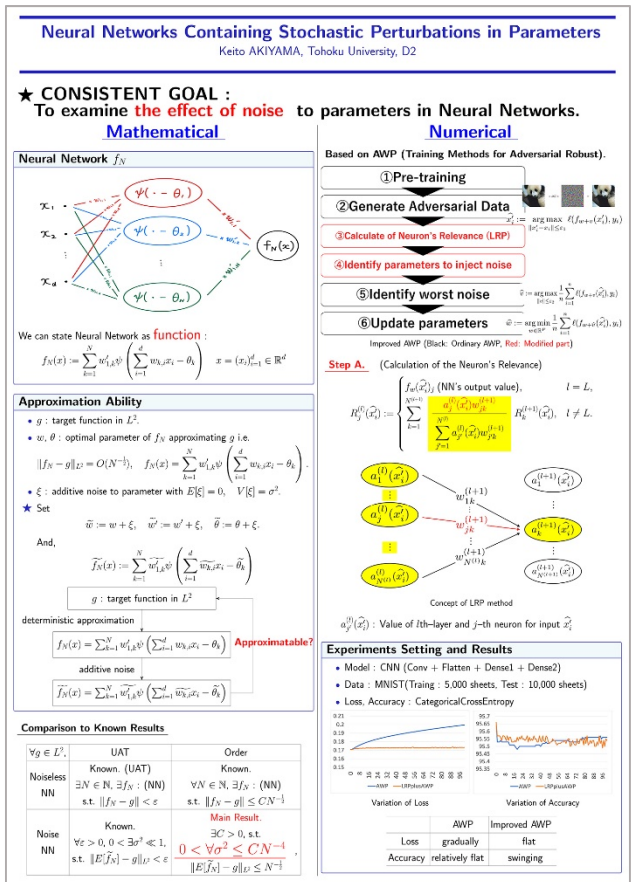
### (0) Keito Akiyama

(1) Mathematical Institute, School of Science, Tohoku University, Japan

### (2) Neural Networks Containing Stochastic Perturbations in Parameters

(3) Neural networks is a mathematical model, which is including many parameters. We consider neural networks whose parameters contain stochastic perturbations. From mathematical perspective, we derive the approximation ability of noise-injected neural networks, quantitatively. From numerical perspective, we introduce the result of numerical experiments, adding partial perturbations to parameters of the neural network.

(4) I'm Keito AKIYAMA, from Mathematical Institute, Tohoku University. I'm studying neural networks using analysis. I'm interested in the effects of stochastic perturbations(noises) on neural networks. I've investigated mathematical analysis of the effect of noise on function approximation ability and numerical experiments on the localization of noise in neural networks. Recently, I've been working on mathematical analysis of mean field neural networks.



2

(0) Jie An

(1) National Institute of Informatics, Tokyo, Japan

(2) **Inferring Switched Nonlinear Dynamical Systems**

(3) Identification of dynamical and hybrid systems using trajectory data is an important way to construct models for complex systems where derivation from first principles is too difficult. In this paper, we study the identification problem for switched dynamical systems with polynomial ODEs. This is a difficult problem as it combines estimating coefficients for nonlinear dynamics and determining boundaries between modes. We propose two different algorithms for this problem, depending on whether to perform prior segmentation of trajectories. For methods with prior segmentation, we present a heuristic segmentation algorithm and a way to classify the modes using clustering. For methods without prior segmentation, we extend identification techniques for piecewise affine models to our problem. To estimate derivatives along the given trajectories, we use Linear Multistep Methods. Finally, we propose a way to evaluate an identified model by computing a relative difference between the predicted and actual derivatives. Based on this evaluation method, we perform experiments on five switched dynamical systems with different parameters, for a total of twenty cases. We also compare with three baseline methods: clustering with DBSCAN, standard optimization methods in SciPy and identification of ARX models in Matlab, as well as with state-of-the-art identification method for piecewise affine models. The experiments show that our two methods perform better across a wide range of situations.

(4) Dr. Jie An is a Project Assistant Professor at the National Institute of Informatics (NII) in Tokyo, Japan. From November 2020 to October 2022, he was a postdoctoral researcher working in the Rigorous Software Engineering Group at the Max Planck Institute for Software Systems (MPI-SWS), Kaiserslautern, Germany. Prior to that, he received a Ph.D. degree in Software Engineering from Tongji University, Shanghai, China in 2020. From 2017 to 2020, he was also a visiting Ph.D. student at the State Key Lab. of Computer Science, Institute of Software, Chinese Academy of Sciences.

**Inferring Switched Nonlinear Dynamical Systems**  
from time-series system behaviours.Jie An  
National Institute of Informatics (NII)**Motivation**

In many areas of science and engineering, need to construct models of a system. This can be followed by verification, control synthesis, and analysis of its properties.

• **Problem:** Deriving a model from first principles may be difficult.

• **Solution:** Learn a model from its observed behaviors.

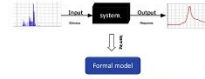


Figure 1: System identification &amp; model learning

**Introduction and Problem Statement**

Recent decades witnessed a large investment in Cyber Physical Systems (CPS) which have become ubiquitous in our daily life, for example in autonomous vehicles, drones, industrial robots, etc. For many real-life complex systems, determining a model by derivation from first principles is very difficult. It is common in CPS applications to use many different kinds of sensors and monitors to gather data from systems.

In this work [1], we focus on identifying Switched Nonlinear Dynamical Systems (SNDS) from given trajectories. A instance of an SNDS consists of a sequence of segments, where the behavior in each segment is given by the ODE of a mode.

An SNDS has a finite number of modes. In different  $N$  modes, position evolves according to the following differential equation

$$\dot{x}(t) = \begin{cases} f_1(x(t)) & \text{if } G_1(x) \geq 0 \\ f_2(x(t)) & \text{else if } G_2(x) \geq 0 \\ \vdots & \vdots \\ f_N(x(t)) & \text{else if } G_N(x) \geq 0 \\ f_{N+1}(x(t)) & \text{otherwise} \end{cases}$$

where  $\forall i \in \{1, 2, \dots, N+1\}$ ,  $G_i(x) \geq 0$  is a polynomial inequality.

• **Switched:** system consists of several modes, corresponding to disjoint sets of state space.

• **Nonlinear:** behavior in each mode is described by a nonlinear ODE. Boundary between modes can also given by polynomials.

**Problem statement:** Identify an SNDS including the switching structure, ODEs, and boundaries from the given trajectories.

**Example**

As an example, consider the Isclinet system shown in Figure 2. Our purpose is to construct a formal model from its observable behaviors, e.g. the trajectory signals of the Isclinet and the box in Figure 3. Our output is an SNDS, represented by a hybrid automaton shown in Figure 4.



Figure 2: The Isclinet system

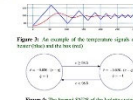


Figure 3: The Isclinet SNDS of the Isclinet system

**Method**

Figure 4: The overall process of identifying SNDS

In the Linear Multistep Method (LMM) to obtain estimates of the derivatives, (both forward and backward)

$$f(x(t_k)) \approx \frac{1}{h} \left( \frac{1}{2} y(t_k) - \frac{1}{6} y(t_{k-1}) + \frac{1}{2} y(t_{k-2}) - \frac{1}{6} y(t_{k-3}) + \frac{1}{2} y(t_{k-4}) - \frac{1}{6} y(t_{k-5}) + \frac{1}{2} y(t_{k-6}) \right)$$

$$f(x(t_k)) \approx \frac{1}{h} \left( \frac{1}{6} y(t_k) - \frac{5}{12} y(t_{k-1}) + \frac{3}{4} y(t_{k-2}) - \frac{25}{24} y(t_{k-3}) + \frac{5}{6} y(t_{k-4}) - \frac{1}{6} y(t_{k-5}) \right)$$

1b. Divide each trajectory into segments by observing sudden changes in derivative.

→ Relative difference  $\Delta x = \frac{|x(t_k) - x(t_{k-1})|}{|x(t_k)|}$

→ Change point: the difference between forward and backward LMM is above a threshold.

