ReaDiNet 2020: An online conference on mathematical biology

October 19th to 23rd

Organizers: Chiun-Chuan Chen, Tadahisa Funaki, Thomas Giletti, Jong-Shenq Guo, Hyung-Ju Hwang, Yong-Jung Kim, Hiroshi Matano, Benjamin Mauroy, Masaharu Nagayama, Stefano Olla.

Register by email to thomas.giletti(at)univ-lorraine.fr and you will receive an invitation to the Zoom meeting.

Below timetable is French time (UTC +2). Add 6 hours for Taiwan, 7 hours for Japan and Korea.

Time (UTC +2)	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 - 9:30		H. Ishii	F.B. Wang	J.K. Kim	Sunmi Lee
9:30 - 10:00		S. Choi	F. Noel	H. Son	N. Bacaer
10:00 - 10:30	Y.J. Kim	T. Sushida	Seongwon Lee	C.H. Hsia	C.Y. Cheng
10:30 - 11:00	J.S. Guo	*break*	*break*	*break*	*break*
11:00 - 11:30	R. Mori	C.H. Wu	L. Xu	P. El Kettani	H. Monobe
11:30 - 12:00	L. Roques	S. Nordmann	B. Xie	M. Simon	C.C. Chen

Sunday, October 18th

- **11:00 -** *Informal meeting*

Monday, October 19th

- **10:00 - 10:30 : Yong-Jung Kim**, KAIST,

  A thought experiment to find the correct anisotropic diffusion model

- **10:30 - 11:00 : Jong-Shenq Guo**, Tamkang University,
  Traveling wave solutions for some three-species predator-prey systems
- **11:00 - 11:30 : Ryunosuke Mori**, Tokyo Institute of Technology,
  A reaction-diffusion model for Neolithic transition in Europe
- **11:30 - 12:00 : Lionel Roques**, INRAE,
  Adaptation in general temporally changing environments

Tuesday, October 20th

- **9:00 - 9:30 : Hiroshi Ishii**, Hokkaido University,
  Motion of interacting front solutions for nonlocal reaction diffusion equations
- **9:30 - 10:00 : Sunho Choi**, Kyunghee University,
  SIR type rumor spreading models
- **10:00 - 10:30 : Takamichi Sushida**, Tokyo Salesian College of Technology,
  A reaction-diffusion model of retinal processing and negative afterimages

Break

- **11:00 - 11:30 : Chang-Hong Wu**, National Chiao Tung University,
  Entire solutions originating from traveling fronts for a two-species competition-diffusion system
- **11:30 - 12:00 : Samuel Nordmann**, University of Tel-Aviv,
  Activity/Susceptibility models: a general class of reaction-diffusion systems for the spread of epidemics, population dynamics and collective social behaviors

Wednesday, October 21st

- **9:00 - 9:30 : Feng-Bin Wang**, Chang Gung University,
  Spatial dynamics of a dengue transmission model in time-space periodic environment

- **9:30 - 10:00 : Frederique Noel**, Université de Nice Sophia-Antipolis,
  Minimization of the power spent during respiration
- **10:00 - 10:30 : Seongwon Lee**, National Institute of Mathematical Sciences,
  Mathematical modeling for Th cells with plasticity of Th17

Break

- **11:00 - 11:30 : Lu Xu**, Gran Sasso Science Institute,
  Quasi-static limits for Burgers' equation and ASEP
- **11:30 - 12:00 : Bin Xie**, Shinshu University,
  The asymptotic behavior of a quasilinear PDE in random environment

Thursday, October 22nd

- **9:00 - 9:30 : Jae Kyoung Kim**, KAIST,
  Robust oscillations against spatial-temporal noise in intra-inter cellular kinetics
- **9:30 - 10:00 : Hwijae Son**, POSTECH,
  Real-world implications of a rapidly responsive COVID-19 spread model with time-dependent parameters via deep learning
- **10:00 - 10:30 : Chun-Hsiung Hsia**, National Taiwan University,
  On the mathematical analysis of synchronization theory

Break

- **11:00 - 11:30 : Perla El Kettani**, Ecole Normale Supérieure,
  Singular limit of a stochastic Allen-Cahn equation with nonlinear diffusion
- **11:30 - 12:00 : Marielle Simon**, INRIA,
  Macroscopic evolution of mechanical and thermal energy in a harmonic chain

Friday, October 23rd

- **9:00 - 9:30 : Sunmi Lee**, Kyunghee University,
  Mathematical modeling for MERS-CoV and COVID-19 outbreaks in South Korea

- **9:30 - 10:00 : Nicolas Bacaer**, IRD,
  SIR, SEIR, etc.

