3. Program members and their research outlines

FY2009

Meiji University Global COE Program

Formation and Development of Mathematical Sciences Based on Modeling and Analysis

MODELING GROUP

Group Leader

Yasunori OKABE	KM2O -Langevin equation and its application to time series analysis
Masao MUKAIDONO	Study on Risk Assignment between Man and Machine in Ensuring Safety
Takeaki KARIYA	(1) Corporate bond pricing model and its applications (2) Department store brands, value-creating management, and value assessment (3) Environmental CSR and a self-recycling model
Hiroyuki MORI	Studies on Optimization, Forecasts, and Rule Extraction for Smart Grids
Ryo KOBAYASHI	Study on biotic morphogenesis and movement
Kaoru ARAKAWA	Audiovisual processing in consideration of human sensitivity —Deteriorated image restoration and aesthetic appearance improvement by interactive evolutionary computing—
Hiraku NISHIMORI	Elucidation of dynamics and functions of migratory element crowds
Tatsuo SHIBATA	Physical biology of cellular information processing and control of early development
Joe Yuichiro WAKANO	Elucidation of biological evolution by mathematical models

MATHEMATICAL ANALYSIS GROUP

Group Leader

Toshikazu SUNADA	Quantum walk —moving around in the quantum world—
Masayasu MIMURA	Mathematical analysis of self- organization
Hisao TAMAKI	Theoretical Foundation of Combinatorial Optimization and Application to Mathematical Sciences Based on Modeling and Analysis
Hirokazu NINOMIYA	Mathematics of diffusion/propagation phenomena and pattern structures

SIMULATION GROUP

Group Leader

Kanya KUSANO	Simulation of solar flare onset process
Kokichi SUGIHARA	Development of an art creation support system with an optical illusion effect incorporated: "you can become an Escher" project
Daishin UEYAMA	Elucidation of pattern formation mechanism observed in the chemical reaction precipitation system

GCOE RESEARCH FELLOWS

Kazuyuki NAKAMURA	Data-based inference and forecast: Data assimilation and nonlinear SSA
Kota IKEDA	Analysis of spatial patterns observed in reaction-diffusion systems
Chiyori URABE	Mathematical modeling, analysis and simulation of large-scale collective motions in ecosystem
Shu-ichi KINOSHITA	Impacts of the loop structure of gene network on the expression dynamics
Wataru NAKAHASHI	Theoretical Study of Evolution of Learning
Akiyasu TOMOEDA	From elucidation of jamming phenomena in traffic flow to mitigation of traffic jams
Shiro HORIUCHI	Theoretical/empirical study of community formation
Nobuhiko J. SUEMATSU	Spatio-temporal patterns generated by collective motion of both living and inanimate objects
Shin I. NISHIMURA	Simulation of cell migration

MATHEMATICAL ANALYSIS GROUP

Mitsuru KIKKAWA	Evolutionary Game Theory in financial market microstructure
Eiichi DOI	Empirical study of the national bond price estimation model using market date
Makoto TOHMA	Study on the spiral dynamic coexistence state of three competitive species
Tetsuji HIDAKA	Development of a method for measuring advertising effects using Design of Experiments and time series analysis
Jian ZU	Evolution of phenotypic traits in a predator-prey community

KM2O -Langevin equation and its application to time series analysis

Yasunori OKABE *Modeling Group Leader*

Position Title,Affiliated Department : Fellow, MIMS; Professor, School of Science and Technology, Meiji University

Specialized Field, Academic Degree : Stochastic Analysis and Time Series Analysis, Ph. D., Osaka University

Research Description · MMA of Time Series Data

Research Outline

(1) We held the "Time Series Analysis of Complex Phenomena" joint workshop at the Surugadai Campus bimonthly for five times since July to discuss the time series analysis of complex phenomena. I applied the dynamic Test (DYN) to the geophysical time series including viz. solar wind, magnetic storm, aurora, and earthquake, which is based on the KM2O -Langevin equation to investigate how the dynamic structures change before and after the occurrence of geophysical events. In particular, the locally nonlinear (6,2) dynamic function graph shows a characteristic that, of three-time auroras generated in a single event, while the graph fluctuates sharply before and after the first occurrence, the graph showed no changes in the fluctuation before and after the second and the third occurrence. In the next fiscal year, I wish to investigate other aurora events and to discuss with Professor Yumoto of Kyushu University, who is an expert in geophysical phenomena, to provide new findings to open issues regarding aurora dynamics.

