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Series on Advances in Bioinformatics and Computational Biology – Volume 2

INFORMATION PROCESSING AND LIVING SYSTEMS

EDITORS Vladimir B Bajic & Tan Tin Wee

Imperial College Press

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INFORMATION PROCESSING AND LIVING SYSTEMS

Key Features

- Contains a systematic and comprehensive survey of biocomputing not existing in the current literature
- Provides a broad overview of bioinformatics with a number of novel bioinformatics applications that illustrate some of the principles of biocomputing
- A unique source of information on the biological/physiological background on the biological "computing" processes that are performed in living systems, including higher cognitive processes
- Shows how some of these computing examples in biology have found their way into useful computing applications such as genetic algorithms

Information processing and information flow occur in the course of an organism's development and throughout its lifespan. Organisms do not exist in isolation, but interact with each other constantly within a complex ecosystem. The relationships between organisms, such as those between prey or predator, host and parasite, and between mating partners, are complex and multidimensional. In all cases, there is constant communication and information flow at many levels.

This book focuses on information processing by life forms and the use of information technology in understanding them. Readers are first given a comprehensive overview of biocomputing before navigating the complex terrain of natural processing of biological information using physiological and analogous computing models. The remainder of the book deals with "artificial" processing of biological information as a human endeavor in order to derive new knowledge and gain insight into life forms and their functioning. Specific innovative applications and tools for biological discovery are provided as the link and complement to biocomputing.

Since "artificial" processing of biological information is complementary to natural processing, a better understanding of the former helps us improve the latter. Consequently, readers are exposed to both domains and, when dealing with biological problems of their interest, will be better equipped to grasp relevant ideas.

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Eds: Yi-Ping Phoebe Chen and Limsoon Wong

Vol. 2: Information Processing and Living Systems
Eds: Vladimir B. Bajic and Tan Tin Wee

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INFORMATION PROCESSING AND LIVING SYSTEMS

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Preface

This is a book on information processing by and information processing for living systems. It is about the Information of Life, of living computers and the human endeavour of computing life.

> "... No man is an island, entire of itself; every man is a piece of the continent, a part of the main. If a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friend's or of thine own were: any man's death diminishes me, because I am involved in mankind, and therefore never send to know for whom the bell tolls; it tolls for thee...."
> *Meditation XVII, John Donne (1623)*

All living systems reproduce after their kind to perpetuate their lineage. The offsprings inherit characteristics from both parents and the basis for this inheritance lies with genetic material, whether it is DNA for most unicellular or higher organisms, or RNA in some viruses.

From the genetic material inherited from the parents, the progeny must decode the information within the genetic material which then manifests as various traits that we observe amongst the great diversity of organisms in the living world. This involves information processing and information flow at the most fundamental level throughout the course of the organisms development and lifespan.

Organisms do not exist isolated, but interact with each other constantly within a complex ecosystem. The relationships between organisms such as those between prey or predator, host and parasite, mating partners, or amongst members of a colony of social insects, etc., are both complex and multi-dimensional. In all cases, there is constant communication and infor-

mation flow at many levels. Therefore it is important for us to appreciate that living systems need to compute and process information.

For example, the hottest area in microbiology today is quorum sensing in bacteria. How does a bacterium know how many of its kind is present in its surroundings before it can launch an attack successfully against a host? How does a cell calculate a density gradient and propel its motion towards a food source at the right speed without overshooting the target? How does transcription of DNA know when there is enough messenger RNA, and how does a ribosome know when to stop producing proteins? Where are the feedback loops and how is the regulation tied to the computation or sensing of how much is out there? How do biological systems calculate time - time to live, time to spawn, circadian rhythms and so on? How does the brain process information, count, sense time or store information in memory? How do living systems retain information and transmit it to the next generation? How do living systems share information with others? Thus our book focuses on information processing by life forms and the use of information technology to understand the wonder and fascination of living things.

Overview of the Book

Today, far too many books have been written about bioinformatics. Most of them are highly mathematical and emphasize the underlying mathematical principles and how they may be applied to biological data; or else, they take a superficial but practical approach towards processing and analyzing biological data, covering the so-called "how-to" approach. Few books come close to dealing with computing challenges and computing phenomena in nature, but none combines these with the complementary bioinformatics topics and useful bioinformatics applications. In this book we attempted to do so and we believe that the benefits to the reader will be multiple, going from a simple-to-grasp presentation, to sophisticated and innovative applications.

This book is organised into two major parts, focussing on Biocomputing and Bioinformatics. Both are facets of the information of life - the flow of information in life forms, as well as the use of information technology and computing to understand the mystery of living things.

In the first part, the first two chapters present a comprehensive overview of biocomputing. This constitutes the biocomputing part "Living Computers" that attempts to explain natural processing of biological information using physiological models and analogous models in computing.

The bioinformatics part "Computing Life" - deals with "artificial" processing of biological information as a human endeavour in order to derive new knowledge and insights into life forms and how they function. This part provides overviews of different bioinformatics topics and a glimpse of specific innovative applications for biological discovery as the link and complement to biocomputing.

Why are we putting these two domains together?
Artificial processing of biological information is complementary to natural processing, and by juxtaposing the two, we attempt to enhance our understanding of the natural processing by elucidating and discovering new relevant biological information in a way not commonly done in the literature today.

Our thesis is that a better understanding of the natural processing of biological information, as coming from the biocomputing part, helps us improve the way of processing biological information in deriving new knowledge and insights into life forms and how they function. Consequently, readers will be exposed to complementary domains and will be better equipped to grasp ideas of biocomputing and bioinformatics in tandem when dealing with the biological problems of their interest.

Overall, this book contains a systematic and comprehensive survey of biocomputing not existing in the current literature, and combines it with overviews of different bioinformatics topics complemented by a number of novel bioinformatics applications that illustrate some of the principles of biocomputing.

The book represents a unique source of information on the biological and physiological background against which biological "computing" processes are performed in living systems, including higher cognitive processes. It also shows how some of these computing exemplars in biology have found their way into useful computing applications, many of these applications useful in themselves for dealing with biological information. In particular, we focussed on representative, easy-to-read overviews complemented by a few illustrative applications in dealing with biological information in the bioinformatics realm.

The recent phenomenon of genomics, where large amounts of information stored in the genetic code of living organisms have been elucidated, the accompanying wave of proteomics, metabolomics, transcriptomics, systems biology and other newer 'omics, urgently calls for a quantum leap of advance in information processing needed for deciphering the meaning of

all this information in living systems. In dealing with this deluge, we hope that you will enjoy this ecletic combination of thoughts found in this book and take time out from the rush of the Internetised world today, to ponder over the intriguing issues raised in this book. Enjoy!

Vladimir B Bajic and Tin Wee Tan
September 2004
Singapore

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