- **10:00 - 10:30 : Chang-Yuan Cheng**, National Pingtung University,
  Periodic drug efficacy and cell diffusion within a host

Break

- **11:00 - 11:30 : Harunori Monobe**, Okayama University,
  Fast reaction limit of a three-components Lotka-Volterra competition-diffusion system

- **11:30 - 12:00 : Chiun-Chuan Chen**, National Taiwan University,
  Three-phase traveling waves for a gradient system

Abstracts

Nicolas Bacaer, IRD

SIR, SEIR, etc.

Chiun-Chuan Chen, National Taiwan University

Three-phase traveling waves for a gradient system

In this talk, we consider traveling wave solutions of a gradient system in an infinite strip. As the potential of the system is even-symmetric and has three local minima, we prove the existence of a traveling wave that propagates from one phase to the other two phases, where these phases correspond to the three local minima of the potential. To control the asymptotic behavior of the wave at minus infinity, we successfully find a certain convexity condition on the potential, which guarantees the convergence of the wave to a constant state.

Chang-Yuan Cheng, National Pingtung University

Periodic drug efficacy and cell diffusion within a host

Overuse of a drug can lead to deleterious side effects, and overestimating the efficacy of a drug can result in failure to treat infection. In this talk, we will explore the viral dynamics within a treated host by incorporating the spatial heterogeneity with the intrinsic incubation period of the actively infected cells and virions. A threshold dynamics of either extinction of virus or the uniform persistence of infection will be determined by calculating the value of the basic reproduction number (R_0). In addition, by conducting numerical simulations, we will also explore the effects of various parameters on the value of R_0. The main issues include how the value of R_o affected by the incubation period, the mobility of infected cells or virions, and the spatial fragmentation of the virus environment.

Sunho Choi, Kyunghee University

SIR type rumor spreading models

We consider two rumor spreading models. One is an SIR type rumor spreading model with a variable trust rate. Based on the large population limit or thermodynamics limit, we present a rigorous proof for the existence of threshold on the final size of the rumor with respect to the basic reproduction number R0. We also provide a phase transition phenomenon for the final size of the rumor with respect to the basic reproduction number when the trust rate depends on the populations of ignorants and spreaders. The other one is a stage-structured model. On this model, we present the existence of a unique solution and the basic reproduction number for the corresponding discrete model.

Jong-Shenq Guo, Tamkang University

Traveling wave solutions for some three-species predator-prey systems

In this talk, we shall present the existence vs non-existence of traveling waves for some three-specie predator-prey systems. These waves describe the invasion phenomena of the alien species to the habitat of the aboriginal species. The existence of waves is based on the well-known method of Schauder's fixed point theorem with the help of generalized upper-lower solutions. We shall present some new forms of upper-lower solutions. Furthermore, some new ideas to derive the stable tail limit of wave profile are introduced.

Chun-Hsiung Hsia, National Taiwan University

On the mathematical analysis of synchronization theory

Synchronization is a pervasive phenomena which has been observed in biological, chemical, physical and social systems. The first reported observation of synchronization dates back to the 17th century; a Dutch scientist, Christiaan Huygens has discovered in 1665 that two pendulum clocks hanging on the wall have always ended up swinging in exactly the opposite direction from each other. Since then, various synchronization phenomena have been reported. These include circadian rhythms, chirping crickets, flashing fireflies, croaking frogs, electrical generators, Josephson junction arrays, intestinal muscles and menstrual cycles. In this talk, we shall introduce the development of the mathematical theory in the past 70 years and some scientific applications of synchronization theory.