(2) As a theoretical study of the KM2O -Langevin equation, I proved a theorem solving a nonlinear fluctuation-dissipation equation system forming between the covariance function and the fluctuation-dissipation systems, which are coefficients of KM2O -Langevin equation describing the local dynamics of continuous time normal stationary processes, given a covariance function. Further, I derived a time-delay second order elliptic partial differential equation by applying the Ito's rule to the above KM2O -Langevin equation. This equation corresponds to a second order elliptic partial differential equation incidental to a diffusive stochastic process and is a new finding in a stationary stochastic process.

(3) As an application of the KM2O -Langevin equation to the analytical number theory, I proved that the Riemann's zeta function satisfies the time-delay ordinary differential equation using the nonlinear fluctuation-dissipation equation system as described in paragraph (2) with attention to the fact that the Riemann's zeta function is a covariance function for continuous time normal stationary processes with reflection positivity. This is a noteworthy finding against the suggestion, which was made by Hilbert in association with Riemann's assumption at the Second International Congress of Mathematicians held in 1900 at Paris, that Riemann's zeta function does not satisfy an algebraic ordinary differential equation.

Study on Risk Assignment between Man and Machine in Ensuring Safety

Masao MUKAIDONO

Position Title,Affiliated Department : Deputy Director, MIMS; Professor, School of Science and Technology, Meiji University
Specialized Field, Academic Degree : Safety Study, Ph.D., Meiji University
Research Description : Modeling and Analysis on uncertainty systems

Research Outline

I am engaged in a study on safety in manufacturing focusing on "products" designed, manufactured, managed and used by human beings, or "manufacturing related safety". The study on safety entails consideration of the concept and definition of safety. First of all, safety needs to be defined quantitatively, reasonably, and objectively based on the risk concept. In addition, the consideration of safety through the "product safety" involves not only the aspect of technical production but also includes the organizations, institutions, and human psychology and behaviors, and thus it inevitably entails the finding of a common safety framework for a wide variety of fields including the safety in a broader sense, such as safety and prevention of crimes in urban areas, and, in an extreme case, the security field. In this fiscal year, I examined the comprehensive structures of safety as well as those conceptual aspects of safety (1).

In the modern society, various products and machines based on advanced technologies are wide spread at home, in workplaces, in communities, etc. While we enjoy the convenience of them, the safety of our life is threatened by frequent incidents. This study outlined the previous concepts of safety and safety technologies in Japan; outlined the accidents and liability issues and ideal accident investigation through examples of cases, which we general consumers and users consider as comfortable or uncomfortable, and of how they react to accidents based on a survey of global trends; and discussed the concepts and mechanisms required for products with risk and convenience to be accepted by the society as safe products with a service robot taken as an example (2).

On the other hand, as for the technical approach, I insisted that a new approach to prevention based on the international safety standards, ISO and IEC, is important and that safety should be ensured based on the policy of identifying and removing all the existing hazard sources in a scientific and engineering manner in advance, or on the risk assessment basis (3), and made a proposal, from this point of view, on the recent issues of vehicle recall and human interface problems, and so on (4).