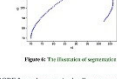


Figure 5: The illustration of segmentation

2. Obtain estimates of  $f(x(t))$  for each segment using linear regression.

→ Estimate  $\hat{f} = f(t(t))$  by  $\hat{f}_i = f(t(t)) / P_i$

→ Suppose the highest order of polynomials is  $d$ .

→  $\hat{f}_i(t) = \sum_{j=0}^d \hat{f}_{i,j} t^j$ ,  $\hat{f}_{i,j}$  are the values of the monomials in  $\hat{f}_i$ .

→  $\hat{f}_{i,j}(t)$  is the  $j$ th component of  $\hat{f}_i(t)$ , and  $\hat{f}_i$  is the  $i$ th component of  $\hat{f}$ .

→ Given  $A = D \cdot P$ , using Moore-Penrose pseudoinverse, get  $P = (A^T A)^{-1} A^T D$ .

3. Iteratively merge segments whose combined data fit with linear regression.

→ Merge and split until the combination model that satisfies the procedure by the same model. It's fully correct  $N$  clusters, each for one mode. Compare the final ODEs by linear regression.

→ Now the linear regression on coefficient is not robust. Very different coefficients can induce similar behavior on a small region of space, this problem is especially acute for nonlinear systems.

4. The classification methods to determine each boundary  $G_i$  between modes.

→ E.g. Support Vector Machine, Cong classifiers, etc.

**Experiments**

Table 1: Comparison of the relative difference  $\Delta$  of the derivative of each state points.

→ Preferred better than classical clustering methods, Monte (PWA), ARX method, and standard optimization methods (ODE).

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3

## (0) Edoardo Fabbrini

(1) Graduate School of Mathematics, Kyushu University, Japan

## (2) Energy scaling factors of systems of disclinations: the periodic case

(3) I focus on systems of disclinations by analysing the associated effective energy regimes depending on geometry aspect ratios and mutual distances.

Specifically, I target disclination dipole and quadrupoles under the assumption of linear hyperelastic material with no external loads in plane strain conditions. Field equations (mechanical equilibrium and kinematic incompatibility) are written in terms of the Airy stress function. My main result is the full characterization of configurations of disclination quadrupoles in terms of existence of a minimal energy configuration and optimal geometry for both isotropic and transverse-isotropic hyperelastic materials.

(4) Born in Rome (Italy), after a bachelor in mechanical engineering and a master's degree in aeronautical engineering, both obtained from Roma Tre University, I started a PhD in applied mathematics at Kyushu University working under the supervision of Prof. Pierluigi Cesana. My academic interests reside on studying mathematical models of plastic deformation occurring in metals and on the design of functional materials.

## Energy scaling factors of systems of disclinations: the periodic case

Edoardo FABBRINI  
Kyushu University, Graduate School of Mathematics  
fabbrini.edoardo.8406@kyushu-u.ac.jp

## 1) Background and purpose

- We study systems of plane wedge disclinations on a lattice in various configurations.
- We show that by acting on geometry and loading parameters disclination quadrupoles can effectively describe plastic kinks and dislocations (see Figure 1).



Figure 1: Left: Kink bands of 30° disclinations of length 1/2. Right: disclination in EPD (2).

## 2) Mechanical model

Periodic plane strain linearized elasticity

(Monosymmetric)

(Kinematic incompatibility)

(Constitutive relation)

$$\sigma = C : \epsilon$$

$$\sigma = \frac{1}{2} \left( \sigma + \sigma^T \right)$$

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## 3) Isotropic material [5]

We write the solution to (4) in terms of 2D Fourier series expansion. Setting  $\alpha = (\alpha_1, \alpha_2)$ , we write

$$u(\alpha) = \sum_{\alpha} \hat{u}(\alpha) e^{i\alpha \cdot x}$$

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## 4) Transversely isotropic material [5]

We assume the medium is isotropic in the  $xz$  plane. The governing equation reads

$$\frac{1}{2} \left( \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial z^2} \right) u = \frac{\partial^2}{\partial x^2} u$$

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## (0) James Haydon

(1) ERATO MMSD, National Institute of Informatics, Japan

## (2) Mathematical Safety Proofs for Automated Driving Vehicles

(3) We introduce our methodology to provide strong mathematical safety guarantees to automated driving vehicles. Building on the existing methodology called "Responsibility-Sensitive Safety (RSS)" for mathematical proofs of automated driving safety, our research established its extension called "Goal-Aware RSS (GA-RSS)" that expands RSS's application domain to a variety of real-world driving scenarios. The techniques in GA-RSS derived from theoretical results in formal logic enable one to provide mathematical safety proofs to more complex driving scenarios than before, especially those which require achievement of certain goals such as an emergency stop.

(4) James Haydon, Ph.D., is a Technical Specialist at the JST ERATO "Metamathematics for Systems Design" Project at National Institute of Informatics (NII), Tokyo, Japan. He received a PhD in Mathematics from the University of Oxford (UK), in 2014, where he was supervised by Prof. Minhyong Kim. Before his current position, he held positions as a software engineer in industry, mainly working on formal systems and domain specific languages. His interests include formal systems, programming language design and category theory. He created the lawvere categorical programming language.

## Mathematical Safety Proofs for Automated Driving Vehicles</

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## (0) Ka Long Keith Ho

(1) JGMI, Kyushu University, Japan

## (2) Adaptive Ridge Approach to Heteroscedastic Regression

(3) We propose an Adaptive Ridge-based estimation scheme for a heteroscedastic linear model equipped with log-linear errors. We show new asymptotic distributional and tightness properties under sparsity and also show iterating will shrink estimates for zero parameters under suitable assumptions. We present numerical evidence that illustrates the efficacy of the proposed estimation scheme and incentivizes extensions of this paper's results.

(4) Keith graduated from Jesus College, University of Cambridge reading Mathematics in 2019. He began his postgraduate studies in April 2021 at Kyushu University and is currently in his first year PhD Course. One of his research areas in Statistics is regularization, where he has recently completed his Master's Thesis in.

**Adaptive Ridge Approach to Heteroscedastic Regression**  
 Keith Ho  
 Joint Graduate School of Mathematics for Innovation, Kyushu University  
 Email: ho.kalongkeith.224@kyushu-u.ac.jp

**Overview and Motivation**

Adaptive Ridge (AR) estimation scheme for a Heteroscedastic Linear Regression Model with Log-Linear Errors [3]:

$$Y = X\alpha + e^{Z\beta}\epsilon$$

We addressed the following themes simultaneously: **Sparsity, Estimation, and Computational Efficiency**. We also provided new asymptotic results  $\alpha$  and  $\beta$  under suitably chosen tuning parameters  $\Lambda$  and  $\Gamma$ .

**Adaptive Ridge (AR) Estimator [1], [2]**

**Initial Estimators**

$$\hat{\alpha}_0^{(0)} = (X^T X + \Lambda_0)^{-1} X^T Y$$

$$\hat{\beta}_0^{(0)} = (Z^T Z + \Gamma_0)^{-1} Z^T L_n(\hat{\alpha}_0^{(0)})$$

- Unknown expectation  $E[\log(\epsilon)]$  in estimation of  $\beta \leadsto *$  used in joint estimate of  $\hat{\alpha}^* = (\hat{\beta}_0, E[\log(\epsilon)])$ .
- Tuning Parameters  $\Lambda_0$  and  $\Gamma_0$ .
- $L_n(\alpha) = \log|Y| - X\alpha_1 - \dots - Y_n - X_n\alpha_n$ .

