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Editorial

Complex bio rhythms

Akif Akgul[1,a], Marcelo A. Savi[2], Mustafa Zahid Yildiz[3], Miguel A. F. Sanjuan[4], and Jun Ma[5]

[1] Department of Computer Engineering, Faculty of Engineering, Hitit University, 19030 Corum, Turkey
[2] Center for Nonlinear Mechanics, COPPE - Department of Mechanical Engineering, Universidade Federal do Rio de Janeiro, P.O. Box 68.503, Rio de Janeiro, RJ, Brazil
[3] Department of Electrical and Electronics Engineering, Faculty of Technology, Sakarya University of Applied Sciences, 54050 Sakarya, Turkey
[4] Nonlinear Dynamics, Chaos and Complex Systems Group, Departamento de Física, Universidad Rey Juan Carlos, Tulipán s/n, Móstoles, 28933 Madrid, Spain
[5] Department of Physics, Lanzhou University of Technology, Lanzhou 730050, China

Abstract Complex biorhythms are characteristic of ubiquitous phenomena appearing in many disciplines of human knowledge. This Special Issue collects articles devoted to different complex biorhythms phenomena such as cardiac dynamics, Covid-19 dynamics, dynamics of neural networks, cell dynamics, and a few articles devoted to general methods. It furnishes a rich overview of the field and can stimulate and inspire further researches.

1 Introduction

In the past years, there has been a growing interest in the study of chaos and its applications, together with the development of technology [1–3]. The increasing development of our knowledge on chaos, fractals and nonlinear dynamics at large, allows one for a better understanding of the world around us, helping to explain numerous natural phenomena. As a matter of fact, fractals and chaotic phenomena are observed in galaxies, storms, trees, cell structures and even in our bodies. Much work has been carried out to improve our knowledge on how to detect them, and to analyze them in depth, as well as to find appropriate benefits for the humanity [4,5].

Truly, a nonlinear approach to nature shows a great variety of responses and, in some sense, defines characteristics of its biodiversity. A nonlinear dynamics perspective is of special interest for a proper understanding of natural rhythms that can represent the most striking manifestations of natural and biological system behaviors. Natural rhythms can be either periodic or irregular over time and space, where each kind of dynamical behavior may be related to both normal and pathological functioning. Maybe, the main power depends continuous supply of energy and energy exchange in and among nonlinear systems [6].

Nonlinear dynamics of biological systems have been investigated treating different approaches and perspectives, focused on distinct purposes. Accordingly, investigations can be related to the general comprehension of physiological functioning, pathologies, control and biomedical engineering applications. Modeling, numerical and experimental approaches are all employed in the analysis of complex biological rhythms. The main goal of this Special Issue was to present original research papers in complex biorhythms related to applied sciences and biomedical engineering applications.

The Special Issue presents a broad perspective about Complex Biorhythms, highlighting the nonlinear dynamics perspective for a better understanding of natural and biological systems.

The following complex systems give a general perspective about the subject, being classified as phenomena such as: cardiac dynamics; Covid-19 modeling; dynamics of neural networks; cell dynamics, cancer cells and beta-cells, including a few articles contributing to general methods. Each group contains several papers, providing a rich overview of the recent advances in this field of research. Furthermore, we believe that it will stimulate further research and inspiration on the topics to finally improve the knowledge on the area of biological complex rhythms.

2 Cardiac dynamics

Undoubtedly, cardiac dynamics is a topic of much interest as what concerns biological rhythms. Several papers are included in this topic. Sankararaman [7] introduces a novel method for detecting heart valve dysfunction early, showing normal (NM) and aortic stenosis (AS) murmur signals' phase portraits and power

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[a] e-mail: akifakgul@hitit.edu.tr (corresponding author)

spectral properties. Gu et al. [8] review the methods for strengthening the circadian rhythms (i.e., increasing the amplitude) of the SCN network based on the mathematical models, including the use of noise, heterogeneity in neural characteristics, and network structural heterogeneity. On the other hand, Cheffer and Savi [9] investigate the heart dynamics by considering a mathematical model that is built from three coupled nonlinear oscillators. The main strategy in this paper is to investigate a natural pacemaker behavior and see how it affects electrocardiograms, which show the electrical activity of the heart (ECGs). Another interesting approach is given by Stenzinger and Tragtenberg [10] by using a three-dimensional map-based membrane potential model in lattices to represent the heart muscle. Rojas-Vite et al. [11] perform the heart rate variability (HRV) of eight hypertension patients and eight normotensive persons using linear and nonlinear analyses. The authors show that the hypertensive group lost chaotic behavior, while the normotensive group had chaotic nature. Finally, Karatas et al. [12] study the design and implementation of arrhythmic ECG signals for biomedical engineering applications on FPGA. All these novel approaches are very interesting for complex applications.