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(1) Masao Mukaidono, Idea of Safety, science trends, Vol.14, No.9, pp.14-19, Science Council of Japan, 2009-9

(2) Masao Mukaidono, present-day issues and social acceptability of safety technologies, Journal of Japan Society of Precision Engineering, Vol.75, No.9, pp.1041-1044, Japan Society of Precision Engineering, 2009-9

(3) Kenji Sugihara, Masao Mukaidono, Basic Concept of Safety Design, Quality Control, Vol.39, No.4, pp.7-15, Japanese Society for Quality Control, 2009-10

(4) Masao Mukaidono, reconsider safety from users' viewpoint, chain of troubles—Alarm Invoked by the Recall of "Prius", Toyota Recall Issue Reporting Crew, Nikkei BP, pp.130-135, 2010-3

(1) Corporate bond pricing model and its applications
(2) Department store brands, value-creating management, and value assessment
(3) Environmental CSR and a self-recycling model

Takeaki KARIYA

Position Title,Affiliated Department : Fellow, MIMS; Professor, Graduate School of Global Business, Meiji University

Specialized Field, Academic Degree : Financial Technology, Ph.D., University of Minnesota, Kyushu University

Research Description : MMA of Finance

Research Outline

(1) Corporate bond pricing model and its applications

Continuing from last fiscal year, I furthered the formulation of a corporate bond model assuming a company with several business risks. In particular, I clarified the meaning of the model, indicated the difference between the corporate bond model and the mathematical finance model, and discussed the practicability of the proposed model in accordance with the model structure. For estimation problems, I proposed an optimized generalized least squares method given that the correlation matrix depends on the term structure parameters of the probability of default to be derived. In addition, I discussed the credit risk management and CDS pricing of banks.

(2) Department store brands, value-creating management, and value assessment

One of the characteristics of the business models of the department stores in Japan is the consignment system. In this report, the options obtained from this system will be recognized as important strategic options in the management to discuss the management problems in effectively using them. In particular, those options will be examined and analyzed from the perspective of the brand-value-creating management to discuss the ideal of the brand-related-value-creating ERM (enterprise risk management) and the value assessment method. I compared the department store business with the commercial real estate leasing business in terms of the evaluation method, and examined the brand's premium value with respect to the ideal of management based on the capitalization values of risk and return rooted in the consignment from the perspective of the comparison and with respect to the selection of product lineup portfolio from the perspective of brands.

(3) Environmental CSR and a self-recycling model

I examined the problems in the idea of the enterprise value creation process by exploiting their environmental CSR (Corporate Social Responsibility) as an intangible asset. I discussed the feasibility of a self-recycling model for a residue waste (biomass resource) generated in the production process of the soft-drink industry as a concrete example and formulated a quantitative model of using the biomass resource in the form of activated carbon. I further performed cost benefit analysis in implementation of this self-recycling model based on the above model and evaluated the value by simulation. I further analyzed the cost and benefit of implementing this self-recycling model and evaluated the value by simulation. The above analysis was performed assuming a case of Coca-Cola using only disclosed data to add a practical sense.

Studies on Optimization, Forecasts, and Rule Extraction for Smart Grids

Hiroyuki MORI

Position Title,Affiliated Department : Fellow, MIMS; Professor, School of Science and Technology, Meiji University

Specialized Field, Academic Degree : Intellectual Informatics, Ph.D., Waseda University

Research Description : MMA of Intelligent Systems

Research Outline

In fiscal 2009, I focused my study chiefly on the following issues relating to power distribution networks and power transmission networks under smart grid environment:

(1) Power distribution network extension program under smart grid environment

(2) Unit Commitment under smart grid environment

(3) Voltage stability analysis for power transmission network under smart grid environment

As for Issue (1), I studied a method of efficiently obtaining Pareto solutions by optimizing three multi-objective functions (new facility cost, power distribution network loss, electric power quality) to ensure an efficient networking plan in terms of the wind power generation unit's output, which is a renewable energy for the decentralized power source, and node loads under the smart grid environment with fluctuating probability. Given that the algorithm based on the conventional GA (Genetic Algorithm) cannot always obtain acceptable results with respect to the solution accuracy for global optimization and solution distributions for Pareto solutions, I studied on a MA (Memetic Algorithm) with GA and local search combined. In order to consider the uncertainty in the power distribution network such as the wind power generation unit and node loads, I studied on the evaluation of more frequent power distribution system extension planning patterns by conducting a Monte Carlo simulation (MCS). In addition, in order to enhance the convergence property of the solution of MCS, I applied a MCS in consideration of the correlations between designated values of nodes in the network and obtained acceptable results.