Hiroshi Ishii, Hokkaido University

Motion of interacting front solutions for nonlocal reaction diffusion equations

We will present about the interaction of standing front solutions for scalar reaction-diffusion equations with a nonlocal effect. We consider the case that a nonlocal effect is given by the convolution with a suitable integral kernel. At first, we deduce the equation describing the movement of interacting front solutions, assuming that there exists a linearly stable front solution for scalar reaction diffusion equations with a nonlocal effect. When the distances between localized patterns are sufficiently large, the motion of localized patterns can be reduced to the equation for the distances between them. Finally, using this equation, we analyze the interaction of front solutions to some nonlocal scalar equation. Under some assumptions, we can show that the front solutions are interacting attractively for a large class of integral kernels. This talk is based on a joint work with S.-I. Ei.

Perla El Kettani, Ecole Normale Superieure

Singular limit of a stochastic Allen-Cahn equation with nonlinear diffusion

In this talk, I will study the singular limit of a stochastic Allen-Cahn equation with nonlinear diffusion. We will consider the case of a mild noise which is the derivative of an approximate Brownian motion. We will prove that the limiting problem involves stochastic motion by mean curvature, extending results by Alfaro, Antonopoulou, Karali and Matano, who themselves extend earlier results by Funaki, and by Weber. We will first present a proof for the generation of interface and then discuss a result about interface motion by constructing suitable sub-and super-solutions. This is a joint work with Danielle Hilhorst, Yong Jung Kim and Hyun Joon Park.

Jae Kyoung Kim, KAIST

Robust oscillations against spatial-temporal noise in intra-inter cellular kinetics

Circadian clock generates ∼24h rhythms everyday via a negative feedback loop. Although this involves the daily entry of molecules to the nucleus after random diffusion through a crowded cytoplasm, the period is extremely well preserved. Furthermore, the period is well maintained across the cell population whose size differs considerably. In this talk, I will illustrate how thousands of molecules work together in time and space to compensate for their spatio-temporal variations and maintain robust rhythms, which we identified using the combination of agent based modeling and single cell imaging experiments. Furthermore, the population of individual oscillatory cells can be communicated via intercellular signal to generate synchronous rhythms. I will describe that cells use an intracellular signal amplification to achieve long range temporal synchrony with local signal, which we identified via the combination of delay PDE model and synthetic biology experiments.

Yong-Jung Kim, KAIST

A thought experiment to find the correct anisotropic diffusion model

There have been a lot of discussions about the correct diffusion equation under a heterogeneous environment. In this talk a thought experiment test for the validity of anisotropic diffusion model is introduced. We will see that a diffusion model obtained from revertible random walk corrected with mean curvature effect passes the test.

Seongwon Lee, National Institute of Mathematical Sciences

Mathematical modeling for Th cells with plasticity of Th17

In the immune system, the CD4+ T cells are known for their significant role in a way that derives other immune cells' activation by releasing the cytokines. This paper establishes a mathematical model of the immune system describing the activities of Th cells in response to various doses of polycytidylic acid (poly I:C). The numerical analysis of the model shows the bistability of Th phenotypes when the dose of poly I:C is high. The model also predicts switching behaviors between Th1 and Th2 phenotypes in the presence of stochasticity, which cannot be observed by the system of ordinary differential equations.

Sunmi Lee, Kyunghee University

Mathematical modeling for MERS-CoV and COVID-19 outbreaks in South Korea

The novel coronavirus emerged in December 2019 and spread to 214 countries. South Korea was one of the countries that have experienced the early stage of the COVID-19 pandemic. In the absence of vaccines and treatments, South Korea has implemented and maintained effective interventions such as large-scale epidemiological investigation, rapid diagnosis, social distancing, and prompt clinical classification of severe patients with appropriate medical measures. This was possible because the Korean government and health officials learned valuable lessons from the Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak in 2015. The 2015 MERS-CoV outbreak in Korea was the largest outbreak outside the Middle Eastern countries and was characterized as a nosocomial infection and a super-spreading event. In this talk, we present mathematical modeling for both MERS-CoV (2015) and COVID-19 (2020) outbreaks in South Korea. We investigate the effectiveness of case isolation and contact-tracing interventions in the early transmission dynamics of COVID-19 in South Korea.

