Spiral wave propagation on the excitable Kuramoto lattice.

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We study the dynamical and structural properties of spiral waves propagating on excitable media consisting of a network made of phase-coupled Kuramoto elements. Each element in the network has an intrinsic oscillation frequency and a threshold of excitability. We numerically study the effects of the excitability and coupling strength on the structure and stability of spiral waves.

Effect of coupling strength on frequency enhancement in excitable medium : Application to Cultured Cardiac Myocyte Synchronization

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By applying noises to coupled excitable FitzHugh-Nagumo elements, the spiking frequencies can be varied. In some coupling ranges, the frequency can be enhanced up to 60%. This frequency enhancement is due to phase mismatch of spike induced by noises, which can be improved by increasing the number of connections. Variation in heart beat rates during the development of cell connections and synchronized beating observed in experiment can be reproduced from our modeling.

Predicting the distribution of spiral waves from cell properties in a model of Dictyostelium pattern formation

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The slime mold Dictyostelium discoideum is one of the model systems of biological pattern formation. It exhibits large-scale cooperative patterns, organized by cAMP signaling between cells, in order to aggregate, exhibiting well-known and generic excitable media dynamics.

Here we analyse the spatio-temporal emergence of circular (target) and spiral waves from heterogeneities caused by biological variability on the cellular level in a mathematical model of Dictyostelium discoideum.

We demonstrate how the spatial distribution of cell properties systematically shapes the spatial distribution of spiral waves. It can be seen that the initial properties of potentially very few cells have a driving influence on the resulting asymptotic collective state of the colony. We discuss how data on cellular properties can be used totatistically predict the allocation of large-scale pattern features.

Controlling of Excitable Waves in Heart Tissue: Two Different Approaches

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Kyoto University

We present two different approaches to terminate an obstacle pinned spiral wave in excitable medium. On the one hand we show that a single stimulus can be sufficient to unpin the spiral wave, and on the other hand we show that high-frequency pacing apart from the spiral lead to unpinning. The numerical and theoretical results are confirmed with experiments of cardiomyocyte monolayers.

Behavior of multi adaptive reaction system and environment-dependent response

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The University of Tokyo

Microorganisms regulate the intracellular reactions to show "homeostasis" when the external condition is changed, whereas they also show history dependent response following some environmental change. We study a variety of adaptation process by using a dynamical system model and show how the two behaviors, adaptation and environment-dependent response, emerge and mutually influence with each other.

Full Synchronization and Partial Synchronization of a Multi-country Inventory Cycle Model

Kenichi Ishiyama
Seikei University

The inventory cycle model discussed in the article can represent both full and partial synchronization phenomena. The model shows that if economies in two countries fluctuate with zero phase-difference through dynamic coupling, it results in increase in the volatility of business cycle and decrease in that of the other.

Perturbation of BZ patterns by amphipliles

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In the presence of amphiphilic molecules in the BZ medium, hydrophilic and hydrophobic intermediates of BZ reaction may interact with those depending on their charge, hydrophobicity, etc. We investigated the influence of the anionic surfactant, bis(2-ethylhexyl)sodium sulfosuccinate (AOT) on the pattern dynamics of BZ aqueous system. For comparison, cationic and nonionic surfactants were also investigated.

Method to control dynamics of coupled oscillators using multi-linear feedback

Takeshi Kano
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Osaka University

Methods to control the dynamics of coupled oscillators have been developed owing to various medical and technological demands. In the presentation, we will develop a new method to control coupled oscillators in which the coupling function expressed in a phase model is regulated by the multi-linear feedback. This method has wide applicability because we do not need to measure an individual output from each oscillator, but only measure the outputs from several measurement nodes. Moreover, it allows us to easily control the coupling function up to higher harmonics. The validity of the method is confirmed through a simulation.

On the intermittency phenomena in the shell-model turbulence

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Kyoto University

The intermittency is one of the most important phenomena in the chaotic dynamical systems and can be observed in various chaotic dynamical systems from the low dimensional chaotic systems to turbulence systems. For almost low dimensional chaotic systems, e.g. logistic map, the mechanism of the intermittency phenomena is well-known. However for high dimensional chaotic systems, e.g. turbulence, the mechanism is unknown. In this poster presentation, we investigate the intermittency in the shell-model turbulence and elucidate the relation between the intermittency and the non-hyperbolicity of shell-model.

