Mathematical Modelling for Complex Systems and its Applications

Kazuyuki AIHARA

Institute of Industrial Science, University of Tokyo
4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan
E-mail: aihara@sat.t.u-tokyo.ac.jp

Abstract

In this talk, I will review our recent work on mathematical modelling for complex systems and its applications to biological and economical systems.

Keyword: complex systems, dynamical network biomarkers, mathematical engineering, biological and economical systems

1. Introduction

Mathematical Engineering is a discipline where mathematical models are built and theoretically analysed in order to understand, optimize, control, and predict real-world systems. Our FIRST (Funding Program for World-Leading Innovative R&D on Science and Technology) project entitled "Mathematical Theory for Modelling Complex Systems and its Transdisciplinary Applications in Science and Technology" [1] developed mathematical theory of modelling complex systems and its wide-ranging transdisciplinary applications in science and technology from the viewpoint of this mathematical engineering.

2. Mathematical Modelling for Complex Systems

We aimed not only to systematize methodology for modelling complex systems mathematically on the basis of advanced control theory of complex systems [2], complex networks theory, and nonlinear data analysis, but also to provide solutions for complex problems with high importance and urgency for society, such as treatment strategies for complex diseases like cancer and HIV [2], optimization and control of power grids, communication networks, and trafic flows, and development of novel nonlinear electronic technology such as chaos chips, neurochips, and AD converters based on β encoders [3].

3. Applications to Biological and Economical Systems

Recently, early-warnig signals anticipating critical transitions have been intensively studied for real-world systems in nature and society [4]. We have extended this concept to complex networks with a large number of nodes, especially biological complex networks, and formulated DNB(Dynamical Network Biomarkers) that can detect early-warning signals for a predisease state with a critical transition form a healthy state to a disease state [5]. We further generalize DNB to complex networks from which only point-process data can be observed, and explore a possibility to detect early-warning signals for large changes of economical data.

References

[1] FIRST, Aihara Innovative Mathematical Modelling Project supported by Japan Society for the Promotion of Science (JSPS), initiated by the Council for Science and Technology Policy (CSTP). http://www.sat.t.u-tokyo.ac.jp/first/en

[2] K. Aihara(Ed.): Theme Issue on Theory of Hybrid Dynamical Systems and its Applications to Biological and Medical Systems," Philosophical Transactions of the Royal Society A, Vol.368, No.1930 (2010).

[3] T. Kohda, Y. Horio, Y. Takahashi, and K. Aihara: "Beta Encoders: Symbolic Dynamics and Electronic Implementation," International Journal of Bifurcation and Chaos, Vol.22, No.9, 1230031-1-55 (2012).

[4] M. Scheffer, J. Bascompte, W.A. Brock, V. Brovkin, S.R. Carpenter, V. Dakos, H. Held, E.H. van Nes, M. Rietkerk, and G. Sugihara: "Early-warning Signals for Critical Transitions," Nature, Vol.461, pp.53-59 (2009).

[5] L. Chen, R. Liu, Z.-P. Liu, M. Li, and K. Aihara: "Detecting early-warning signals for sudden deterioration of complex diseases by dynamical network biomarkers," Scientific Reports, Vol.2, Article No.342, pp.1-8 (2012).