Preface

The understanding of how the brain works and enables intelligence, memory, learning and control of behaviour has been perhaps the most desired knowledge that mankind seeks. Improved understanding of the working principles of the brain could lead to accurate diagnosis and cure of neural diseases including seizure disorders (such as epilepsy), movement disorders (such as Parkinson's disease), migraine, delirium and dementia (such as Alzheimer's disease), as well as design of efficient neural prosthesis, such as bionic eye, ear, tongue and nose, to overcome the effects of structural, biochemical and/or electrical abnormalities.

Neurophysiological studies are of paramount importance in revealing the underlying behaviours and properties of neurons, providing a good understanding of the nervous system. These studies have paved the way for the development of neuro-prosthetics and brain–machine interface (BMI) devices. For instance, intra-neuronal recordings from the primary motor cortex have been investigated to develop neural decoders that can eventually drive artificial prostheses or machines. The contribution of these studies in understanding neurological disorders, such as the use of intracranial electrodes to gather information pertaining to epileptic patients, has played a key role in developing new therapies. Indeed, extracellular cellular recording technologies have been employed to understand the influence of gamma-protocadherine, which regulates the endurance of a neural network and the generation of new synapses.

One of the common factors behind all the aforementioned neuroscientific breakthroughs is the ability to access inter- and intra-neuronal functionality and communication, so as to decipher the neural networks' collective behaviours without disrupting their natural functioning. Extracellular recordings are the preferred techniques to aid in neurophysiological studies, and the recordings can be mainly grouped into two categories: in vivo (invasive) and in vitro (non-invasive).

In this book, we have made an attempt to explore the emerging trends of neuroengineering technologies and neural computation techniques to provide a general insight of the current research advancements and future research directions in this domain. New technologies and techniques appear on a regular basis, giving rise to the need of a unified information source that could keep readers up to date with the advancements in this field. This book will serve as a great resource of information in addressing the current trends and future prospects in the fields of neuroengineering and neural computation.

The book is divided into two major parts: neuroengineering and neural computation. The neuroengineering part covers emerging technological trends and novel techniques to interact with the brain. The neural computation part covers a variety of computing models and techniques to decipher useful information processing capabilities of the human brain.

Neuroengineering is an emerging multidisciplinary field of research that is about using scientific methods to understand and model the nervous system, and to use this knowledge to engineer systems that interact with, augment, or mimic the functionality of the nervous system. The dynamics, biophysical mechanisms, and information processing capabilities of individual neurons are fairly well understood; however, a detailed collection of the facts concerning the functionality of single neuron is insufficient to explain that of a large neuronal network. A quantitative and scalable explanation of how large recurrent neuronal assemblies develop and learn is the unsolved problem, and has attracted a great deal of attention in recent years.

Chapters "CMOS-Based High-Density Microelectrode Arrays: Technology and Applications" and "Microelectrode Arrays: Architecture, Challenges and Engineering Solutions" of this book highlight the technology trends, which include the architecture, challenges and material solutions, in developing highly efficient micro/nano electrodes as well as neural interfacing technologies such as CMOS-based microelectrodes for high resolution recording of the brain activity. Chapters "Revolutionizing Causal Circuitry Neurostimulation Utilizing the Optogenetic Technique Through Advanced Microsystems Development" and "Physiological Monitoring in Deep Brain Stimulation: Toward Closed-Loop Neuromodulation Therapies" highlight the emerging trends in opto-genetics and deep brain stimulations, which have attracted paramount attention from the neuroscience communities in recent years. Opto-genetics involves the use of light to control cells in living neurons, whereas deep brain stimulations have proven useful in treating a variety of neurological disorders, such as Parkinson's disease, tremors, rigidity, stiffness, slowed movement, and walking problems. Chapter "Mechanism of Docosahexaenoic Acid in the Enhancement of Neuronal Signalling" presents the use of extracellular recording and analysis to explore the effects of chemical stimulations. Chapter "Insects Neural Model: Potential Alternate to Mammals for Electrophysiological Studies" highlights the potential of electrophysiological studies of insects' neural model as an alternate to mammals, employing neuroengineering and extracellular analysis techniques. Chapter "Synchronization Criteria for Delay Coupled Izhikevich Neurons" describes the neural functionality of the brain employing mathematical techniques and stability analysis of the presented model.

Neural computation covers computing models and techniques that represent the characteristics and functionalities of the human brain, particularly the biological nervous system. As part of machine learning, these computing models attempt to imitate the information processing capabilities of the human brain through the combination of simple computational elements, or known as neurons, in a highly interconnected system. Some of the key characteristics of neural computation include input–output mapping (supervised learning), nonlinearity, adaptability, parallelism, and fault tolerance. While research in neural computation has been in existence for a few decades now, this area still attracts the attention of many scientists and researchers owing to the intrinsic importance of understanding and imitating the capabilities of the human brain in information processing.

Chapter "Capturing Cognition via EEG Based Functional Brain Networks" highlights the use of transfer entropy to analyse multi-channel electroencephalography (EEG) data and to examine the dynamics of functional brain networks with respect to cognitive activities. Chapter "Modelling of Tumour-Induced Angiogenesis Influenced by Haptotaxis" describes a mathematical model to simulate the influence of haptotaxis on angiogenesis, which shows that that migration of endothelial cells can be accelerated when the invasive tumour enhances haptotaxis. Chapter "Noise Reduction in ECG Signals Using Wavelet Transform and Dynamic Thresholding" presents a noise reduction technique to process noisy electrocardiogram (ECG) signals. Wavelet transform and dynamic thresholding are used to reduce different types of noise such that a high signal-to-noise ratio could be produced.

Chapters "Development of a Co-evolutionary Radial Basis Function Neural Classifier by a *k*-Random Opponents Topology"–"Monotone Data Samples Do Not Always Generate Monotone Fuzzy If-Then Rules" describe research in data analytics problems using artificial neural networks and related methods. A competitive co-evolutionary radial basis function neural network is presented in Chapter "Development of a Co-evolutionary Radial Basis Function Neural Classifier by a *k*-random Opponents Topology". During the co-evolutionary process, individual networks interact with each other in an intra-specific competition, while global and local search procedures are exploited to find the optimal solutions. In Chapter "Mining Outliers from Medical Datasets Using Neighbourhood Rough Set and Data Classification with Neural Network", a modified neighbourhood rough set is used as a pre-processing method to select representative samples for training the radial basis function network. An enhanced functional link neural network for data classification is described in Chapter "A Modified Functional Link Neural Network for Data Classification". The genetic algorithm is employed to optimize the functional link neural network by performing both weight tuning as well as selection of expanded input features. Chapter "Experimental Study of Elman Network in Temporal Classification" evaluates the usefulness of the Elman neural network as a temporal data classifier. In Chapter "Monotone Data Samples Do Not Always Generate Monotone Fuzzy If-Then Rules", a technique to generate fuzzy if-then rules is described. The results indicate that a set of multi-attribute monotone data may lead to non-monotone fuzzy rules, which is in agreement with the observation obtained from the adaptive neural fuzzy inference system that has neural learning capabilities.

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Geelong, VIC, Australia Asim Bhatti
Rochester, MN, USA Kendall H. Lee
Atlanta, GA, USA Hamid Garmestani
Geelong, VIC, Australia Chee Peng Lim

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