Modified Detrended Fluctuation Analysis (mDFA)

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Series Editors' Preface

Biomedical and Nanomedical Technologies (B&NT)
This **concise** monograph series focuses on the implementation of various engineering principles in the conception, design, development, analysis and operation of biomedical, biotechnological and nanotechnology systems and applications. The primary objective of the series is to compile the latest research topics in biomedical and nanomedical technologies, specifically devices and materials.

Each volume comprises a collection of invited manuscripts, written in an accessible manner and of a concise and manageable length. These timely collections will provide an invaluable resource for initial enquiries about technologies, encapsulating the latest developments and applications with reference sources for further detailed information. The content and format have been specifically designed to stimulate further advances and applications of these technologies by reaching out to the non-specialist across a broad audience.

Contributions to *Biomedical and Nanomedical Technologies* will inspire interest in further research and development using these technologies and encourage other potential applications. This will foster the advancement of biomedical and nanomedical applications, ultimately improving healthcare delivery.

To my wife, Keiko, and late wife, Etsuko

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Preface

Peng et al. invented detrended fluctuation analysis (DFA) in the 1990s as a method to quantify the scaling property of a biological signal. They analyzed data of heartbeat interval time series. Since then the DFA method has become popular in the field of basic research analyzing cyclic behavior. However, its clinical utility has not been established. In the 1990s, I was doing electrophysiology investigating the cardiovascular system of crabs and lobsters, but I did not have enough physical, mathematical, and computing knowledge to use DFA. Twenty years later, I met physicists, and then learned DFA. Now I can analyze heartbeats, owing to the development of personal computer. I tested DFA on my specimens and learned that my DFA distinguished between sick hearts and healthy hearts of invertebrate animals. I got an idea that the findings obtained from invertebrate animals might be applicable to humans.

What is DFA? This book does not describe physics and mathematics, but describes physiology and biomedical engineering. It shows empirical results from experiments applying DFA onto the heart of animal specimens and human subjects. Those who take this book into their hands expecting to find explanations of DFA theory will be disappointed. Again, this book does not intend to explain details of DFA. However, I hope it helps readers to make their own device that validates heart health. This book belongs to the disciplines of physiology and biomedical technology.

All data, electrocardiograms (EKG), are derived from the author's own recordings. FM-tape-analogue recordings helped log the data since the early 1990s, and thereafter, PC-digital recordings. Specimens' and subjects' life and health conditions behind each recording were all known. Registry data taken by other researchers were not used because their physiological backgrounds are unknown to me.

This book argues little about the following: (1) mathematical modeling, (2) mathematical prediction, (3) complexity theory, and (4) various aspects of statistical physics, for example, probability distribution function, Fourier analysis, self-similarity, Lyapunov exponent, fractal dimension, or determinism. It presents physiology of the heart and control of heartbeat. DFA is just an analytical tool, but a useful one.

The original idea behind Peng et al.'s DFA seems to have been derived from the field of physics. But there is very little in the whole field of DFA/fractal/physics that has entered pathology, medicine, biology, and technology at Peng et al.'s level yet. I hope that readers would get an idea of how to make their own DFA devices to suit to their own engineering requirements. DFA does not seem to be a well-established idea, unlike power spectrum analysis. But I would like to stress that DFA is a useful, practical technology. I hope this article inspires public discussion on the practical use of DFA because contradictory viewpoints are put forward through debate.

I would like to thank Dr. Nigel Hollingworth, ASME Press, for his support throughout this project, I would also like to thank Professor Taniguchi for reading and editing this manuscript. I am thankful to Dr. Tomoo Katsuyama and Mr. Katsunori Tanaka, both physicists, who have explained physics and DFA to me, as well as Dr. Yukio Shimoda, a medical physiologist, who has helped me with his detailed knowledge of invertebrate physiology, human cardiology, and electric-circuit engineering. Without long-term collaboration with these people, I could not have continued my DFA investigation.

Once again, this book is not designed to explain what DFA is, nor review hundreds of DFA publications. Empirical evidence in this book shows that DFA is powerful if it is properly used, even if the implications are not instantly recognized by all.

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Author Biography

Toru Yazawa is a biologist of invertebrate animals. A major focus of his research has been neurobiology of the cardiovascular system using electrophysiological and biochemical methods. He has experienced recordings of a crab's autonomic cardiac-nerve impulses and myocardial action potentials at both in-situ condition and isolated-heart conditions. His research experiences includes the following: 1985–1987: Division of Neuroscience, City of Hope Institute, Duarte, Los Angeles, CA, crayfish neuron research; and 1995 and 1997: Department of Biological Sciences, Department of Cardiology, Calgary University, BC, Canada, lobster cardiac muscle research. Toru Yazawa is currently an assistant professor of neurobiology at the Tokyo Metropolitan University, Tokyo, Japan. He has been an ASME member since 2006.

Abstract

The ultimate aim of this study is to make detrended fluctuation analysis (DFA) useful for everybody. It introduces a practical method for making a device that can check cyclic rhythm in nature, such as the heartbeat. This book presents empirical evidences revealed by a modified DFA (mDFA). A heartbeat-checking algorithm, DFA, was made by Peng et al. in the mid-1990s. However, the technique has not been incorporated in a device for practical use. With a view to creating a device DFA, mDFA was made by modifying Peng's DFA—and a former graduate student Katsunori Tanaka created the program under supervision of the author. To verify mDFA, hundreds of cyclic phenomena were studied and recorded.

Crustacean hearts have more than a 100-year history in biology and physiology. They are advantageous to conduct experiments such as isolated-heart electrophysiology. Crustacean hearts are thus good models for human hearts. DFA techniques are essentially just tools quantifying the state of the heartbeat and its control. This book does not describe details about DFA, but it does describe how mDFA works and it is useful for analyzing fluctuation of various cyclic behaviors such as heart movements. mDFA is a useful tool for studying the heart function in terms of biomedical technology, engineering and animal physiology.