As for Issue (2) above, I proposed a hybrid metaheuristic method to solve the generator start/stop problem in 48 sections for 24 hours under the smart grid environment. It is known that the unit commitment is a mixed integer programming problem consisting of discrete and serial variables that cannot be easily solved by the conventional methods. Accordingly, I used the GRASP algorithm in this study to generate a viable solution for starting value, and devised a two-level metaheuristic method to solve the mixed integer programming problem. While the first layer is comprised of a TS (TabuSearch) to obtain the start/stop condition of the generator, the second layer is comprised of a PSO (Particle Swarm Intelligence) to obtain the generator output. In order to enhance the performance of the two-layer metaheuristic method, I took a strategy of introducing priority list TS and variable neighborhood for TS while introducing EPSO to make parameter adjustment adaptive in PSO, resulting in favorable results.

As for Issue (3) above, I studied a method of estimating a margin to the saddle node bifurcation point at a given neural network condition after generating learning data by obtaining a margin of voltage stability to a saddle node bifurcation point relative to the condition of transmission network for massive power generated at random from the continuation power flow calculation. In order to improve the estimate accuracy at the point, I classified the generated learning data into clusters by a data mining method, CART, and constructed artificial neural networks in each cluster. If-then rules for the network conditions were stored in each cluster to enable extraction of cluster characteristics.

Study on biotic morphogenesis and movement

Ryo KOBAYASHI   *Sub-leader of all researches*

Position Title, Affiliated Department	: Fellow, MIMS; Professor, Department of Mathematical and Life Sciences, Graduate School of Science, Hiroshima University
Specialized Field, Academic Degree	: Mathematical Modeling and Analysis, Ph.D., The University of Tokyo
Research Description	: Mathematical study of structure formation, locomotion and information processing of living organisms

Research Outline

Networks transporting people, goods, energy, and information such as railroad networks, road networks, power networks, telephone networks, and Internet need to meet several criteria including efficiency, cost, and robustness in a proper balance. Networks formed by organisms survived many years of natural selection and are thus expected to serve as a guide to the designing of a good network. We had a plasmodium of the true slime mould form a railroad network in the Tokyo metropolitan area to demonstrate formation of a network equivalent of (or, in some cases, larger than) the actual railroad network. In addition, we demonstrated that it is possible to design a network better than those formed by the slime mold or than the actual railroad network by using a mathematical model.

We mathematically modeled the motion mechanism of Amoeba proteus for posterior contraction. The simulation revealed that the constant speed movement switches to the rhythmic movement or vice versa with the tail movement speed as a parameter. The previous experiment had failed to selectively reproduce those two movement modes. However, this model predicted that the rhythmic movement will be reproduced by starving the slime mold to deactivate it and the prediction was demonstrated by experiment.

We collected snake movement data through the cooperation of Japan Snake Center. It was gradually revealed that snakes perform extremely advanced movements by using different movement modes depending on the condition and by sometimes mixing them. Along with the data collection, we constructed a mathematical model for snake movement and simulated it using an autonomous distributed control rule based on the discrepancy function.

We produced an ameboid robot to validate the effectiveness of the autonomous distributed control based on the discrepancy function. A simulation of the robot rushing into a narrow space revealed that an environment-dependent adaptive motor function will emerge with phasing performed spontaneously through the exploitation of long-distant interaction stemming from the law of conservation of protoplasmic mass despite the complete autonomous distributed control.

