NEURAL CODE BASED ON CONCEPTS OF NONLINEAR DYNAMICS?

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Abstract

Neural science has been intersected and combined with nonlinear science for exhibiting nonlinear properties and behaviors of its objects studied. Neural coding is viewed as the measure and metric of neural activities in the field of bio-neural science. In this paper, based on the theory of nonlinear dynamics which has been applied to analyze the behaviors and mechanisms of the neural activities, the points of view and problems of the types and mechanisms of the neural coding using rigorous nonlinear dynamics concepts and theory are provided.

Felling information outside and adapting and affecting the circumstances are reached by nerve systems and exhibited the activities of nerves. In the field of neural science, it is paid much attention to how the information are transferred and processed in such situations, and the patterns of the interspike interval (ISI) sequence (spike trains) of a neuron and the assembly features of neurons caused by stimulus outside and inner physical and chemical activities and processes are regarded as a kind of neural coding. In the field of brain neural science, the neural coding is used to mean a measurement and metric of neuronal activity. Besides, the Shannon theory based on probability theory has also been introduced for considering neural coding.

Due to the consideration of that a lot of the behaviors and mechanisms of neural activities is found and revealed using the nonlinear dynamics theory, a question is presented: Does a system of neural coding based on rigorous concepts of nonlinear dynamics be constructed?

It is well known that the behavior and process of the firing activity of a neuron can be described as a dynamical system with a map form or ordinary differential equation form. Thus, from the viewpoint of nonlinear dynamics, two kinds of neural coding due to nonlinear dynamics of these systems can be provided: the neural coding which reflects the correspondence between stimulus and responses, and the neural coding which describes how to form the various and distinct behavior of the stimulus and response by simple dynamical element.

Different styles of the correspondences between the stimulus and the responses, which can describe that some characteristics of stimulus be exhibited in the responses, are:

Synchronization, Hodkin-Huxley neuron, and a pair of Locus Ceruleus neuron;

Mirror reflection, a pair of Locus Ceruleus neuron under excitation of Lorenz chaotic signal;

Integer multiple spiking of neural firing;

Bifurcation: bifurcation that leads to qualitatively distinct motions, presents capacities of neural coding, where the relations between stimulus and the responses are presented by

different styles before and after bifurcation;

Bursting firing;

Correlation between stimulus and response.

Coding styles exhibiting the characteristics and behaviors of dynamics of a neuron or the firing activities of a neuron can be indicated as:

Determination and stochastic;

ISI and IBI patterns of neuron firing;

Characteristic quantities of neural dynamics: Lyapunov exponents, entropy, fractal dimension;

Complexity, Kolmogorov complex bit number;

Mutual information and signal-noise ratio;

Period characteristic of orbits as a coding element;

Characteristics of unstable periodic orbit embedded in chaotic attractors as a coding element; For example, for plan phase portrait case, the detail differences of different chaotic attractors can be identified by the visiting times, numbers, and distributions of the unstable periodic orbits embedded in these chaotic attractors;

Unstable invariant saddle set as a coding element, which can induce dramatic changes in dynamical properties;

Symbol sequence defined as a coding element.

The concrete reasons and the examples for explaining above considerations are given.

Besides, there are two situations of coding: transient state and stationary state. For transient state, more techniques of data processing are needed. The effect of noise is important due to that the bifurcation, synchronization, and stochastic resonance can be induced by noise. The effects of synapse plasticity property are also needed to pay closely attention.

It is expected this consideration may be of some help to know and find the mechanisms of the transferring and processing of bio-neural systems.