**Iterated ( $k$ th) Estimators**

$$\hat{\alpha}_k^{(k+1)} = (X^T D_n^{-1}(\hat{\beta}_k^{(k)}) X + \Lambda_k T(\hat{\alpha}_k^{(k)}))^{-1} X^T D_n^{-1}(\hat{\beta}_k^{(k)}) Y$$

$$\hat{\beta}_k^{(k+1)} = (Z^T Z + \Gamma_k S(\hat{\beta}_k^{(k)}))^{-1} Z^T L_n(\hat{\alpha}_k^{(k+1)})$$

- Re-weighting for Heteroscedasticity  $D_n^{-1}(\hat{\beta}_k^{(k)})$ .
- Adaptive Ridge Penalties  $T(\hat{\alpha}_k^{(k)})$  and  $S(\hat{\beta}_k^{(k)})$  are inverse of components squared  $\leadsto$  Shrinkage for Sparse Signals.
- Exploit Sparsity (Computational Efficiency)

**Main Contribution [4]**

**Asymptotic Normality and Tightness of Initial Estimators**

We first showed asymptotic normality of  $\hat{\alpha}_0^{(0)}$  and  $\hat{\beta}_0^{(0)}$  (tightness ( $\epsilon < 1/2$ ) of  $\hat{\beta}_0^{(0)}$ ). Furthermore, under stricter restrictions of  $\epsilon$ , asymptotic normality of  $\hat{\beta}_k^{(k)}$  can be obtained as well.

**Distributional Results of Iterated Estimators**

For each  $k \geq 1$ , the distribution of  $\hat{\alpha}_k^{(k)}$  is  $\sqrt{n}$  tight and depends on the limiting distribution of  $\hat{\alpha}_0^{(0)}$ .  $\sqrt{n}$ -tightness remains true for  $\hat{\beta}_k^{(k)}$  and a similar distributional result holds under the same set of stricter conditions for  $\epsilon$ .

**Shrinkage**

Estimates for zero parameters shrink to 0 in probability:

$$\|\hat{\alpha}_k^{(k+1)}\|_{\infty} \rightarrow 0 \text{ and } \|\hat{\beta}_k^{(k+1)}\|_{\infty} \rightarrow 0 \text{ as } n \rightarrow \infty.$$

We can expect geometric shrinkage under finite sample  $n$ .

**Numerical Experiments**

The densities above show how the AR scheme robustly estimates non-zero parameters. The histograms display **shrinkage** when  $\beta_k = 0$  after two iterations.

**Electricity Consumption Forecast**

Predicting Electricity Consumption in Tokyo with AR10, LASSO, and Elastic Net. Training: 2018, 2019. Testing: 2020, 2021.

Selected Predictors / 64	LASSO	Elastic Net	AR10
MSPE	74425.05	73281.74	74487.11
Time Taken	1.12s	1.00s	9.47s
Optimization Procedures	1	1	22

Similar Performances: AR10 is easier to interpret. The time taken per optimization problem is also shorter despite the overall longer procedure.

LEFT: Winter week (Feb 1 to Feb 7, 2020) and RIGHT: Summer week (Aug 1 to Aug 7, 2020). BLACK: True consumption, RED: LASSO, BLUE: Elastic Net and GREEN: AR10.

**References**

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- Keith Ho. An iterative ridge approach to heteroscedasticity and sparsity in regression. Master's Thesis, 2023.

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## (0) Rinki Imada

(1) Department of General Systems Studies, The University of Tokyo, Japan

## (2) Dynamical Systems in Origami/Kirigami Tessellations

(3) Many origami/kirigami-based engineering applications have developed based on the periodic-folding of periodic patterns. Though nonperiodic-folding of periodic patterns paves the way to nonlinear phenomena that cannot be feasible through periodic-folding, its high complexity makes it challenging to capture the phenomena mathematically. In this presentation, we propose a novel mathematical model for the analysis of nonperiodic-folding, which we call the dynamical system of origami/kirigami tessellations induced by the coupled folding motion of unit cells. Using the model, we introduce some phenomena, including the undulation of tubular origami tessellations and the solitons with the propagation of the localized deformation.

(4) Rinki Imada is a Ph.D. student in the Graduate School of Arts and Sciences at the University of Tokyo. He studied computer sciences and mathematics and received his M.S. in multidisciplinary sciences from the University of Tokyo. His research interests lie in the kinematics of geometric objects such as origami, kirigami, and linkages. He is now trying to understand the hidden mathematical structure behind phenomena that arose in such geometric objects and create novel characteristics using the theory of dynamical systems.

**Dynamical Systems in Origami/Kirigami Tessellations**  
 Rinki Imada\* and Tomohiro Tachi  
 Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo

**Research Topic: Nonperiodic Folding of Periodic Origami**

**Kinematics of Rigid Origami**

- Kinematics of rigid origami has played a central role in origami science/engineering, where face-to-faces of origami are replaced by rigid panels/rotational hinges.
- The preservation of the shapes of panels and their connectivities impose multiple nonlinear constraints, which are generally hard to solve directly.

**Periodic Folding of Periodic Origami**

- The periodicity makes solving the kinematics easier and leads to global deformations of the entire structure, which is useful for engineering applications.
- However, it also limits the potential of periodic origami, i.e., origami tessellations.

**Nonperiodic Folding of Periodic Origami**

- Although it is a source of interesting phenomena that cannot be feasible through periodic folding, it is hard to solve and mathematically understand the kinematics. Thus, there can be not only global deformation but also local deformations.
- We established a novel mathematical model of nonperiodic folding, dynamical systems of origami tessellations, and found some nonlinear global deformations.

**Proposed Model: Dynamical Systems of Tessellated Structures**

**Deterministic Origami Tessellation**

- An infinite sequence of unit cells, where the folded state of a unit cell determines that of its adjacent one because of the geometric constraints.
- We define the discrete dynamical system  $F: x_k \mapsto x_{k+1}$ , where  $x_k$  represents the folded state of  $k$ -th unit cell. Then,  $(x_k)_{k \in \mathbb{Z}}$  represents the entire folded state.

**Global/Local DOF of Periodic Folded State and Linear Stability Analysis**

- A Fixed Point  $x^*$  satisfying  $F(x^*) = x^*$  corresponds to a periodic folded state.
- The linear stability tells us how the deformation in an initial unit cell propagates to subsequent cells if we deform an initial cell along with an eigenvector of  $DF(x^*)$ .

**Result: Some Global Deformations in Nonperiodic Folding and Connection to Mathematical Structures**

**Global Deformations Induced by Global DOF**

- Undulations of rotationally symmetric origami tessellations and quasiperiodic solutions/conservative systems [12].
- Dynamical systems of N-fold symmetric waterbomb tube can have fixed point corresponding to a cylindrical folded state with its gDOF=2. Around such a fixed point, quasiperiodic solutions exist which induce the undulating folded states, where we can change their "Amplitude" and "Phase" by tuning an initial value  $x_0$  [1].
- This undulation is not limited to waterbomb tube, but the universal phenomenon in a family of N-fold symmetric tubular origami tessellations, which we explained by proving that their dynamical system is conservative. The conservativeness vanishes if the crease pattern includes the scaling [2].

**Global Deformations Induced by Local DOF**

- "Soliton-like" behavior and homoclinic/heteroclinic solution [3].
- Cylindrical state with zero gDOF=0 (i.e., rigid and 1-fold symmetric).
- Propagation of Localized Deformation: Homoclinic Orbit.
- Propagation of Localized Deformation: Heteroclinic Orbit.
- Periodic State A' with local gDOF=2.
- Periodic State A' with local gDOF=2.

**Future Work**

- Realize undulations/solitons and so on in the physical prototypes.
- Consider origami tessellations with no symmetry assumptions, which induces the dynamical systems in a higher dimensional space.
- Connect mathematical properties e.g., A periodic state with the large number of unit cells with its gDOF=2  $\Rightarrow$  Flexible, and gDOF=0  $\Rightarrow$  Rigid?
- Can we realize phenomena known in the dynamical systems theory such as Chaos?

This work was supported by JPS KAKENHI Grant Number JP23K00882 and JST PREST Grant Number JPMJPR1827.

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## (0) Yoshihiro Ishiguro

(1) Graduate School of Mathematics, Nagoya University, Japan

## (2) Formalization of Measure Theory Using Dependent Types

(3) Formal verification of computer programs is best done with proof assistants, which are typically software implementations of type theory to verify mathematical proofs. Our concern is that the semantics of probabilistic programs relies on advanced measure theory whose support is lacking in the Coq proof assistant. Our project is to formalize advanced measure theory using the dependent type theory of Coq. We target the formalization of the Fundamental Theorem of Calculus as a milestone and in this poster we explain our first results in this direction: the formalization of the Radon-Nikodym theorem and of the Lebesgue-Stieltjes measure.