We proposed a mathematical model describing cleavage, the cleavage process of sea urchin egg in particular. The model was composed based on a hypothesis that the motion of the centrosome is controlled by two types of diffusive morphogens generated at the vegetal pole and the animal pole. The simulation could reproduce the results of normal cleavage and perturbative experiment up to the fourth cleavage including unequal cleavage. This result shows that the direction and the position of the cleavage plane can be controlled only by controlling the timing of morphogen generation at the two poles without assuming the complicated morphogen distribution.

Audiovisual processing in consideration of human sensitivity
－Deteriorated image restoration and aesthetic appearance improvement by interactive evolutionary computing－

Kaoru ARAKAWA

Position Title,Affiliated Department	: Fellow, MIMS; Professor, School of Science and Technology, Meiji University
Specialized Field, Academic Degree	: Image and Speech Processing, Ph.D., The University of Tokyo
Research Description	: MMA of Perception Systemss

Research Outline

I studied a new image processing system with consideration given to personal tastes and subjective evaluation.

More specifically, I proposed an image processing system that removes noise and sharpens images optimally based on human subjective views by interactive evolutionary computing and an image processing system that provides a human facial image with skin enhancement and processing to make the face look smaller to realize a near-ideal facial image. First of all, I proposed a method of designing nonlinear filter system, which effectively removes the impulsive noise superimposed on a color image, by interactive evolutionary computing. The impulsive noise superimposed on a picture signal can be removed by a median filter in general. In this case, however, image components will be deteriorated as well. One possible solution to this is to provide median filter processing only to the region, on which noise is superimposed, by obtaining the size of local characteristics of the noise superimposed images and by discriminating between the region with and without noise superimposition by the size. It is difficult, however, to accurately discriminate the noise superimposed region as various rules need to be applied to the region using several sizes of characteristics around the individual picture elements. In this case, numerous parameters representing complicated rules need to be optimally set. However, the parameters were difficult to be set optimally by the conventional methods. To cope with that situation, I demonstrated that the parameters can be optimally set effectively, in addition, in consideration of the human subjective evaluation against images, by introducing interactive evolutionary computing anew. The designing by interactive evolutionary computing was revealed as effective for removal of Gaussian white noise with relatively large amplitudes superimposed on picture signals as well, with acceptable processing properties obtained. On this occasion, it was revealed that human eyes tend to prefer clear images even with certain residual grain to blurred images.

As for facial images, I demonstrated that the face can be made look smaller as well as making the skin look smoother with more shading by emphasizing the brightness contrast, in addition to the removing of unnecessary uneven elements of the skin by a non-linear filter bank as previously studied by this researcher. I designed several parameters relating to this contrast intensity and the smoothness of the non-linear filter bank by interactive evolutionary computing and realized a system to enhance the skin and make the face look smaller in facial images with consideration given to human subjective evaluation and tastes.

In addition, I could realize the effective removal of impact noise from an acoustical signal by the unsteady wiener filter based on a mixture Gaussian model. Further, I proposed a method of effectively removing scratches from aged deterioration images by a window-selection median filter.

Elucidation of dynamics and functions of migratory element crowds

Hiraku NISHIMORI

Position Title,Affiliated Department : Fellow, MIMS; Professor, Department of Mathematical and Life Science, Graduate School of Science, Hiroshima University
Specialized Field, Academic Degree : Non-equilibrium Physics, Ph.D., Tokyo Institute of Technology
Research Description : MMA of Cooperative Phenomena

Research Outline

There are various types of crowds in the nature surrounding us. Familiar examples are a school of fish, a flock of birds, and swarm of insects. In addition, various collective motions are also found in the human society. For crowds of vehicles, crowds of pedestrians, and so on, the flow rate and the degree of traffic congestion are significantly involved with the productivity of the entire society. In addition, an isolated dune called barchan seriously damages artificial constructions such as roads and pipelines by moving in a crowd. Our study subject is to understand those collective motions through numerical experiments and analysis by setting up a mathematical model based on observations and experimental data. In fiscal 2009, we advanced our discussion focusing on the following three points:

1. Formulation and analysis of a particle cluster flow model using findings on insect chemotaxis and phototaxis.
2. Formulation of a new mathematical model to grasp the formation and movement of barchan/transverse dunes in a unified manner.
3. Mathematical analysis of the influence of fluctuations on the crowd dynamics.