Design principle of multi-cluster and desynchronized states in oscillatory media

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A theoretical framework is developed for a precise control of spatial patterns in oscillatory media using nonlinear global feedback, where a proper form of the feedback function corresponding to a specific pattern is predicted through the analysis of a phase diffusion equation with global coupling. In particular, feedback functions that generate the following spatial patterns are analytically given: i) 2-cluster states with an arbitrary population ratio, ii) equally populated multi-cluster states, and iii) a desynchronized state. Our method is demonstrated numerically by using the Brusselator model in the oscillatory regime. Experimental realization is also discussed.

Dynamical response of oscillator networks: linking cell-level and system-level responses

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JST PRSTO researcher

We report on a new reduction theory that describes the response of an oscillator network as a whole to external forcing applied nonuniformly to its constituent oscillators. Any network structure can systematically be treated.

Reference:

[1] H. Kori, Y. Kawamura, H. Nakao, K. Arai, Y. Kuramoto, arXiv: 0812.0118

The total regulation of gene expression by DNA- membrane complexes formation.

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We propose new mechanism of regulation of gene expression and consider the reason of many diseases as failure of such regulation. The understanding of the nature of cancer is impossible without an accepting the basic role of DNA-membrane complexes (DMC).

In accordance with our model [1], DMC are formed in the chromatin areas with three-stranded hybrids: DNA- low molecular weight RNA (lmwRNA) at their interactions with the nuclear envelope. The triple helix unwinds during interaction with nuclear membrane forming a classical R-loop: DNA–RNA hybrid and a single-stranded DNA. The number of DMC determinate the set of genes attached to nuclear envelope. Single- stranded DNA in DMC is the site of transcription initiation. The result of such interaction is nuclear pores which thereby serve as sites of initiation of transcriptions in a cell. Therefore, the attachments of any gene to a nuclear envelope result in enhanced level of expression of this and neighboring genes.

The structure of interphase chromatin cannot be considered without taking into account its interaction with nuclear pores. The sequence of an attachment and detachment of genes to nuclear envelope is programmed in the course of cellular differentiation and set of such genes is invariable for the differentiated cells. Impairment of this order can lead to such diseases as a cancer and many other diseases connected with a failure of gene expressions.

The cancer can be considered as a partial dedifferentiation of a cell in an environment of the differentiated cells in a tissue. The set of active genes of the differentiated cells is tissue specific; the number of such genes is much lower than that of genes expressing in oocyte at the first stages of its division. However, dedifferentiation can lead to the diseases only if the newly expressed genes give advantage of cell division speed or growth inhibition of neighboring cells. The high activity of dedifferentiated genes having no effect on a lung cells, can result in a liver cancer. Nevertheless, this is only the beginning of carcinogenesis.

Further follow more significant events transforming normal cells to malignant. Form important role of lmwRNA in DMC formation we can suggest their role in a tumor progression. The lmwRNA can leave the cancer cells and enter into normal cells. Then they induce in normal cells the formation of additional DMC of the same genes such as in cancer cells. That enhance expression of cancer genes in normal cells result in their transformation in cancer cells. Therefore, before a metastasis stage cancer cells stimulate self-supporting chain reaction in normal cells near to the centre of growth of a tumor.

Reference:

[1] Kuvichhkin V.V. 2002, Lipid-nucleic acids interactions in vitro and in vivo, Bioelectrochemistry 58, pp. 3– 12

Multiscale Networks of Interacting Biological Systems: From network constructions to causality among them

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From microscopic biomolecules to macroscopic functional organisms, biological systems are known to be operating not just in a single scale but across a broad range of spatiotemporal hierarchies. Our knowledge of these multiscale biological processes has been significantly advanced by recent developments in the high resolution measurements. Here I present our novel data-driven methodology to extract the underlying multiscale biological modeling with the firm mathematical foundation. The outcome is the multiscale state-space networks describing the biological process across different spatiotemporal scales with high predictive power. The multiscale state-space networks enable us to extract the causal (driven/response) relation between network components and dynamics at different scales, This can offer us a possible device or means to address the complex dynamics across scales, and the validity of slaving principle and adiabaticity in biological systems.

