Multifractals and Chronic Diseases of the Central Nervous System

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Preface

"Neurodegeneration" corresponds to any pathological condition which primarily affects neurons. Neurological disorders not only affect the brain but also the nerves that are found throughout the body and spinal cord. Neurodegenerative diseases (NDDs) are defined as disorders that affect the central nervous system causing progressive dysfunction of the nervous system. These incurable and exhausting conditions are characterized by loss of neuronal cell function and are often associated with the deterioration of structures of the affected nervous system. Diagnosis of neurological diseases is a growing concern and one of the most difficult challenges for modern medicine. According to the World Health Organization's recent report, neurological disorders, such as epilepsy, Alzheimer's disease, Parkinson's disease, Huntington's disease (HD), stroke, and headache, to name a few, affect up to one billion people worldwide. An estimated 6.8 million people die every year as a result of neurological disorders.

The book primarily focuses on the study of different neurological disorders like epilepsy, Alzheimer's, Parkinson's, HD, and motor neuron diseases (MNDs) from a new perspective by analyzing the physiological signals such as EEG, EMG, ECG, and gait rhythm associated with these diseases using nonlinear dynamics.

Physiological signals such as heart rate, blood pressure, respiration, and stride intervals fluctuate continuously over time reflecting the complex regulation of these signals by the central nervous system. Analyzing the dynamics of these human physiological signals is an important area of research to help control and to be able to predict the onset of pathological conditions. Since long, several researchers have used different techniques, mostly linear, for studying various diseases, but, of late, research on nerve-related diseases or disorders has gained much importance as the world suffers a lot of deaths due to these progressive neuron diseases which are a slow and silent killer due to the lack of proper knowledge and appropriate medication. Since we have been working on various neurological disorders for more than 10 years, we decided to summarize our works and also the works of other researchers in this field in the form of a book.

Like every other system found in nature, physiological signals are also of complex character, as they are composed of many subsystems which are strongly correlated to each other, but not in a linear fashion. Conventional linear techniques like amplitude, root mean square, or Fourier analysis cannot provide detailed information about these subsystems. The development of nonlinear methods has significantly helped in studying complex nonlinear systems in detail by providing accurate and precise information about them. Nonlinear time series analysis methods enable the determination of characteristic quantities of a particular system solely by analyzing the time course of one of its variables. Thus, from this viewpoint, nonlinear time series analysis methods are superior to mathematical modeling, since they enable the introduction of basic concepts directly from the experimental data. Since works of several researchers have established the complex nonlinear character of physiological signals like EEG, ECG, EMG, and human gait rhythm, we have been motivated to use nonlinear techniques in our work.

In a nutshell, the book provides a comprehensive study on most of the neurological disorders with special emphasis on the methods used which are not only new but also rigorous and robust. The findings provide simple parameters for the diagnosis and prognosis of different neurodegenerative disorders, and adequate software can be developed which can easily be coupled with machines. The overall premise of the book for analyzing bioelectrical signals using nonlinear techniques is easily achievable and need of the day. The book will be easily accessible and useful to a very large community working in biomedical sciences and engineering.

We hope that this compilation of the original research work on the analysis of brain through fractal analysis will definitely provide a platform and a direction for inquisitive students and researchers of biomedical engineering and neuroscientists to think objectively on the premises. We also feel that this work will stimulate more exhaustive research on different other neurological disorders which are not commonly studied.

We are really happy that the leading publisher Springer Nature has accepted to publish the book. We sincerely thank the editors and all the other staffs of Springer Nature for their continual help, support, and suggestions.

Kolkata, West Bengal, India — Dipak Ghosh
Howrah, West Bengal, India — Shukla Samanta
Agartala, Tripura, India — Sayantan Chakraborty

Acknowledgment

We begin this acknowledgment section with Albert Einstein's philosophical thought:

> *Many times a day I realize how much my own outer and inner life is built upon the labors of my fellow men, both living and dead, and how earnestly I must exert myself in order to give in return as much as I have received.*

We would like to express our deepest appreciation to all brilliant authors, researchers, and doctors who have provided us with a wealth of wisdom in the domain of diseases of the central nervous system. We believe that the analysis of biomedical signal with a novel new approach yielding precise results has become possible due to a breakthrough idea of Mandelbrot introducing a new concept of "fractals." We take this opportunity to record our acknowledgment to Benoit Mandelbrot.

We would like to express our heartiest thanks to Springer Nature and the editors for their kind support and encouragement which have helped us in the completion of the book. We would also like to express our gratitude toward the reviewers for their kind cooperation and important suggestions which have helped to enrich the book. We also want to extend our thanks and appreciation to all the other staff members of Springer Nature for their continual support and suggestions.

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Prof. Dipak Ghosh a University Gold medalist and a Ph.D. in High Energy Physics, is currently an Emeritus Professor at Sir C.V. Raman Centre for Physics and Music, and Director (Hony.) of the Biren Roy Research Laboratory for Radioactivity and Earthquake Studies, Jadavpur University. Formerly, he was a Professor and Dean of the Faculty of Science, Jadavpur University. Prof. Ghosh has received several awards like the S.N. Bose Memorial Medal, C.V. Raman Award by the University Grants Commission, etc. in recognition of his in-depth research work. He was the Principal Investigator from India in projects with prestigious research institutes like CERN and FERMI Lab. He has over 500 publications in reputed international journals and several books to his credit. His research interests include nuclear and particle physics, nonlinear dynamics applied to biomedical problems, and neurocognition of music. He has also served as a reviewer for international journals like *Physical Review Letters*, *Physica A*, *EPL*, etc.

Dr. Shukla Samanta who holds a Ph.D. in Physics from Jadavpur University, is currently associated with Seacom Engineering College, Kolkata, as an Assistant Professor and Head of the Basic Science and Humanities Department. She holds a postgraduate degree in Physics from Presidency College, and an M.Tech. in Computer Science and Application from the University of Calcutta. She has published several papers on seismic activity, econophysics, and physiological systems in various peer-reviewed international journals. She has also served as a reviewer for international journals like Physica A, IJAV etc. Her current research interest is focused on the nonlinear study of different neurological disorders.

Mr. Sayantan Chakraborty is currently pursuing his Ph.D. in Electrical and Biomedical Signals at the Department of Instrumentation and Electronics Engineering, Jadavpur University. He completed his postgraduate degree in Electrical Power Engineering at the University of Calcutta. He has published several papers on electric bid prices, the Stock Exchange of India and biomedical signals in journals of international repute. He has also served as a reviewer for international journals such as *Physica A*, *IET Science*, *Measurement & Technology*, etc. Mr. Chakraborty is also an Assistant Professor and Head of the Department of Electrical and Electronics Engineering at ICFAI University, Tripura. He was previously affiliated with Dr. Sudhir Chandra Sur Degree Engineering College and Seacom Engineering College, Kolkata, as an Assistant Professor and Head of the Department of Electrical Engineering.

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