(4) My interest is mainly on formal verification of mathematics. I also be interesting in program semantics and category theory and categorical logic.

I studied formalization of analysis with Coq proof assistant in my master course. The formalization of Radon-Nikodym theorem and Hahn decomposition is among the results.

Now I studying further extension of Coq library for analysis, MathComp-Analysis, and my goal is make good tool for formal verification of computer programs with advanced theory of analysis.

### Formalization of Measure Theory Using Dependent Types

Yoshihiro Ishiguro, Graduate School of Mathematics, Nagoya University  
Joint work with: Naoyuki Ishimura, Faculty of Commerce, Chuo University

**Formalization of signed measures and of the Lebesgue-Stieltjes measure**

The structure of the paper:

- 1. Change (A signed measure) from possibly negative values to non-negative values.
- 2. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.
- 3. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.

**Formalization of the Lebesgue-Stieltjes measure**

The structure of the paper:

- 1. Change (A signed measure) from possibly negative values to non-negative values.
- 2. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.
- 3. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.

### Towards a formalization of the FTC

Yoshihiro Ishiguro, Graduate School of Mathematics, Nagoya University  
Joint work with: Naoyuki Ishimura, Faculty of Commerce, Chuo University

**Formalization of the Fundamental Theorem of Calculus**

The structure of the paper:

- 1. Change (A signed measure) from possibly negative values to non-negative values.
- 2. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.
- 3. The structure of the paper: from part 1 to 3, we prove the Radon-Nikodym theorem.

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## (1) Naoyuki Ishimura

(2) Faculty of Commerce, Chuo University, Japan

## (3) Insurance Design for the Loss of Epidemic Outbreaks involving the Cramér-Lundberg Model

(4) A simple model of the insurance coverage for the damage of COVID-19 is introduced. Concerning the estimation of the numbers of patients and/or deaths, we employ the Cramer-Lundberg model for the risk process, which is combined with the discrete SIR model. Under various premium principles, we are able to design suitable insurance. Numerical research with the data of Tokyo region are also performed.

(5) Naoyuki Ishimura obtained his PhD from University of Tokyo in 1993. He was Research Associate of Mathematics at University of Tokyo from 1989 to 1996. He moved to Hitotsubashi University, Japan as Associate Professor of Mathematical Sciences from 1996 and became full Professor from 2005. His interest gradually involves Mathematical Finance and he has moved to Chuo University from 2015. Ishimura is a member of JSIAM. His area of research includes the applied analysis, the theory of nonlinear partial differential equations, and the mathematical finance.

### Insurance Design for the Loss of Epidemic Outbreaks involving the Cramér-Lundberg Model

Chenwei SUN<sup>1</sup>, Andres Mauricio Molina Barreto<sup>2</sup>, Naoyuki Ishimura<sup>3</sup>, and Koichiro Takakura<sup>4</sup>

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#### 1 Introduction

After a cluster of certain infections was reported at Wuhan in December 2019, the worldwide confusion was followed and our way of life has been forced to change. In the academia, intensive studies have been performed from various point of view. It is also important to provide suitable insurances for the loss of epidemic outbreaks, in order to mitigate the disaster in some extent. In this respect one of the authors considers certain insurance for the epidemic bursts in 2019 [2], three years before COVID-19. Here we take a different approach to design better insurances for the loss of COVID-19.

infectives become immune. The important parameter is  $\rho = \gamma/\beta$  which is related to the reproduction number. The total population  $N = S(t) + I(t) + R(t)$  is preserved. Following [5], Lal and Kott [4], and Wacker and Schütte [3], we employ the implicit discrete system.

#### 3 Empirical Study

Principally, the insurance should be designed so that the ruin does not occur:

$$\delta(t) = P(U(t) > 0 \text{ for all } t > 0).$$

There are also known several premium principles which an insurer charges to cover a risk, to name allow, the expected value principle, the variance principle, the Bühlmann premium principle, and so on. The crucial part in our model is the estimation of  $C(n)$ . Here we undertake an empirical study on the treatment of  $C(n)$ . The dataset can be downloaded from <https://covid19.mhlw.go.jp>. The details will be shown at the conference place.

#### 2 Our Model

##### 2.1 Risk process

We consider a discrete time risk process given by

$$U(n) = u + cn - C(n), \quad n = 0, 1, 2, \dots \quad (1)$$

where  $u = U(0)$  is the initial surplus, and  $c$  is the insurer's rate of premium income per unit time. Here

$$C(n) = \sum_{k=1}^n X_k \quad (2)$$

denotes the total claim process,  $\{X_k\}_{k=1,2,\dots}$  is the number of claim process, which is a Poisson process with parameter  $\lambda$ .  $\{X_k\}_{k=1,2,\dots}$  is the nonnegative i.i.d. sequence of insurer's aggregate claim with common distribution function  $F_X(x)$ . The process  $\{N(t)\}_{t \geq 0}$  and the sequence  $\{X_k\}_{k=1,2,\dots}$  are assumed to be independent. See [1][6] for further information.

Our motivation is that we employ the risk model (1) for the insurance coverage due to the loss of COVID-19:

$N(n)$  is the number of infectives at date  $n$ .  
 $\{X_k\}$  is modelled by the infectious distribution of real data.

##### 2.2 SIR model

The original SIR model is the system of ordinary differential equations for three sub-populations:  $S(t)$  is the number of susceptibles to the disease,  $I(t)$  is the number of infectives, and  $R(t)$  is of removals.

$$S'(t) = -\beta S(t)I(t), \quad I'(t) = \beta S(t)I(t) - \gamma I(t), \quad R'(t) = \gamma I(t),$$

where the constant  $\beta$  is the infection parameter and  $\gamma$  is the removal parameter representing the rate at which

#### 4 Conclusion

We have proposed an insurance coverage model for the loss of epidemic outbreaks. Our model is based on the Cramér-Lundberg risk process with the SIR model. We have developed empirical studies with the data of COVID-19 in Tokyo area. Our method seems work well.

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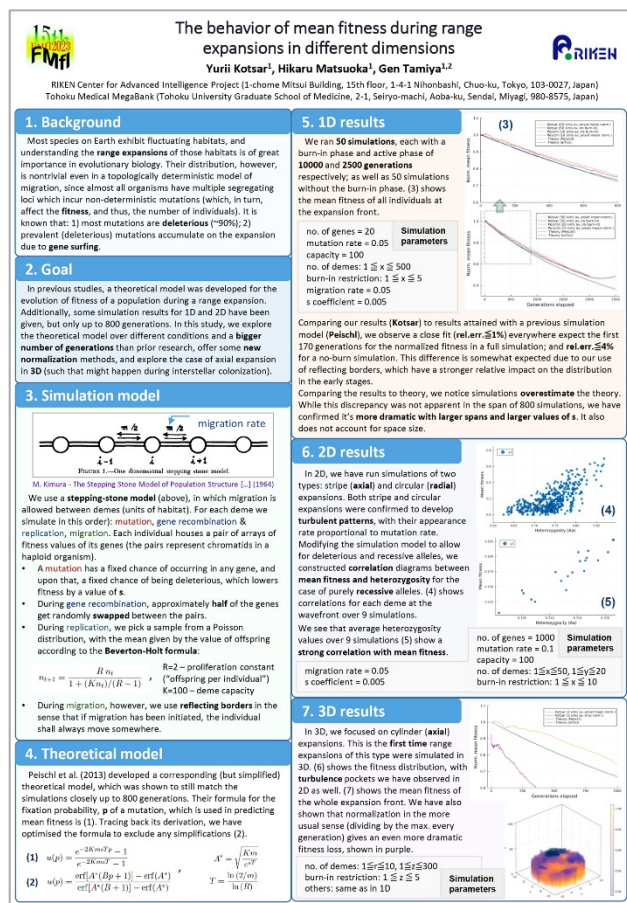