Self-sustained Oscillation in a Non-oscillatory Cell Chain and Its Bifurcation Analysis

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Spatio-Temporal Order Project, ICORP, JST

A type of self-sustained global oscillation is observed in excitable discrete cell chain in which none of individuals are oscillatory. The model provide yet another possible scenario for biological clock. The bifurcation with respect to coupling strength is investigated.

The relation between thermodynamic indices and pattern formation

Hitoshi Mahara
National Institute of Advanced Industrial Science and Technology

Introduction of the relative chemical potential enables us to calculate the entropy change and the entropy flow. The relations between the pattern formation and thermodynamic indices are discussed with this introduction. Moreover, we discuss the relation between two definitions of the entropy production (for reversible and irreversible reaction).

Freezing transition of unidirectional lattice-gas flow of flexible chainlike objects

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Shizuoka University

In simulations of two-dimensional, unidirectional, lattice-gas flows of flexible, chainlike, self-driven objects, we found a freezing transition from a smoothly flowing state to a completely jammed state, in which the objects get immobile and cannot move anymore. This transition, which is the first observation for a unidirectional traffic flow without obstacles, proves to be attributable to the flexibility of the objects.

Distribution of residence time at quasi-stationary states in globally coupled map.

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Tomoyuki Yamamoto and Takashi Hashimoto
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An anomalous temporal aspect of intermittency in globally coupled map is studied. It is found that distributions of residence time at quasi-stationary states differ depending on parity (i.e., odd or even) of the residence time. This feature appears on a parameter region near turbulent phase, where probability density of trajectories splits into several regions.

Mathematical analysis on a continuum model for a flow of granular materials

Naoto Nakano
Keio University

Recently, granular materials have been studied by the use of continuum mechanics. Under certain conditions the response of them can be described as motion of inhomogeneous incompressible fluid-like bodies. Furthermore, it is well known that slip phenomena on the surface of the body play the significant role of its motion. Here, we shall present our mathematical works concerning this model.

Achievement of Emergent Alternative Configurations of Vehicles for Easing Traffic Congestion on Weaving Sections

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[2)]JST PRESTO researcher

For releasing the heavy congestion occurring at merging sections on highway, we discuss the possibility of alternative configuration of vehicles on multiple-lane road. We show, by developing a cellular automaton model for multiple lanes, that this configuration is simply achieved by local interactions between vehicles neighboring each other. The degree of the alternative configuration in terms of the spatial increase of parallel driving length is measured by using numerical simulations, and by using cluster approximation.

Discreteness-induced pattern formation in nonlinear proliferation systems

Kenta Odagiri
The University of Tokyo

We study the dynamics and pattern formation in three constitutively structured autocatalytic proliferation systems. To analyze various patterns and dynamics emerging from these models, we perform comparative studies between the methods of reaction-diffusion equations (RD) and cellular automata (CA). We show that stochastic and discrete dynamics are critical roles to generate rich patterns and dynamics through the comparison.

Memory, hysteresis and oscillation induced by multiple covalent modifications and its application to circadian rhythm of Cyanobacteria

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Hiroshima University

No transcription-translation feedback system of circadian clock by KaiC protein's phosphorylation is very interesting and also significant as a kind of core cycle of the circadian rhythm in Cyanobacteria. In order to understand the oscillation phenomena, we pay attention to a function of memory in a cell level. A standard structure of such a binary digit of memory is presented by use of multiple covalent modifications in this presentation. A key idea is bistability of covalent modification states which creates hysterically and digitally switching mechanism between them. By use of this kind of memory, we see the circadian oscillation be realized. In fact, by deterministic simulations as well as by stochastic simulation, it is shown that the system obtains stable circadian oscillations, and shown that multiplicity of modification sites reinforces the stability of memory in several senses. Moreover, it is reported that this model explains well several molecular biologically experimental facts about period's change by use of mutants of Kai proteins in the circadian rhythm of Cyanobacteria. This is a joint work with Kazumi Ebisu, and Tatsuo Shibata in Hiroshima University.

