BioSystems 139 (2016) 1–11

Contents lists available at ScienceDirect

BioSystems

journal homepage: www.elsevier.com/locate/biosystems

Review Article

The system-resonance approach in modeling genetic structures

Sergey V. Petoukhov

Institute of Machines Studies, Russian Academy of Sciences, 101990 Moscow, Russia

ARTICLE INFO

Article history:
Received 24 September 2015
Received in revised form 29 October 2015
Accepted 1 November 2015
Available online 3 November 2015

Keywords:
Genetics
Resonances
Tensor product of matrices
Noise-immunity coding
Vibrational mechanics

ABSTRACT

The founder of the theory of resonance in structural chemistry Linus Pauling established the importance of resonance patterns in organization of living systems. Any living organism is a great chorus of coordinated oscillatory processes. From the formal point of view, biological organism is an oscillatory system with a great number of degrees of freedom. Such systems are studied in the theory of oscillations using matrix mathematics of their resonance characteristics. This study is devoted to a new approach for modeling genetically inherited structures and processes in living organisms using mathematical tools of the theory of resonances. This approach reveals hidden relationships in a number of genetic phenomena and gives rise to a new class of bio-mathematical models, which contribute to a convergence of biology with physics and informatics. In addition some relationships of molecular-genetic ensembles with mathematics of noise-immunity coding of information in modern communications technology are shown. Perspectives of applications of the phenomena of vibrational mechanics for modeling in biology are discussed.

Contents

1. Introduction

The idea about the structural pattern of the observed world, including living matter, on the basis of vibrations arises to Ancient China and Ancient India. Among many works about resonances in different systems, the theory of resonance of Linus Pauling takes an important place. His book (Pauling, 1940) about this theory in structural chemistry is the most quoted among scientific books of the XX century. Its first Chapter is titled «Resonance and chemical bond». The theory was developed to explain the formation of hybrid bonds in molecules. The actual molecule, as Pauling proposed, is a sort of hybrid, a structure that resonates between the two alternative extremes; and whenever there is a resonance between the two forms, the structure is stabilized. His theory uses the fundamental principle of a minimal energy because – in resonant combining of parts into a single unit – each of members of the ensemble requires less energy for performing own work than when working

E-mail address: spetoukhov@gmail.com

http://dx.doi.org/10.1016/j.biosystems.2015.11.001
0303-2647/

individually. Pauling claimed that living organisms are chemical in nature, and resonances in their molecules should be very essential for biological phenomena.

This study continues the approach developed by Pauling and his followers in applications to some single molecules, about an important role of resonances in living organisms. The new in the paper is a detection of crossing the world of genetic phenomena with the world of classical mathematics of resonance spectra of vibration systems with many degrees of freedom. On this basis, a unified mathematical approach is developed to the analysis of a number of systems of genetic coding and genetic phenomena. This approach reveals hidden relationships and regularities in these systems and leads to a new class of bio-mathematical models using matrices of resonances. These results support the feasibility of understanding the genetic system and genetic phenomena on the basis of mathematics of special systems of resonances. Energetic principles of biological organization are also under attention in this approach because frequency characteristics of vibro-systems are associated with energetics.

The proposed approach is correlated with the following situation in modern science. In the past century, science has discovered that the molecular basis of genetic coding (DNA structures, etc.) is identical in all species of organisms. A new understanding of life appeared: «*Life is a partnership between genes and mathematics*» (Stewart, 1999). All physiological systems of the body should be structurally coordinated with the genetic code for their reproductions in descendants to avoid extinction. It is obvious that unifying mathematical approaches are needed for the simulation of the genetic unity of different structures of organism. Every organism is endowed with the inherited ability to tune into resonances and to use resonances as carriers of information. Our speech and singing are examples of this because they use resonances of our voice apparatus, which is the oscillatory system with many degrees of freedom. According to the classics of structural linguistics (Roman Jakobson and others), our language did not come out of nowhere, but it is a superstructure over the oldest language – the genetic language (Jakobson, 1987, 1999; Petoukhov and He, 2010). This is one of the reasons to investigate the genetic system, including genetic alphabets, from the standpoint of mentioned mathematics of resonances.