Harunori Monobe, Okayama University

Fast reaction limit of a three-components Lotka-Volterra competition-diffusion system

Ryunosuke Mori, Tokyo Institute of Technology

A reaction-diffusion model for Neolithic transition in Europe

In 1996, Aoki, Shida and Shigesada proposed a three-component reaction-diffusion model describing the spread of the early farming during the New Stone Age. By numerical simulations and some formal linearization arguments, they concluded that there are four different types of spreading behaviors depending on the parameter values. We give mathematical justification to all of the four types of spreading behaviors observed by Aoki et al.

Frederique Noel, University of Nice Sophia-Antipolis

Minimization of the power spent during respiration

The main goal of the lung is to bring enough oxygen to the blood and to remove carbon dioxide from it. The lung transports gases by convection and by diffusion through its tree-like geometry to an exchange surface called acinus. However, this transport causes a loss of power due to the air circulation through the bronchi and due to the mechanical action of the respiration. We aim to minimize this power using an oxygen flow constraint in order to satisfy our body needs. In this talk, I will first present a gas transport model in an idealized lung which gives us the oxygen flow exchange with the blood. I will then show our minimization results for three physiological tests: the impact of physical activity, the response to altitude and finally the change of hydrodynamic resistance which implies the change in the lung's size.

Samuel Nordmann, University of Tel-Aviv

Activity/Susceptibility models: a general class of reaction-diffusion systems for the spread of epidemics, population dynamics and collective social behaviors

(in collaboration with Henri Berestycki and Luca Rossi) A considerable number of studies are devoted to the introduction and analysis of variants of the SIR epidemiology models. Similar models are also used to describe collective behaviors in other contexts, such as the dynamics of riots, the adoption of a technology or a belief, etc. Given the variety of models considered in the literature, an important task is to identify a general paradigm and to provide mathematical tools to analyze it. In this talk, we propose a class of Reaction-Diffusion systems that aims at unifying and generalizing classical epidemiology models. Our model involves two quantities, the level of activity u, and a field of susceptibility v, which play asymmetric roles: u is thought of as the actual observed or explicit quantity while v is an implicit field that modulates the growth of u. We try to keep the assumption on the parameters as general as possible, in particular, we do not assume any monotonicity. Many diverse models fit our general paradigm: the SIR epidemiology model and some variants, the prey/predator and competitive Lotka-Volterra systems, models for flame propagation, models for the dynamics of riots, the Bass model in marketing for the diffusion of a new product in a market, etc.

We prove on this class of systems general results dealing with the stability of steady states, the asymptotic speed of propagation of compactly supported initial data, and the existence/non-existence of traveling wave. We also highlight a threshold phenomenon in terms of the initial level of susceptibility v_0 which generalizes the well-known threshold on the reproductive number R_0 in the classical SIR model. We give further results on two specific subclasses of systems, namely the inhibiting and the enhancing case, which generate ephemeral or time-lasting episodes of activity respectively and illustrate the richness of the framework.

Lionel Roques, INRAE

Adaptation in general temporally changing environments

Marielle Simon, INRIA

Macroscopic evolution of mechanical and thermal energy in a harmonic chain

It has been recently observed that some physical or biological systems which are maintained in a bath of constant temperature can behave in an unexpected way: in some cases the temperature stationary profile presents a maximum inside the system higher than the thermostats temperatures, as well as the possibility of uphill diffusion (energy current against the temperature gradient). This is the case for instance in mitochondria, which are present in nearly all types of human cell.

In a collaborative work with T. Komorowski and S. Olla, we derive rigourously this "heating inside the system" phenomenon from a microscopic infinite chain of coupled oscillators in contact at both ends with heat baths at different temperatures, and subject to an external force at one end. While heat flows from the thermostats, the mechanical energy produced by the force is then transformed into thermal energy by the bulk dynamics. We follow an approach based on Wigner distributions, which permit to control the energy distribution over various frequency modes and provide a natural separation between mechanical and thermal energies.