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## (0) Yuri Kotsar

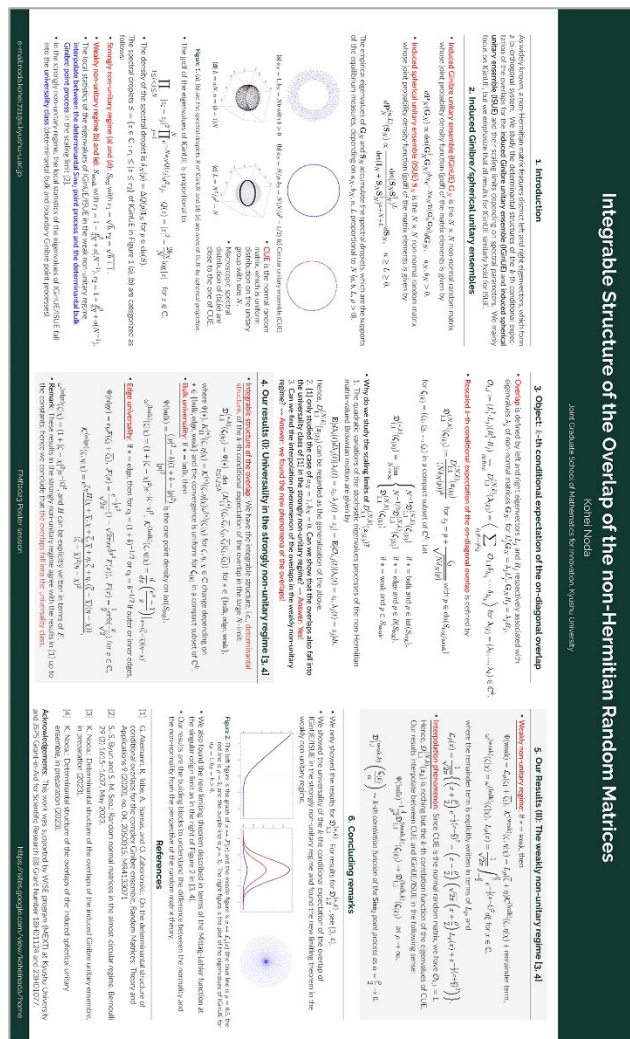
- (1) RIKEN Center for Advanced Intelligence Project, Japan  
 (2) **The behavior of mean fitness during range expansions in different dimensions**  
 (3) Most species on Earth exhibit fluctuating habitats, and understanding the range expansions of those habitats is of great importance in evolutionary biology. Their distribution, however, is nontrivial even in a topologically deterministic model of migration, since almost all organisms have multiple segregating loci which incur non-deterministic mutations. In previous studies, a theoretical model was developed for the evolution of fitness of a population during a range expansion. Additionally, some simulation results for 1D and 2D have been given, but only up to 800 generations. In this study, we explore the theoretical model over different conditions and a bigger number of generations than prior research, offer some new normalization methods, and explore the case of axial expansion in 3D (such that might happen during interstellar colonization).  
 (4) A ukrainian-born genetics researcher in Japan. Graduated with a BSc degree in astrophysics from Kyiv University in 2018. Moved to Japan in 2019 to pursue a Master's course in particle physics at Kobe University. Enrolled in said course in 2020, and developed practical research skills during the two-year MSc course; graduated in 2022. Was employed at RIKEN Spring-8 the same year as an engineer. Moved inside RIKEN to a research post at the Center for Advanced Intelligence Project (AIP) at the start of 2023. Presently engaged in big data analysis and probabilistic research in the field of genetics.



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## (0) Kohei Noda

- (1) Joint Graduate School of Mathematics for Innovation, Kyushu University, Japan  
 (2) **Integrable Structure of the Overlap of the non-Hermitian Random Matrices**  
 (3) As widely known, a non-Hermitian matrix features distinct left and right eigenvectors, which form a bi-orthogonal system. We study the determinantal structures of the k-th conditional expectation of the overlaps for the induced Ginibre unitary ensemble (IGinUE) and induced spherical unitary ensemble (ISUE) and their scaling limits depending on spectral parameters.  
 (4) Kohei Noda is a Ph.D. student at Joint Graduate School of Mathematics for Innovation, Kyushu University. His research interests are random matrix theory and the statistical mechanics of Coulomb systems. He is currently focused on investigating the overlap defined by the left and right eigenvectors of non-Hermitian random matrices, which is related to integrable systems such as orthogonal polynomials and skew-orthogonal polynomials.



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(0) Ryotoku Ota

(1) Graduate School of Mathematics, Kyushu University,  
Japan

### (2) Computation of a zariski closure using Noether operators

(3) We will give a set of generators of the ideal defining the zariski closure of the image of polynomial mappings. The standard method is based on the Gröbner basis computed by using elimination theory.

However, if the number of generators of the Gröbner basis is too large, it may not be practical to find them.

We will perform a primary decomposition of the ideals using prime ideals and Noether operators, and give the representation of the ideals.

We also recover the Gröbner basis from the Noether operators.

(4) Ryotoku Ota is a second-year doctoral student in the Graduate School of Mathematics at Kyushu University. He is particularly interested in Gröbner bases and properties of algebraic varieties. In the future, he would like to study algebraic varieties using Noether operators and local cohomology.

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(0) Benjawan Rodjanadid

(1) School of Mathematics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima, Thailand

## (2) Solving the Data Imbalance Problem using a Modified Whale Optimization Algorithm

(3) The objective of this study was to create a new undersampling algorithm to tackle imbalanced data problems by integrating the concepts of the whale and binary whale optimization algorithms with K-nearest neighbor classification. To evaluate the effectiveness of the proposed algorithm, twelve datasets with varying imbalance ratios, ranging from 1.82 to 42.01, were selected from the Knowledge Extraction based on Evolutionary Learning (KEEL) repository and the imbalanced-learn repository. To begin the research, each dataset was divided into a training set and a testing set. The minority class in the training set remained unchanged, while the majority class was processed using the proposed algorithm with adjustable parameter K in K-nearest neighbor classification. The algorithm generated an optimal representative subset of the majority class, and a Random Forest classifier was then trained with the new and reduced training set to assess performance.

(4) I'm Benjawan Rodjanadid, an Assistant Professor in Mathematics at Suranaree University of Technology in Thailand. My expertise lies in the field of Analysis, Topology, and Fixed point theory, where I have conducted valuable research. Over time, I have developed a keen interest in the fascinating realms of machine learning and artificial intelligence.

# Computation of a zariski closure using Noether operators

Ryota Ota (大田 了樹)

Graduate School of Mathematics, Kyushu University, Email: ota.ryota@s880.kyushu-u.ac.jp

## Purpose

Find the smallest affine algebraic variety that contains the image of the polynomial map  $f$ .

## Problem

**Definition and assumption:** Let  $A$  be a square matrix of order  $k$ . We define its components with  $a_{ij} \in \mathbb{C}$ . Let  $1 \leq i, j \leq k$ . And denote 36 second order homogeneous polynomials with these 16 variables as follows:  
Suppose  $1 \leq p < q \leq 4$  and  $1 \leq r < s \leq 4$ .

$$f_{pqrs} = a_{pqrs}x_{pq}x_{rs} - a_{qpsr}x_{qr}x_{ps}.$$

Definition of the polynomial map  $f$ :

$$f: \mathbb{C}^{36} \rightarrow \mathbb{C}^{36}, (a_{ij}) \mapsto (f_{pqrs}).$$

❖ **Question:** Find the image of the polynomial map  $f$  in this 36-dimensional linear space.