The genetic coding has noise-immunity properties. According to Mendel's law of independent assortment, information from microworld of genetic molecules dictates macrostructures of living organisms, despite of strong noise and interference, through many independent channels (for instance, colors of hair, eye and skin are inherited independently from each other). This determinism is carried out by means of unknown algorithms of multi-channel noise-immunity coding. Consequently, every organism is an algorithmic machine of multi-channel noise-immunity coding.

To study this genetic machine it is advisable to use the theory of noise-immunity coding, which is based on the mathematics of matrices and which is used in engineering to solve similar problems. An example of this is the noise-immune transmission of high-quality photographs of the surface of Mars to Earth – on the base of mathematics of matrices – in conditions of strong distortions of carrier electromagnetic signals passing through millions of kilometers of interference. This is one of reasons for attention to the matrix analysis of structures of the genetic code, including an analysis of the possibility of using genetic systems of resonances for the transmission of hereditary information. The presented concept of resonance genetics brings together biology with physics and informatics since systems of resonances allow providing a reception and transmission of information (our inherited abilities of acoustic communication through speech and singing are examples of this). This study reveals that the molecular genetic ensembles are structurally related to known formalisms of the mathematical theory of noise-immunity coding of information (functions of Rademacher and Walsh, Hadamard matrices, etc.).

This study pays its main attention to matrices of vibrosystems since we analyze organism as a set of heritable systems of resonances. Vibration mechanics has many applications in engineering due to its phenomena of a resonant synchronization of oscillatory processes, vibratory separation and structuring of multiphase systems, vibro-transportation of substances, vibro-transmission of energy within systems and so on (Blekhman, 2000; Ganiev et al., 2015). Our results give a basis for wider use of these phenomena in modeling biological phenomena. They can also pull together genetics and quantum mechanics, which is based on taking into account frequencies and resonant characteristics of objects of the quantum-mechanical world.

2. Background

The background of this study includes well-known genetic and physiological phenomena, such as Mendel's laws, molecular structures of the genetic code and psychophysical Weber–Fechner law.

The main research method to study the mentioned phenomena is their mathematical modeling by means of classical mathematics of theory of oscillations, allowing analyzing the resonant characteristics of oscillatory systems with many degrees of freedom. Our unified approach on the basis of matrix representations of resonances allows to reveal hidden relationships in different genetic and inherited physiological phenomena, and to discover new possibilities of convergence of biology with physics and informatics.

2.1. Oscillatory processes and matrix representations of resonances

Any living organism is a great chorus of coordinated oscillatory processes (mechanical, electrical, piezoelectrical, biochemical, etc.), which are connected with their genetic inheritance along chains of generations. In the ontogenetic development of an organism from embryo to adult, the number of oscillatory processes in the chorus is greatly increased while maintaining their mutual consistency not only at each stage of development, but also at different stages. Since ancient times, chrono-medicine believes that all diseases are the result of disturbances in the ordered set of oscillatory processes.

From a formal point of view, a living organism is an oscillatory system with a great number of degrees of freedom. Theory of oscillations uses mathematics of matrices to study resonant characteristics of oscillatory systems with many degrees of freedom (see, e.g., Gladwell, 2004). We use matrices to study genetic phenomena.

Matrices possess a wonderful property to express resonances, which sometimes is called as their main quality (Bellman, 1960; Balonin, 2000, p. 21, 26). Physical resonance phenomenon is familiar to everyone. The expression $y = A^*S$ models the transmission of a signal S via an acoustic system A, represented by a relevant matrix A. If an input signal is a resonant tone, then the output signal will repeat it with a precision up to a scale factor $y = \lambda^*S$ by analogy with a situation when a musical string sounds in unison with the neighboring vibrating string. In the case of a matrix A, its number of resonant tones S_i corresponds to its size. They are called its eigenvectors, and the scale factors λ_i with them are called its eigenvalues or, briefly, spectrum A. Frequencies $\omega_i = \lambda_i^{0.5}$ (Gladwell, 2004, p. 61) are defined as natural frequencies of the system, and the corresponding eigenvectors are defined as its own forms of oscillations (or simply, natural oscillations).

These free undamped oscillations occur in the system in the absence of the friction forces in it and in the absence of external excitation forces. Behavior of the system in conditions of free