Flexible biochemical switches based on mixed feedback loops

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Graduate School of Arts and Sciences,
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ERATO complex systems biology, JST

An essential attribute of living cell is the capacity to select among various alternatives when confronted with external or internal signals. Such reliable decisionmaking process must be put in place by biochemical machinery, namely interacting genes and proteins. These biochemical regulatory networks frequently combine feedforward and feedback loops, negative and positive ones. Using a simplified model of biochemical circuit, we explore how a certain class of circuit based on mixed feedback loops gives rise to a switching dynamics with flexible and biologically relevant properties.

Time Averaged Properties along Unstable Periodic Orbits in Some Systems of Differential Equations

Yoshitaka Saiki
Research Institute for Mathematical Science,
Kyoto University

By employing low dimensional chaotic systems described by systems of differential equations, we collected many UPOs for each system. Then we study time averaged properties of UPOs compared to those of chaotic orbits and obtain some implications about the role of UPOs in analyzing chaotic systems.

Heteroclinic cycle and propagating pulse wave in a ring of coupled bistable oscillators

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One of the onset mechanisms of the propagating pulse wave observed in a ring of coupled bistable oscillators is investigated. In particular, a formation mechanism of the pulse wave solution and its related dynamics are discussed. Namely, it is verified from 6 to 10 coupled oscillator cases that the heteroclinic cycle at the saddle-node bifurcation point of a group of periodic solutions appearing from the symmetric structure, induces the propagating pulse wave after the bifurcation. From these results, we propose a conjecture that one of the onset mechanisms of the propagating pulse wave is based on the heteroclinic cycle.

Pattern evolution on the surface of reactive oil droplets

Kosuke Suzuki and Tomohiko Yamaguchi
National Institute of Advanced Industrial Science and Technology

We present the emergence of patterns on the surface of reactive sessile oil droplets that were made of two chemical components. After contacted with an aqueous phase, the droplets on a glass plate gradually hydrated to form such macroscopic structures as wrinkles and tubular structures. These morphological changes were influenced not only by the composition but the characteristic length of oil droplet.

Swarm Oscillators

Dan Tanaka
Univ. of Fukui,
PRESTO, JST

We propose a general chemotactic model describing a system of interacting elements. Each element in this model exhibits internal dynamics, and there exists a nonlinear coupling between elements that depends on their internal states. From this model, we derive a simpler model describing the phases and positions of the chemotactic elements by means of centre-manifold and phase reduction methods. We find that, despite its simplicity, the model obtained through this reduction exhibits a rich variety of patterns.

Two-parameter bifurcations in the Hodgkin-Huxley equations for muscle

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In order to reveal the mechanism behind channelopathies, some bifurcation phenomena in the space-clamped Hodgkin-Huxley equations for muscles (HHM) are studied. A codimension two bifurcation point which might be an inclination-flip point plays important roles on two-parameter plane of HHM. Totally, there is a good correspondence of the model (HHM) and the real muscle.

Folding patterns of stable/unstable manifolds in high dimensional dynamical systems

Hiroshi Teramoto
Research Institute for Electronic Science, Hokkaido University

In this talk, we investigate folding patterns of stable/unstable manifolds in systems with many degrees of freedom. Those in two-degree-of-freedom systems have been studied since Poincare and are well understood today, however those in systems with more than two degree-of-freedom systems have not been fully explored yet. We classify the possible folding patterns in terms of singularity theory and discuss about their physical roles in some Hamiltonian systems.

Spatiotemporal Pattern Formation in the Molecular Machinery in Biological Systems

Yuichi Togashi
Graduate School of Frontier Biosciences,
Osaka University

Biochemical processes are often modeled as reaction-diffusion (PDE) systems. However, features of biological systems such as great variety and complexity of proteins and complex structures of the cell, their behavior may be beyond the scope of classical PDE systems. In this work, we model and discuss effects of such features, especially intramolecular dynamics, on pattern formation.