## Motivations

- The map  $f$  is regarded as 
$$f: M(4, \mathbb{C}) \rightarrow M(6, \mathbb{C})$$
 with the identification  $\mathbb{C}^{36} = M(4, \mathbb{C})$ ,  $\mathbb{C}^{36} = M(6, \mathbb{C})$  and  $\mathbb{C}^n = M^2(\mathbb{C})$ , where  $M^2(\mathbb{C})$  is the set of complex square matrices of size 4.
- The smallest affine algebraic variety containing a subset  $S$  of the  $n$ -dimensional affine space  $\mathbb{C}^n$  is called the Zariski closure of  $S$  [1, 2].
- There exist algorithms for computing a Zariski closure [1]. Thus, we will describe  $f(\mathbb{C}^{36}) \subset \mathbb{C}^{36}$  as an affine algebraic variety.

## Main results (Grobner basis)


- $f = (f_{11} - f_{22}, x_2 - f_{13}, \dots, x_6 - f_{44})$ : the ideal in  $\mathbb{C}[x_1, \dots, x_{36}]$  is  $\langle x_1, \dots, x_{36}, a_{11}, \dots, a_{44} \rangle$ .
- $\mathbb{C}[x_1, \dots, x_{36}]$  is a unique factorization domain. Grobner bases of  $I$  with the degree reverse lexicographical order with  $x_{11} > x_{12} > \dots > x_{44} > x_1 > x_2 > \dots > x_{36}$ :
  - we complete  $\mathbb{C}$  as
 
$$G = \begin{cases} x_{36}x_{35} - x_{32}x_{34} + x_{31}x_{36}, \\ a_{11}x_{35} - a_{42}x_{34} + a_{41}x_{36}, \\ -x_{32}x_{35}x_{36}x_{34}x_{31}^2 + \dots - x_{32}x_{35}x_{36}x_{34}x_{31}^2. \end{cases}$$
  - The elimination Grobner basis  $G_{10} = G \cap \mathbb{C}[x_1, \dots, x_{30}]$  is computed as
 
$$G_{10} = \begin{cases} -x_{32}x_{35} - x_{32}x_{34} + x_{31}x_{36}, \\ -x_{32}x_{35}x_{36}x_{34}x_{31}^2 + \dots - x_{32}x_{35}x_{36}x_{34}x_{31}^2 \end{cases}$$
 with  $r = 772$ .
- The Zariski closure  $\overline{f(\mathbb{C}^{36})}$  of the image  $f(\mathbb{C}^{36})$  is given by
 
$$\mathbf{V}(G_{10}, \dots, g_6) = \left\{ (x_1, \dots, x_{30}) \in \mathbb{C}^{30} \mid \begin{matrix} g_1(x_1, \dots, x_{30}) = 0, \\ g_1(x_1, \dots, x_{30}) = 0, \\ g_1(x_1, \dots, x_{30}) = 0 \end{matrix} \right\}$$
- $\overline{f(\mathbb{C}^{36})} \subset \mathbf{V}(G_{10}, \dots, g_6)$ .

## Discussion

- Using Grobner basis, we are able to find the Zariski closure of  $f(\mathbb{C}^{36})$ . Now we have the following advantage. Suppose we want to know, for example, whether the point  $\mathbf{x}_0 = (b_1, \dots, b_{36}) \in \mathbb{C}^{36}$  is on  $\overline{f(\mathbb{C}^{36})}$ . In this case, we need to solve a system of equations for  $a_{ij}$  ( $1 \leq i, j \leq 4$ ) by substituting  $\mathbf{x}_0$  in the parameter representation. On the other hand, if  $\mathbf{x}_0 = (b_1, \dots, b_{36})$ , we only need to substitute  $\mathbf{x}_0 = \mathbf{x}_0$  into  $G_{10}$ .  
 $r = 772$  is quite large.
- We may expect to replace the generator representation  $G_{10}$  by more concise expression of the elimination ideal using Noether operators, which will give a faster algorithm for primary decomposition [3, 4].

## References

- [1] D. Cox, J. Little and D. O'Shea, *Ideals, Varieties, and Algorithms*, 4th edition, Springer-Verlag, New York, 2015.
- [2] D. Cox, J. Little and D. O'Shea, *Using Algebraic Geometry*, GTM, Vol.185, Springer-Verlag, New York, 1998.
- [3] K. Ushibuchi and S. Taniya, *Computing Noetherian differential operators of zero-dimensional primary ideals and their applications*, *Computer Algebra - Theory and its Applications*, Research Institute for Mathematical Sciences, Kyoto University, RIMS Kokyuroku, **Vol.2185**, pp. 1-15, 2021.
- [4] K. Ushibuchi and S. Taniya, *Effective algorithm for computing the Zariski closure of zero-dimensional ideals*, *Algebraic Combinatorics in Combinatorics and Computing*, vol. **33**, pp. 807 - 899, 2022.



# Solving the Data Imbalance Problem using a Modified Whale Optimization Algorithm

**Jakkrit Polrob, Benawan Rodjanadit, Jessada Tanthanuch, Eckart Shulz**  
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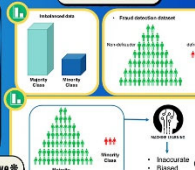
### Abstract

The objective of this study was to create a new undersampling algorithm to tackle imbalanced data problems by integrating the concepts of the whale and binary whale optimization algorithms with K-nearest neighbor classification. To evaluate the effectiveness of the proposed algorithm, twelve datasets with varying imbalances ratios, ranging from 182 to 4206, were selected from the Knowledge Extraction based on Evolutionary Learning (KEEL) repository and the imbalanced learn repository. To begin the research, a dataset was divided into a training set and a testing set. The minority class in the training set remained unchanged, while the majority class was processed using the proposed algorithm with adjustable parameter K in K-nearest neighbor classification. The 8 algorithms generated an optimal representative subset of the majority class, and a Random Forest classifier was then trained with the new and reduced training set to assess performance.

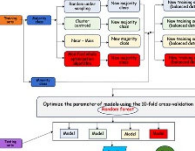
### Research objective

To develop a novel technique for solving imbalanced data problems based on undersampling which uses whale and binary whale optimization algorithms.

### Introduction



### Methodology



### Binary Whale Optimization Algorithm

**Initialization:** Random search initialization, Current iteration, Best fitness, Worst fitness, etc.

**Exploration Phase - circle motion (exploring):** Update position and velocity based on random search.

**Exploitation Phase - bubble-net feeding method:** Update position and velocity based on current best position.

**Search for the prey together:** Update position and velocity based on current best position.

### Results

Ranking score	Original	Cluster centroid	Random forest	RUS	WBEWA (182)	WBEWA (4206)
Accuracy	0.78	0.78	0.78	0.78	0.78	0.78
F1 score	0.78	0.78	0.78	0.78	0.78	0.78
AUROC	0.78	0.78	0.78	0.78	0.78	0.78
Precision	0.78	0.78	0.78	0.78	0.78	0.78
Recall	0.78	0.78	0.78	0.78	0.78	0.78
F0.5	0.78	0.78	0.78	0.78	0.78	0.78
Specificity	0.78	0.78	0.78	0.78	0.78	0.78
ROC	0.78	0.78	0.78	0.78	0.78	0.78
Prevalence	0.78	0.78	0.78	0.78	0.78	0.78

**Conclusion:** Results indicated that the proposed algorithm outperformed three other undersampling methods, namely random undersampling cluster centroid, and near-neighbors algorithm. The proposed algorithm demonstrates average efficiency values of Accuracy: 0.9381, F1 score: 0.9374, G-mean: 0.9379, AUROC: 0.9212, AUPRC: 0.9457, Sensitivity: 0.9399, Precision: 0.9403, MCC: 0.9570.



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## (0) Hiroki Sasaki

(1) Graduate School of Mathematics, Kyushu University, Fukuoka, Japan

## (2) Board Game and Combinatorics of a Triangulated Square

(3) There is a remarkable connection between Brouwer's fixed-point theorem and a board game called the Hex: the fact that there is no draw in the game is equivalent to the fixed-point theorem.

We propose a novel two-player board game on a triangulated square. We prove that there is no draw in the game, which can be considered as a generalization to the corresponding statement of the Hex game.

(4) Hiroki Sasaki is a student at the Graduate School of Mathematics, Kyushu University.

He specializes in combinatorics and board games. He enjoys playing and watching board games such as Shogi and Mahjong. He also creates board games and will be exhibiting at a board game event in Tokyo in December. His motto is to research interesting board games from both an academic and hobbyist perspective.