Hwijae Son, POSTECH

Real-world implications of a rapidly responsive COVID-19 spread model with time-dependent parameters via deep learning

The COVID-19 pandemic has caused major disruptions worldwide since March 2020. In this talk, we will discuss a new SIR (Susceptible-Infected-Recovered) model with time-dependent parameters via deep learning. The time-dependent reproduction number R_{TD} computed from the time-dependent SIR model enables more rapid response to the dynamic situation of the outbreak. The methodology could also be employed for short-term prediction of COVID-19, which could help the government prepare for a new outbreak.

Takamichi Sushida, Tokyo Salesian College of Technology

A reaction-diffusion model of retinal processing and negative afterimages

Negative afterimage is perceived as an opposite brightness or color for a removed original image. In the subject of neurophysiology, it has been discussed that they are produced by responses of retinal nerve cells, and convolution integral models based on spatial-temporal receptive field structures of cells have been proposed. In particular, the temporal response is described by using the temporal impulse response (TIR) function and the spatial response is described by radial symmetrical Mexican-hat function. In this study, we propose a reaction-diffusion model based hierarchical interactions of retinal nerve cells, and we show that our model possesses the receptive field structure with the TIR function and the Mexican-hat function by representing the exact solution as the convolution integral. Moreover, we give using numerical computations a theoretical prediction that asymmetrical perception of after-image rotations is induced by asymmetrical temporal responses of the horizontal cells which play an inhibitory effect in the retina processing. This talk contains results obtained in a joint work with Dr. Shintaro Kondo (Gifu University, Japan).

Feng-Bin Wang, Chang Gung University

Spatial dynamics of a dengue transmission model in time-space periodic environment

In this talk, I shall present a recent work devoted to the investigation of dengue spread via a time-space periodic reaction-advection-diffusion model. The existence of the spreading speeds and its coincidence with the minimal speed of almost pulsating waves will be established. We also illustrate the analytic results by numerical simulation, for the temporal periodic case and the temporal and spatial periodic case, respectively.

Chang-Hong Wu, National Chiao Tung University

Entire solutions originating from traveling fronts for a two-species competition-diffusion system

In this talk, we will consider entire solutions (classical solutions defined globally in time and space) of a two-species strong competition model. For this system, it is well known that there exist two-front entire solutions which behave as two traveling fronts moving towards each other from both sides of the x-axis. In this paper, in terms of traveling fronts connecting two different constant states from the coexistence state and the two semi-trivial states, we build entire solutions originating from three and four fronts stuck between appropriate super and subsolutions. Moreover, the non-existence of entire solutions originating from more than seven traveling fronts is proved. This is joint work with Jong-Shenq Guo.

Bin Xie, Shinshu University

The asymptotic behavior of a quasilinear PDE in random environment

We study the asymptotic behavior of a certain quasilinear PDE with mild noise, which originally appears in the hydrodynamic scaling limit of a microscopic interacting particle system called zero-range process in a random environment on 1-d discrete lattice. We mainly establish the convergence result of the quasilinear PDE with mild noise and show a local in time well-posedness of the limit stochastic PDE with spatial white noise by the method of the paracontrolled calculus. We also mention the global solvability and convergence to its stationary solutions under proper conditions. This talk is based on the joint work with T. Funaki, M. Hoshino and S. Sethuraman.

Lu Xu, Gran Sasso Science institute

Quasi-static limits for Burgers' equation and ASEP

We consider the asymmetric simple exclusion process (ASEP) with open boundaries. The exterior boundary rates move in a time scale slower than the macroscopic time. We prove that the hydrodynamic limit is the unique entropy solution of the quasi-static conservation law. This defines rigorously the quasi-static transformations between non-equilibrium stationary states. From macroscopic point of view, we prove that similar limit holds for inviscid Burgers' equation. Based on joint works with Anna De Masi (Univ. L'Aquila), Stefano Olla (Paris-Dauphine) and Stefano Marchesani (GSSI).