

# Computational Intelligence in Biomedical Engineering



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# **Computational Intelligence in Biomedical Engineering**

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## *Dedication*

This book is dedicated to,

*My caring wife Dola, son Rashad and my parents*  
Rezaul K. Begg

*My lovely wife Carennie, my parents and family*  
Daniel T. H. Lai

*My supportive family and the healthcare workers of the world*  
Marimuthu Palaniswami

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## *Preface*

In recent years, there has been an explosion of interest in computational intelligence (CI) as evidenced by the numerous applications in health, biomedicine, and biomedical engineering. This book presents innovative developments in the emerging field of applied CI and biomedical engineering. We describe state-of-the-art applications that have benefited from the application of CI, including cardiology, electromyography, electroencephalography, movement science, and biomechanics.

Biomedical engineering is the application of engineering concepts and techniques to problems in medicine and healthcare. It is a relatively new domain of research and development consisting of subdisciplines such as bioinstrumentation, bioinformatics, biomechanics, biosensors, signal processing, medical imaging, and computing. Typical applications include design and development in prosthetics and medical instruments, diagnostic software, imaging equipment, and health-monitoring and drug delivery systems.

CI techniques are computing algorithms and learning machines, including artificial neural networks, fuzzy logic, genetic algorithms, and support vector machines. Most CI techniques involve establishing a nonlinear mapping between the inputs and outputs of a model representing the operation of a real-world biomedical system. Although CI concepts were introduced a few decades ago, impressive new developments have only recently taken place about theoretical advances. New theory has, however, led to a mushrooming in applications, in which input–output relations are too complex to be expressed using explicit mathematical formulations.

This book consists of eight chapters each with a specific focus. Following an overview of signal processing and machine-learning approaches, four application-specific chapters are presented illustrating CI's importance in medical diagnosis and healthcare. Chapter 1 is an overview of biomedical signals and systems; it discusses the origin of biomedical signals within the human body, the key elements of a biomedical system, and the sources of noise in recorded signals. The second chapter continues with an extensive overview of signal-processing techniques commonly employed in the analysis of biomedical signals and for improving the signal-to-noise ratio. Chapter 3 presents an overview of the major CI techniques.

Electrical potentials generated by the heart are recorded on the body's surface and represented using an electrocardiogram (ECG). The ECG can be used to detect many cardiac abnormalities. Chapter 4 concerns recent CI techniques that have been applied to the postprocessing of ECG signals for the diagnosis of cardiovascular diseases. This field is already well advanced and almost

every new CI technique has been tested on processed ECG data. Chapter 5 focuses on CI applications in electromyography (EMG), pattern recognition, and the diagnosis of neuromuscular pathologies that affect EMG-related signal characteristics. More recently, CI has also been applied to the control of myoelectric prostheses and exoskeletons. Of interest here is the combination of signal-processing and classifier systems to detect the user's intention to move the prosthesis. In Chapter 6, CI applications to bioelectric potentials representing brain activity are outlined based on electroencephalogram (EEG) recordings. CI approaches play a major role in EEG signal processing because of their effectiveness as pattern classifiers. Here we concentrated on several applications including the identification of abnormal EEG activity in patients with neurological diseases (e.g., epilepsy) and in the control of external devices using EEG waveforms, known as brain-computer interfaces (BCI). The BCI has many potential applications in rehabilitation, such as assisting individuals with disabilities to independently operate appliances. Chapter 7 provides an overview of CI applications for the detection and classification of gait types from their kinematic, kinetic, and EMG features. Gait analysis is routinely used for detecting abnormality in lower-limb function and also for evaluating the progress of treatment. Various studies in this area are discussed with a particular focus on CI's potential as a tool for gait diagnostics. Finally, Chapter 8 discusses progress in biomedical engineering, biomedicine, and human health areas with suggestions for future applications.

This book should be of considerable help to a broad readership, including researchers, professionals, academics, and graduate students from a wide range of disciplines who are beginning to look for applications in health care. The text provides a comprehensive account of recent research in this emerging field and we anticipate that the concepts presented here will generate further research in this multidisciplinary field.

**Rezaul K. Begg**  
**Daniel T. H. Lai**  
**Marimuthu Palaniswami**

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## *Abbreviations*

<b>Acronym</b>	<b>Definition</b>
AD	Alzheimer's disease
AEP	Auditory evoked potential
AIC	Akaike's information criterion
ADALINE	Adaptive linear networks
AMI	Acute myocardial infarctions
ANN	Artificial neural networks
ANFIS	Adaptive neurofuzzy system
A/P	Anterior–posterior
AR	Autoregressive model
ARMA	Autoregressive model with moving average
ART	Adaptive resonance theory
BCI	Brain–computer interface
BP	Backpropagation
CI	Computational intelligence
CP	Cerebral palsy
CV	Cross-validation
CVD	Cardiovascular disease
CHF	Congestive heart failure
CNV	Cognitive negative variation
CSSD	Common spatial subspace decomposition
ECG	Electrocardiogram
EMG	Electromyogram
EVP	Evoked potentials
FA	Fuzzy ARTMAP
FDA	Food and Drug Administration
FIR	Finite impulse response
FFT	Fast fourier transform
FPE	Final prediction error
FLD	Fisher's linear discriminant
GA	Genetic algorithm
GRF	Ground reaction forces
HD	Huntington's disease
HMM	Hidden Markov model
HOS	Higher-order statistics
IIR	Infinite impulse response
ICD	Implantable cardioverter–defibrillators
i.i.d	Independent and identically distributed
IIP	Intelligent information processing
KKT	Karush–Kuhn–Tucker optimality conditions
LS	Least squares
LDA	Linear discriminant analysis



LMS	Least mean squares
LS-SVM	Least squares support vector machines
LRM	Likelihood ratio method
LVQ	Learning vector quantization
MI	Myocardial infarction
ML	Maximum likelihood
M/L	Medio-lateral
MDL	Minimum description length
MOE	Mixture of experts
MRI	Magnetic resonance imaging
MTC	Minimum toe clearance
MUAP	Motor unit action potentials
MUAPT	Motor unit action potential train
NCS	Nerve conduction studies
NSR	Normal sinus rhythm
PSD	Power spectral density
PVC	Premature ventricular contraction
PSVM	Proximal support vector machines
QP	Quadratic programming or quadratic program
RLS	Recursive least squares
RBF	Radial basis function
ROC	Receiver operating characteristics
ROM	Range of motion
RNN	Recurrent neural networks
SA	Sinoatrial node
SEP	Somatosensory evoked potential
SMO	Sequential minimal optimization
SRM	Structural risk minimization
SVM	Support vector machines
SVR	Support vector regressor
VT	Ventricular tachycardia
VPB	Ventricular premature beats
VEB	Ventricular ectopic beats
VEP	Visual evoked potential

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## *Acknowledgments*

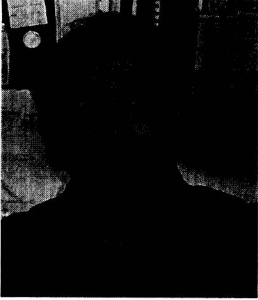
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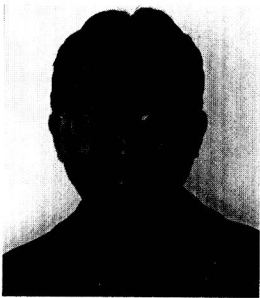
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## Authors



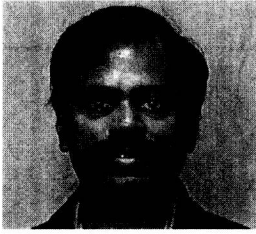
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