3 COVID-19 modeling

Needless to say, epidemiological models have been a focus of interest for many years, and certainly its study has increased much due to the Covid-19 pandemics. A compilation of a group of papers dealing with different aspects of Covid-19 dynamics is presented in this Special Issue. Wang et al. [13] provide the contribution introducing complex behavior of a Covid-19's mathematical model. Their results show that for a certain set of parameters can be related to chaos. dos Reis and Savi [14] present a dynamical map to explain Covid-19 epidemics based on the standard susceptible-exposed-infected-recovered (SEIR) differential equations and incorporating the vaccinated population. Finally, Borah et al. [15] revisit the past plague epidemic (India) and compare with the Covid-19 pandemic based on fractional-order chaotic models and fuzzy logic control. Multiple rodent species exhibit chaotic dispersion and interaction coupling.

4 Dynamics of neural networks

A very relevant topic in biological rhythms is the dynamics of neural networks and this Special Issue presents a collection of papers. Rajagopal et al. [16] show how to assess time delays in a multi-layer lattice with asymmetric bidirectional layer coupling. The role of time delays on spiral wave turbulence suppression is addressed. Furthermore, Kaçar [17] introduces a new variable-order fractional chaotic neural network with frequency effect based on Hopfield Neural Network under Electromagnetic Radiation, which is used to model brain functions in the literature. The author designs a new data-hiding algorithm for multichannel biomedical signals with this new chaotic system. Díaz-Muñoz et al. [18] use the chaotic systems based on the Hopfield, Cellular, Aihara, and the Rulkov neural models to propose and implement on Raspberry Pi. It enables communication with a Machine to Machine (M2M) broker using the MQTT for IoT protocol. Another series of articles includes Hao and Yang [19] that develop mathematical model with bistability analysis for synaptic tagging and synapse-specific long-term facilitation in Aplysia. In another paper, Emiroglu [20] studies the control of chaos in the Hindmarsh–Rose biological neuron model using model predictive control (MPC). Furthermore, a model of a photosensitive and a thermosensitive neuron that are both controlled by optical signals and heat as the external exciter current is introduced in the paper by Tagne et al. [21]. And finally, Liu et al. [22] suggest a new memristive Radial Basis Function (RBF) neural network for training effectively tiny sample sets, which demonstrates strong power of global searching and great generalization ability in order to overcome the above difficulties.

5 Cell dynamics, cancer cells and beta-cells

Cell dynamics at large is another topic of interest as what concerns the objectives of this Special Issue. Chen et al. [23] study various bifurcations in the development of stem cells using a model based on Furusawa and Kaneko's hypothesis. There is another paper showing a machine learning approach, Pala et al. [24], where viability assays employing fractal dimensions of alive and dead cancer cells are designed, based on digital holographic microscopy and machine learning. The approach suggested in this paper is a new method for studying cell viability that has the advantages of high accuracy and laboratory application potential. The image segmentation algorithm based on neural networks has recently made significant progress in the field of medical image segmentation, but it still faces a number of challenges, including a small set of training sample data, a lack of background training data, poor network generalization ability, and poor network performance. Finally, Zambrano-Serrano et al. [25] introduce a mathematical model of a cluster composed of β-cells with different BEAs represented by a complex network of nearly identical nodes.

6 General methods

Under the term general methods, a collection of papers is included with a broad applicability. Ramakrishnan et al. [26] realize the analysis and field programmable gate arrays (FPGA) implementation of a resistive-capacitive-inductive shunted Josephson junction (RCLSJJ) circuit with topologically nontrivial barrier (TNB). The fractional incommensurate order of Van der Pol equations to explain the nonlinear dynamics of a biological system is investigated in Debbouche et al. [27]. Finally, the paper by Added et al. [28] focuses on the regulation of the complicated and rhythmic behaviors of the bipedal compass-type robot's passive dynamic walk.

Conclusions

The main contents of this Special Issue on complex biorhythms is briefly summarized, including topics describing phenomena such as cardiac dynamics; Covid-19 modeling; dynamics of neural networks; cell dynamics, cancer cells and beta-cells, where a few articles on general methods have been also included. Indeed, this Special Issue offers a rich perspective on some recent advances in the modeling of complex biorhythms. Also, it can throw lights on further investigations on the functional and biophysical oscillators, and potential mechanism can be discovered to clarify new phenomena in nonlinear systems. We believe that the topics and approaches presented here will contribute to the development of novel methods, stimulating and inspiring researchers with new perspectives for their future research efforts.

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