Perturbation Analysis of Anisotropic Traffic Flow Model

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Graduate School of Engineering, The University of Tokyo
[2)JST PRESTO researcher

A new compressible fluid model for one-dimensional traffic flow is proposed based on actual measurement. We have derived the higher Burgers equation as a master equation of a small perturbation by applying the reductive perturbation method to the model. This master equation suggests the possibility of nonlinear saturation in this new model.

Position control of target pattern by annulus illumination on Belousov-Zhabotinsky reaction.

Toshihiro Tsuzuki
Graduate School of Frontier Biosciences,
Osaka University

It is an interesting problem how target pattern is generated in reaction-diffusion system. We performed detailed experiments on BZ reaction and find that the center position of target pattern is fully controlled by the small annulus illumination. By means of analytical and numerical approach, we clarified that concave distribution of inhibitor generated by the illumination is essential for the emergence of the target pattern.

Front interactions in a three component system

Peter van Heijster
CWI, Amsterdam, Netherlands

We analyze a particular three component reaction-diffusion equation. Using the Renormalization Group method, we derive a system of ODEs describing the intertaction of fronts in the semi-strong interaction regime. Finally, we study this system of ODEs.

Self-Organized Pattern Formation of Bacteria Colony

Joe Yuichiro Wakano
Meiji Institute for Advanced Study of Mathematical Sciences

Bacillus circulans colony produces an interesting pattern called knotted-branching pattern. Here we model the pattern formation by combining individual based model and continuous field dynamics denoted by reaction diffusion equation.

Periodic solution of the cylinder wake

Takeshi Watanabe
Graduate School of Natural Science and Technology,
Okayama University

The cylinder wake is investigated numerically by use of the spectral method. Steady and periodic solutions with the degree of freedom of O(10^4) are obtained by the application of the GMRes(k) method in combination with the calculation of fixed points of the Poincare section. It is found that we can even take the degree of freedom of O(10^6) by the efficiency of the method, although it depends on the convergence property of the phase space vector of the system.

Nonlocal Comlex Ginzburg-Landau equation as a model of single Dictyostelium discoideum cell

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Most eukaryotic cells move by locally protruding actin-rich pseudopods while retracting other regions of the cell body. During chemotaxis, cells are able to perceive the directions of chemical gradients and to use this information to guide migration. However, the details of how sensing and movement are coupled are still unclear. Most current models for eukaryotic chemotaxis involve the concept of a 'chemical compass', where localized intracellular signals at the point of highest receptor occupancy are analogous to a compass needle pointing towards the source of chemoattractant. In this poster, we suggest an alternative mechanism of chemotaxis with the dissipative structure's point of view. We propose that the Nonlocally coupled Complex Ginzburg-Laudau equation is the best model of regulation of Dictyostelium cell morphology.

Adaptive locomotion to friction change in one-dimensional modular robot

Tetsuya Yamamoto
Tokyo Metropolitan College of Industrial Technology (TMCIT)

We propose a one-dimensional modular robot model that autonomously adjusts a motion pattern to friction change. A module is composed of a nonlinear oscillator and two mass connected with damper, spring and actuator. The actuator generates a tension in proportion to the state variable of the nonlinear oscillator. One-dimensional modular robot is configured by modules that mechanically connected each other. We numerically demonstrate that the present model autonomously induces a vectorial locomotion and adjusts to friction change.

Effect of Conflicts and Turning on Pedestrian Outflow through an Exit

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In this paper, we have newly introduced the friction function and the turning function, and detailedly studied conflicts and turning, which affects the pedestrian outflow through an exit significantly, to analyze the effect of an obstacle in front of the exit. The validity of the extended model is verified by our experiments and it clearly explains the mechanism of the effect of the obstacle.

Spot Dynamics of Reaction-diffusion system in Heterogeneous Media

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In this research, we employ a three-component reaction-diffusion system which was proposed as a qualitative model of gas discharge phenomena and a jump heterogeneity is introduced to the kinetic parameter. One of the main issue is how the height, slope of heterogeneity influence behavior of traveling spot. Numerical analysis method is used to classify the underlying mechanism of the transition between various behaviors.