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Book Review

Nonlinear Analysis for Human Movement Variability, edited by Nikolas Stergiou. Boca Raton, FL: CRC Press, 2016. 408 pages. ISBN: 1498703321.

This is an excellent book not only for those interested in human movements but for those interested in nonlinear phenomena more generally. The contributors are a number of specialists in human movement variability at the University of Nebraska at Omaha. Human movements show variability that can be quantified using nonlinear methods. Their nonlinear mathematical analyses are appropriate for studying the variability of the motor behaviors, which is important for assessing movement in health and disease.

In the introduction of the book, John McCamley and Steven J. Harrison refer to the nonlinear dynamical features to be found in complex biological systems such as human movement. They mention how dynamical systems began with the three-body problem of Henri Poincaré (1854-1912). Useful information can be gained about the dynamics of a system from phase-space geometry. A graphic is presented to show the correlations of dynamic, nonlinear and chaotic systems showing that all chaotic systems are nonlinear and that nonlinear systems are a particular form of dynamical systems. Detailed descriptions about deterministic versus stochastic, continuous versus discrete, linear versus nonlinear follow, which help to understand the basics. Then, description and plots as well as detailed descriptions of chaotic behaviors follow. Self-organization and especially the self-organization of human movement are described next because this is a basic characteristic of the human movement.

There are uncertainties related to the mechanisms that cause self-organization. The authors first refer to the Haken-Kelso-Bunz (HKB) model that is a dynamical model of motor coordination and describe the well-studied simple task of rhythmic coordination of two fingers of two hands of an individual. Moving the fingers with increased speed, the fingers spontaneously switch from an anti-phase to an in-phase coordination. This is the basis of research in self-organized human motor movements.

The next chapter by Sara A. Mayers describes the time series, i.e. a set or a sequence of observations recorded sequentially. The time series can be studied to produce information about the dynamics of a system. The author describes different patterns of time series, their meaning and investigation. The knowledge of time series evaluation is important for the interpretation of different systems including the dynamical systems. The explanations are simple with examples. Moving one step further, the next chapter by Shane R.

Wurdeman is related to state-space reconstruction. The important attractors of a dynamical system are described simply and in detail. First, with simple examples the transitions from two-dimensional objects to three-dimensional objects are shown, and the attractors in three-dimensional space are presented. The well-known Lorenz attractor is described and explained in detail including its three-dimensional plot. The transformation of a single sequence into a higher dimensional space gives increased information related to the behavior of the dynamical system, and this is described in detail with simple and clear examples and the proper methods for these transformations. The problems with finding an embedding dimension and a time lag are mentioned in more detail.

In the next chapter, Shane R. Wunderman discusses Lyapunov exponents. In the beginning of the chapter, the properties of the chaotic systems are discussed, which helps to understand the meaning of the Lyapunov exponent. Lyapunov exponents quantify the average exponential rates of divergence or convergence of nearby trajectories in state space. The largest Lyapunov exponent estimates the instability of the trajectories. The chaotic systems and deterministic chaos in biology, ecology, economy, engineering and medicine are described and the methods to detect and quantify chaos are mentioned. Details about the algorithms for calculating Lyapunov exponents are presented using simple descriptions and graphics. In particular the Wolf et al. as well as Rosenstein et al. algorithms are described and explained.

A helpful chapter by Sara A. Myers regarding surrogate data analysis follows. As the other chapters, the description is simple and understandable. This nonlinear tool is important to establish evidence of nonlinearity in a time series. The general principles of surrogation are explained along with graphical representations. Examples of researchers who have used the surrogates are presented as well as probe algorithms are explained. Surrogates are used to detect non-linearity in a time-series. The author shows that the surrogates alone cannot decide what dynamics the time series contains but help to do so. Entropy is explained in the next chapter by Jennifer M Yentes. The entropy began with thermodynamics, meaning a state function that quantifies the energy in a system that cannot be used to perform work. Entropy is fundamental for understanding and measuring the randomness of a system. Detailed description of methods of estimations are presented. Examples of the use of the approximate entropy metric for analysis of data generated by biological processes are presented such as in cardiology (analysis of heart rate variability), respiration (analysis of pseudo-periodic activity), endocrinology (study of regularity of hormone secretion), psychology and neuroscience (studies of electroencephalograms), and biomechanics of gait and posture (study of gait parameters during walking as well as postural control). The sample entropy metric that attempts to rectify some of the shortcomings of approximate entropy is described with use in cardiology, respiration, neuroscience, and biomechanics. The descriptions and examples of multiscale entropy are presented, followed by symbolic entropy as well as other entropy measures.

Fractals are described in chapter 7. Benoit Mandelbrot was the first to describe fractals, and since then many studies were produced with the help of this construct. Fractal analysis is also appropriate for studying the fluctuations of human movement data recorded over minutes, hours or days. This study produced new information related to the dynamics of the movements. Several examples are described from fractals in the nature, in movements as well as a health and wellness approach that is based upon fractal dynamics.

In chapter 8, Nathoriel H. Hunt describes autocorrelation functions, mutual information, and correlation dimensions in good detail. These metrics are, in turn, useful for the reconstruction of the state space. Additionally, the correlation dimension as a measure of dimensionality of a dynamical system is explained. In the next chapter, Anastasia Kyvelidou and Leslie M. Decker describe many case studies where nonlinear analysis is useful to study complex problems in human and animal movement variability. This chapter is particularly informative for not only for those who are working with the human movement but for everyone who can see the usefulness of nonlinear analysis in practical application.

Except the tasks the authors describe, we mention many case studies are presented by Anastasia Kyvelidou and Leslie M. Decker: postural control in children such as in ASD, multiple sclerosis, elderly participants, gait in peripheral arterial disease, in chronic obstructive pulmonary disease, in amputations, and in stroke. These examples are indicative of the usefulness of these analyses.

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