## Board Game and Combinatorics of a Triangulated Square

Hiroki Sasaki  
Graduate School of Mathematics, Kyushu University  
E-mail : sasaki.hiroki.711@gs.kyushu-u.ac.jp

### 1. Introduction

There is a remarkable connection between Brouwer's fixed-point theorem and a board game called the Hex: the fact that there is no draw in the game is equivalent to the fixed-point theorem [1].

We propose a novel two-player board game on a triangulated square. We prove that there is no draw in the game, which can be considered as a generalization to the corresponding statement of the Hex game.

**Keywords:** combinatorics, board game, Hex game, Brouwer's fixed-point theorem, graph coloring.

### 2. (Generalized) Hex game

**Hex game [2]** Two players take turns placing on the vertex **orange** and **blue** stones in a board composed of non hexagons.

The **orange player** wins if his stones connect **left-right**, and the **blue player** wins if his stones connect **up-down**.

**Figure 1.** Hex game. **Orange player** wins.

**Definition 1 (Game board)** A square divided into triangles with  $n$  vertices inside. The two vertices on the diagonal of the square are pointed **orange** and **blue**, and the two vertices on the other diagonal of the square are pointed **blue** and **orange**.

**Generalized Hex game [2]** Two players take turns placing on the vertex **orange** and **blue** stones in a game board. The winner is the player who connects the diagonal line with stones of his color.

**Hex theorem [2]** If the game board is symmetric, in generalized Hex game, first player always wins.

**Proposition [2]** If the game board is symmetric, in generalized Hex game, first player always wins.

**Figure 2.** Game board. **Figure 3.** Generalized Hex game. **Blue player** wins.

### 5. Conclusion

In summary, the following relational equation holds.

**Theorem 1**  $\Leftrightarrow$  **Hex theorem**  $\Leftrightarrow$  **Oriented Sperner's lemma [3]**  $\Leftrightarrow$  **Theorem 2 (1)**

**References:**

[1] David Gale, The Game of Hex and the Brouwer Fixed-Point Theorem, *The American Mathematical Monthly*, 1979, Vol.86, No.10, 818-827.

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[3] A. B. Brown and S. S. Cairns, *Proceedings of the National Academy of Sciences*, 1961, Vol.47, No.1, 113-114.

### 3. Minimax game

**Theorem 1** (On the game board, assign  $1, \dots, n$  different numbers to the  $n$  interior vertices. Then the following holds.

$$\min_{P_{\text{blue}}} \max_{P_{\text{orange}}} v_{\text{blue}} = \max_{P_{\text{orange}}} \min_{P_{\text{blue}}} v_{\text{orange}}$$

Where,  $P_{\text{blue}}$  denotes the set of the paths connecting the two vertices 0 on the game board and  $v_{\text{blue}}$  denotes the number assigned to vertex  $v$ .

**Minimax game [3]** On the game board, pieces numbered  $1, \dots, n$  (in even) are divided into **blue** odd numbers  $1, 3, \dots, n-1$  and **orange** even numbers  $2, 4, \dots, n$ , and two players take turns placing their pieces. When all pieces are placed, the player whose color satisfies "minimax = maximax" is the winner.

**Remark:** Minimax game is an extension of generalized Hex game. Therefore, in minimax game, we can play generalized Hex game at the same time!

**Figure 4.** Example of minimax game. Red line is a minimax path, and green line is a maximax path. **Orange player** wins the minimax game, but **blue player** wins the Hex game.

### 4. Combinatorial consequences

**Figure 5.** Face coloring by orientation.

**Notation:** "CW" means "clockwise" and "CC" means "counterclockwise".

**Theorem 2** Let  $G$  be a triangulated planar graph. Number each vertex of  $G$  and face coloring by orientation. Then the following holds.

(1)  $\# \text{CC-triangles} = \# \text{CW-triangles}$   
 $= \# \text{CC-boundary edges} = \# \text{CW-boundary edges}$   
(2)  $\# \text{connected components} = \# \text{CC-connected components}$   
 $= \# \text{CW-boundary triangles with CC-boundary edges}$   
 $= \# \text{CC-boundary triangles with CW-boundary edges}$

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## (1) Takasugu Shigenobu

(2) Graduate School of Mathematics, Kyushu University, Fukuoka, Japan

## (3) On Connectivity of Solution to Integer Linear Systems

(4) An integer linear system (ILS) is a linear system with integer constraints. The solution graph of an ILS is defined as an undirected graph defined on the set of feasible solutions to the ILS. A pair of feasible solutions is connected by an edge in the solution graph if the Hamming distance between them is 1. We consider a property of the coefficient matrix of an ILS such that the solution graph is connected for any righthand side vector. Especially, we focus on the existence of an elimination ordering (EO) of a coefficient matrix, which is known as the sufficient condition for the connectedness of the solution graph for any right-hand side vector. That is, we consider the question whether the existence of an EO of the coefficient matrix is a necessary condition for the connectedness of the solution graph for any right-hand side vector. We first prove that if a coefficient matrix has at least four rows and at least three columns, then the existence of an EO may not be a necessary condition. Next, we prove that if a coefficient matrix has at most three rows or at most two columns, then the existence of an EO is a necessary condition.

(5) Takasugu Shigenobu is currently a doctor course student at Graduate School of Mathematics, Kyushu University. He graduated from School of Mathematics and Physics, Kanazawa University in 2020, and then he finished the Master's Course in Mathematics, the Graduate School of Mathematics at Kyushu University, in 2022. His research topics include the theory of discrete optimization. Especially, he is currently working on structures of the solution graph of an integer linear system.

## On Connectivity of Solutions to Integer Linear Systems

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### Overview

- The results presented in this poster are due to [3].
- An integer linear system (ILS) is a linear system with integer constraints.
- The solution graph of an ILS can be regarded as an undirected graph defined on the set of feasible solutions to the ILS.
- Let us consider the following research problem.
- The matrix of an ILS is universally connected (UC).
- $\Rightarrow$  The matrix of an ILS has an elimination ordering (EO).
- As shown in Table 1, we prove that the size of the matrix determines the truth of the proposition.
- The connectedness of the solution graph of an ILS is closely related to a reconfiguration problem of the ILS (e.g., [2]).
- Kimura and Suzuki [1] proved:
- The matrix of an ILS has an EO.  $\Rightarrow$  The matrix of an ILS is UC.

**Example of ILS:**

Our results	$m$ rows	$n$ columns	Proposition
$5x_1 - 8x_2 + 2x_3 \geq -4$	$m \geq 4$	$n \geq 3$	False
$4x_1 + 6x_2 - 4x_3 \geq 8$	$m \leq 3$	any $n$	True
$x_1, x_2, x_3 \in \mathbb{Z}_{\geq 0}$	any $m$	$n \leq 2$	True

### Preliminaries

Fix  $d \in \mathbb{Z}_{\geq 0}$  and  $D = \{0, \dots, d\}$ .

Define  $[n] := \{1, 2, \dots, n\}$  for any  $n \in \mathbb{Z}_{\geq 0}$ .

**Definition 1 (Integer Linear System (ILS))**

**Input:**  $A \in \mathbb{R}^{m \times n}$ ,  $b \in \mathbb{R}^m$

**Feasible solutions:**  $x \in D^n$  s.t.  $Ax \geq b$

$R(A, b) := \{x \in D^n \mid Ax \geq b\}$  is called the set of feasible solutions.

**Definition 2 (Solution Graph)**

$R \subseteq D^n$ ,  $\forall x, y \in R$ ,  $\text{dist}(x, y) := |\{j \in [n] \mid x_j \neq y_j\}|$

$G(R) = (V(R), E(R))$  is called the solution graph where

$V(R) = R$ ,  $E(R) = \{(x, y) \mid x, y \in R, \text{dist}(x, y) = 1\}$

**Definition 3 (Universally Connected (UC))**

$A \in \mathbb{R}^{m \times n}$

$A$  is universally connected (UC)

$\Leftrightarrow \forall b \in \mathbb{R}^m$ ,  $G(R(A, b))$  is connected graph.