As for Point 1, I have been studying on a mathematical model with the elements of pheromone secretion and attractants incorporated into the conventional mathematical model of the pedestrian flow in two-way traffic with a hint obtained from ant chemotaxis, in collaboration with Mr. Masashi Fujii et al. graduate students in the Doctoral Course, Department of Molecular Life Science, Mathematics, Hiroshima University. In fiscal 2008, I numerically demonstrated that action of pheromone controls traffic congestion in advance to improve the flow rate dependently on the pedestrian density and pheromone evaporation. In fiscal 2009, I demonstrated that the findings obtained up to last year are well construable by designating congested space domain as a "cluster" to represent the time evolution of the cluster size in the form of a Langevin equation. As a specific example, I demonstrated that the transition from non-congestion to congestion can be interpreted as a saddle-node bifurcation (for the congested cluster size). In addition, with regard to camphor collective motion in a annular water tank, I demonstrated that the transition from non-congestion to congestion occurs dependently on the density of camphor boats by setting up a mathematical model corresponding to the theory that showed a quantitative agreement, in collaboration with Dr. Nobuhiko Suematsu (Department of Molecular Life Science, Mathematics, Hiroshima University), a researcher of this GCOE, who is engaged in a study on the motion of camphor boats as a globally rare quantitative experiment of collective motion." In addition, I discovered a new collective motion mode (cluster mode) that does not fall under the category of the conventional traffic flow model.

As for Point 2, I derived a new simultaneous ordinary differential equation that deals with an isolated dune called "barchan" type, each of which moves almost independently, and a motion of dune called "transverse dune" with a long ridge extended in lateral direction, in a unified manner. Those study results were announced in a reviewed meeting minute in fiscal 2009.

As for Point 3, I advanced a study on a mathematical model for stochastic resonance of a system consisting of several elements in collaboration with Ryosuke Kawai et al., graduate students in the Master's Course at the Graduate School, Department of Molecular Life Science, Mathematics, Hiroshima University, and demonstrated by a neural mathematical model that neural response characteristics will be improved significantly by providing external signals with white noises in different sizes by elements.

Physical biology of cellular information processing and control of early development

Tatsuo SHIBATA

Position Title,Affiliated Department : Fellow, MIMS; Associate Professor, Department of Mathematical and Life Sciences, Graduate School of Science, Hiroshima University

Specialized Field, Academic Degree : Mathematical Life Science, Doctor of Philosophy, The University of Tokyo

Research Description : Modeling and analysis of the inner- and inter-cellular process

Research Outline

A cell is a very small system of the size around one to several dozen micrometers. Such a small system has enough capabilities necessary for a living organism, such as responding to changing environment and having memory of previous histories. With the development of experimental technique, more has become known about the dynamical processes of structural formation, information processing, and operation of functions within a cell. With the development of molecular biology, a vast amount of information has been accumulated about molecules and their reactions that constitute the cellular processes. In order to shed light on the mechanisms underlying dynamical processes of a cell, there is an increasing need for analyzing data, constructing mathematical models, and developing theories, which consolidate these pieces of information and apply knowledge of mathematical sciences to highly quantitative experiments in a comprehensive manner.

Recently, there have been many reports that spatiotemporal structural formation is promoted in a cell with mechanisms similar to the reaction-diffusion system. These include temporal oscillations, spatial patterns, and multistability, each of which is responsible for important functions in the respective contexts. As cell-level reactions are highly probabilistic these mechanisms for structural formation must be robust against stochastic noises. On the other hand, the mechanisms bring variability behaviors of a cell by amplifying the probabilistic nature of the elementary steps to the macroscopic level. The researcher is studying how these two seemingly contradictory features are made possible through analysis of fluorescent image data of a single cell and development and analysis of mathematical models. The underlying mechanism of a motile eukaryotic cell to be spontaneously polarized and to be motile is being gradually revealed from a mathematical perspective.

Embryogenesis is a process to activate the reaction program within a cell accurately to generate, from a single cell, many cells of various types and form structures that are spatially harmonious. The cell-level processes for gene expressions and protein functions are probabilistically fluctuating, and it is a big issue in developmental biology to identify the degree of fluctuations and mechanisms for controlling them. In order to approach this problem from both experiments and theories, a method for temporally monitoring functions of genes in the early stage of development has been developed for analysis jointly with the group of Professor Takashi YAMAMOTO in Department of Mathematical and Life Sciences, Graduate School of Science, Hiroshima University.

Elucidation of biological evolution by mathematical models

Joe Yuichiro WAKANO

Position Title,Affiliated Department : Fellow, MIMS; Associate Professor, Organization for the Strategic Coordination of Research and Intellectual Property, Meiji University

Specialized Field, Academic Degree : Mathematical Biology, Ph.D. (Science), Kyoto University

Research Description · MMA of Macrobiology and Ecosystems

Research Outline

Mankind has been attracted by the beauty, complexity, and fineness of organisms since olden times. Even after it was revealed that physical phenomena are not the will of the God but are capable of being explained by science, only biological phenomena was long recognized as a sacred domain that cannot be intellectualized. On the other hand, mankind knows that plants and livestock change their forms and natures by repeating selective breeding and has used it. What is important here is that changes of forms and behaviors are inherited to next generations. selective breeding is, in the language of today, genetic changes. It was Darwin who argued that, given the significant changes of genes over roughly several thousands of years by such artificial selective breeding, all the biological species existing today must be a result of natural selective breeding that occurred over longer period of time.

Darwin could not use mathematics to guarantee the logical correctness of his own theory. Verbal discussions always cause ambiguity or misunderstanding. As a matter of fact, Darwin's book "On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life" was repeatedly revised to respond to and argue against sharp criticism. Unlike the evolutionary biology in that period, the present evolutionary biology can guarantee the logical correctness by the mathematical power using a mathematical model for reasoning. We researchers can discuss the issue of evolution by dividing it into what the reality is (correlations between the mathematical model and reality) and how the model behaves (logical structure of the mathematical model, mathematical analysis).

I am engaged in both the formulation of a mathematical model based on the real phenomena and the analysis of the mathematical model itself. As this approach perfectly agrees with the philosophy of mathematical sciences based on modeling and analysis, I am advancing various studies in cooperation with researchers other than those in this COE. In this fiscal year, I presented a research paper on the evolution of cooperative behaviors in an ecological public utilities game of a two-dimensional world [1]. In addition, I conducted a mathematical study on evolution of generosity in a prisoners' dilemma game and on character phylogeny in a prey-predator system with an Allee effect. further, my research task "Unified Understanding of Two Major Theories of Biological Evolution," which was adopted as a JST pioneering project in 2009, is a theoretical study from a point of view that the inclusion fitness theory and the AdaptiveDynamics theory, which have been widely applied as mathematical models of evolution, may be understood in a unified manner from the perspective of mathematical models. I am committed to continuing my study in line with the philosophy of Mathematical Sciences Based on Modeling and Analysis—deepen the understanding of evolutionary phenomena by exploiting the mathematical power—while positively exchanging views with researchers in mathematical sciences.

[1] Wakano JY, Nowak MA & Hauert C (2009) Spatial Dynamics of Ecological Public Goods. Proceedings of National Academy of Sciences of the USA 106:7910-7914