**Definition 4 (Elimination)**

$A \in \mathbb{R}^{m \times n}$ ,  $j \in [1, \dots, n]$

The column  $j$  of  $A$  can be eliminated if (i) or (ii) holds, where

(i)  $\forall i \in [m]$ ,  $a_{ij} > 0 \Rightarrow (\forall j' \in [n] \setminus \{j\}, a_{ij'} = 0)$

(ii)  $\forall i \in [m]$ ,  $a_{ij} < 0 \Rightarrow (\forall j' \in [n] \setminus \{j\}, a_{ij'} = 0)$

**Definition 5 (Elimination Ordering (EO))**

A matrix  $A$  has an Elimination Ordering (EO)

$\Leftrightarrow$  All the columns of  $A$  can be eliminated one by one.

### Examples

This can be eliminated:

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

This cannot be eliminated:

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

**Example of EO:**  $2 \rightarrow 1 \rightarrow 4 \rightarrow 3$

$$\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \rightarrow \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

### Main Results

**Theorem 6**

Suppose that  $m \geq 4$  and  $n \geq 3$ .

There exists a matrix  $A \in \mathbb{R}^{m \times n}$  satisfying the following conditions.

- $A$  does not have an EO.
- $A$  is UC.

**Theorem 7**

Suppose that  $m \leq 3$  and  $n \leq 2$ .

Any matrix  $A \in \mathbb{R}^{m \times n}$  satisfies the following conditions.

$A$  is UC.  $\Rightarrow A$  has an EO.

### Proof Sketch

**For Theorem 6**

Define  $A' \in \mathbb{R}^{(m-1) \times (n-1)}$

Prove that  $A'$  is UC.

Fix  $b \in \mathbb{R}^m$ .

Prove:  $\forall x, y \in R(A', b)$ ,  $x_1 \geq 1$   
 $\exists p \in G(R(A', b))$ :  $x \rightarrow p$  path

Add 0 elements to  $A'$  to fit  $m$  and  $n$ .

**Figure 1.** Defined matrix  $A'$

**Figure 2.** Constructed path

**For Theorem 7**

Proof of contraposition of statement in Theorem 7

Expansion Lemma

$A \in \mathbb{R}^{m \times n}$ ,  $A'$ : submatrix of  $A$  which columns cannot be eliminated

$A'$  is not UC.  $\Rightarrow A$  is not UC.

Case of  $m = 2$  Case of  $n = 2$  Case of  $m = 3$

## References

- [1] Kimura, K., Suzuki, A.: Trichotomy for the reconfiguration problem of integer linear systems. *Theoretical Computer Science* **856**, 88–109 (2021)
- [2] Nishimura, N.: Introduction to reconfiguration. *Algorithms* **11**(4), 52 (2018)
- [3] Shigenobu, T., Kamiyama, N.: On connectedness of solutions to integer linear systems. Unpublished





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## (2) BICLUSTERING VIA SPARSE PENALTY

(3) This research proposes a new biclustering method via sparse penalty (mixed Prenet penalty). The method is very effective in dealing with overlapped biclusters. And it is more effective in finding non-overlapped biclusters and identifying small biclusters compared with some other biclustering methods.

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**BICLUSTERING VIA SPARSE PENALTY**  
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**Overview**

In this study, we observed that some biclusters produced by the existing biclustering algorithms were excessively similar, and had a high degree of repetition (overlap). Therefore, we extended the Prenet penalty (Hirose and Terada 2022)[1] and successfully used it in the SSVD[2](sparse singular value decomposition) model. This improvement has a noticeable effect on reducing the degree of dummy overlapping.

**What is the biclustering method**

The following figure shows an example of biclustering. We use a simulated data matrix with significant checkerboard structure while covered by strong white noise.

In this research we originally suggested using the following *Mixed Prenet* penalty. Notice that here  $K$  could be any value in  $2 \leq K \leq \min\{n, d\}$ .

**The mixed Prenet**

$$P(U) = \sum_{i=1}^n \sum_{j=1}^d \lambda_i (\gamma \omega_{i1} |u_{i1}| (1 + \delta_1 \sum_{k=2}^K |u_{ik}|) + (1 - \gamma) \omega_{i2}^2 |u_{i1}| (1 + \delta_2 \sum_{k=2}^K |u_{ik}|)).$$

$\omega_{i1}$ : weight of  $u_{i1}$ ;  
 $\lambda_i$ : regularization parameter;  
 $\gamma \in (0, 1)$ : tuning parameter control the balance between  $L_1$  and  $L_2$  penalty;  
 $\delta_1, \delta_2 > 0$ : tuning parameters control the balance between *elastic net* and *Prenet* penalty.  
 Especially, when  $\delta_1 = \delta_2 = 0$  it becomes the elastic net.  
 Details of algorithm are in [4]

**Behavior on simulated data**

The following figure shows the results obtained using different penalties (using the same simulation settings with section 1). The results obtained using *mixed Prenet* effectively restores the true data even with strong noise that is significantly better than using *adaptive Lasso*.

**The SVD and SSVD model**

**SVD**

$$X = UDV^T = \sum_{k=1}^r \lambda_k u_k v_k^T,$$

$r$ : rank of  $X$ ;  
 $U, V$ : singular vectors;  
 $D = \text{diag}(\delta_1, \dots, \delta_r)$ : diagonal singular value matrix.

**SSVD[2]**

$$\hat{X}^{(K)} = (S, U, V) = \arg \min_{(S, U, V)} \|X - USV^T\|_F^2 + P_1(US) + P_2(VS).$$

Here  $S$  is the  $K \times K$  diagonal matrix corresponding to the first  $K$ 's singular value.  $P_1$  and  $P_2$  are the sparse-including penalties corresponding to the column and row variables.

**Sparse penalties**

In [2], the author used the following *adaptive Lasso* as the sparse penalty in the objective function.

**The adaptive Lasso**

$$P(u) = \lambda \sum_{i=1}^n \omega_i |u_i|.$$

Here  $\omega_i$  is the weight of  $u_i$ .  $u = \{u_1, \dots, u_n\}^T$  is a row vector, and  $\lambda$  is regularization parameter.

**Real gene expression data**

In this study, we use gene expression data about breast cancer. This data contains 337 patients and 24481 genes with stage I or II breast cancer. In the two figures on the right, the third column represents the ER values (it can be seen as the "true value" of the first bicluster), which are used to compare with the first bicluster.

**Estimated percentage of different types of patients:**

Penalty	ER+HER2-	ER+HER2+	ER-HER2-	ER-HER2+
adaptive Lasso	70.4%	8.9%	17.8%	2.9%
adaptive Prenet	67.9%	8.3%	22.3%	1.4%
SSVD[3]	70.3%	7.7%	13.1%	8.9%

**References**

[1] Kei Hirose and Yoshikazu Terada. Sparse and simple structure estimation via prenet penalization. *Psychometrika*, pages 1–26, 2022.

[2] Miao Lu, Haipeng Shen, Jianhua Z Huang, and James S Murray. Biclustering via sparse singular value decomposition. *Biometrics*, 66(4):1087–1095, 2010.

[3] Orona E Meanc, Yoonha Kichoon, and Edward J George. Spike-and-slab lasso biclustering. 2021.

[4] Jiqiang Wang. Biclustering via sparse penalty. 2023[unpublished].



## To FMfI2023 Banquet Attendees

**Meet at 17:00 at the main entrance of Nishijin Plaza.**

**Three buses leave here for the banquet venue  
at 17:15 at the entrance.**

**Bring your banquet ticket with you.**



### FMfI2023 Banquet:

- **Date: Wednesday, August 30, 2023, 18:30-20:30**
- Venue: Seido, Koumyo-den 4th floor
- 1-35 Kamikawabatamachi, Hakata-ku, Fukuoka-shi, Fukuoka 812-0026
- TEL: +81-92-710-4305
- Website: <https://www.tomyoden.com/>
- Format: Standing buffet

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