Body Sensor Networks

Guang-Zhong Yang
Editor

Body Sensor Networks

Second Edition

Springer

Editor
Guang-Zhong Yang, PhD
Director and Co-Founder, The Hamlyn Centre
Imperial College London
London, UK

ISBN 978-1-4471-6373-2 ISBN 978-1-4471-6374-9 (eBook)
DOI 10.1007/978-1-4471-6374-9
Springer London Heidelberg New York Dordrecht

Library of Congress Control Number: 2014937397

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Use body as the medium, inspiration and a source of energy to provide continuous sensing, monitoring and intervention

Since the first edition of this book, the field of Body Sensor Networks (BSNs) has advanced rapidly. The original motivation of BSN was to harness allied technologies that underpin the development of pervasive sensing for healthcare, wellbeing, sports and other applications that require "ubiquitous" and "pervasive" monitoring of physical, physiological, and biochemical parameters in any environment without activity restriction and behaviour modification. The ultimate aim of BSN is therefore to provide a truly personalised monitoring platform that is pervasive, intelligent and context-aware, yet "invisible", with applications ranging from managing patients with chronic disease and care for the elderly, to general well-being monitoring and performance evaluation in sports. To ensure its widespread use, there are many technical challenges that need to be tackled. These include the need for better sensor design, MEMS integration, biocompatibility, power source miniaturisation, low power wireless transmission, context awareness, secure data transfer and integration with smart therapeutic systems.

In this second edition of the book, we have updated the chapters with the latest developments in the field, addressing sensor design, micro-electronics and information processing aspects of the system. Since its inception, the development of BSN has been focussed on both wearable and implantable sensors. In the last few decades, we have seen rapid advances in both chemical and biosensor developments. The emergence of new biological sensing modalities is fundamentally changing the way we apply biomeasurements in vivo. In terms of implantable sensing, many of the issues associated with the extension of biosensor technology from in vitro to in vivo applications have long been appreciated, and a number of practical issues are addressed in this book. In a BSN with limited bandwidth and power constraints, the conventional method of data acquisition and analogue-to-digital data conversion with signal processing taking place after transmission is no longer optimal. A BSN represents a prime candidate for bio-inspired local processing to take place at the sensor front-end before transmission. This processing

could include spatial and temporal averaging for drift and failure tolerance. The key principle of bio-inspired engineering in this application area is that biology does not often deal in absolute values, but in relative changes from a given norm.

From a sensor data processing and inferencing point of view, the development of the BSN has introduced a whole range of challenging research issues in pattern recognition, behaviour profiling and machine learning. The pursuit of low-power, miniaturised, smart sensing embodied either as a wearable or implantable device has also imposed significant challenges on integrating information from what is often heterogeneous, incomplete and error-prone sensor data. In practice, it is therefore desirable to rely on sensors with redundant or complementary data to maximise the information content and reduce both systematic and random errors.

One important aspect of the book is the introduction of bio-inspired concepts both for hardware design and for developing software components that possess the self-* properties of autonomic sensing. We have discussed the use of artificial neural networks for performing context-aware sensing, and the use of autonomic principles of self-healing, self-organisation and self-protection for developing BSNs with effective fault tolerance and self-protection.

As mentioned in the first edition of this book, advances in science and medicine are intimately linked. In current clinical practice, ranging from prevention to complex intervention, we rely heavily on early, accurate and complete diagnosis followed by close monitoring of the results. Attempts so far, however, are still limited to a series of snapshots of physiological, biomechanical and biochemical data. Transient abnormalities cannot always be reliably captured. The concept of BSN is therefore an important ingredient for the future development of pervasive healthcare because technological developments in sensing and monitoring devices will not only change chronic disease management in a home or community setting, but also reshape the general practice of clinical medicine.

With demographic changes associated with the aging population and the increasing number of people living alone, the social and economic structure of our society is also changing rapidly. In a population consisting of several vulnerable groups, such as those with chronic disease and the elderly, the need for effective individualised health monitoring and delivery is the primary motivation for the development of BSNs. There is little doubt that for the development of the BSN, a panoply of technologies will need to be combined in new and previously unsuspected ways. However, the rewards for success, in terms of the quality and duration of life in the case of many of those suffering from chronic conditions, will be substantial.

There has been tremendous effort from all contributors of this book in making this 2nd edition possible. I would like to express my sincere thanks to all the contributing authors. Without their enthusiasm, support, and flexibility in managing the tight publishing schedule, this book would not have become possible. In particular, I would like to thank Su-Lin Lee, Emily Yang, Benny Lo, and Surapa Thiemjarus, for all their hard work in providing essential editorial support, as well as being actively involved in the preparation of some of the technical chapters. I would also like to thank the editorial staff of Springer, the publisher of

this volume. In particular, I am grateful to Helen Desmond and her colleagues in helping with the editorial matters.

This work would not have been possible without the financial support from all the funding bodies that supported our work, particularly the Engineering and Physical Sciences Research Council (EPSRC), UK. Their generous support has allowed us to establish and promote this exciting field of research – a topic that is so diversified, and yet brings so many challenges and innovations to each of the disciplines involved.

I do hope this book will act as a valuable resource to a very wide spectrum of readers interested in, or inspired by, this multifaceted and exciting topic.

London Guang-Zhong Yang
November 2013

About the Editor

Guang-Zhong Yang (PhD, FREng) is Director and Co-founder of the Hamlyn Centre, Deputy Chairman of the Institute of Global Health Innovation, Imperial College London, UK. Professor Yang also holds a number of key academic positions at Imperial College – he is Director and Founder of the Royal Society/ Wolfson Medical Image Computing Laboratory, co-founder of the Wolfson Surgical Technology Laboratory, Chairman of the Centre for Pervasive Sensing. He is a Fellow of the Royal Academy of Engineering (RAEng), fellow of IEEE, IET, MICCAI, AIMBE, IAMBE, City of Guilds and a recipient of the Royal Society Research Merit Award and The Times Eureka 'Top 100' in British Science.

Professor Yang's main research interests are in medical imaging, sensing and robotics. In imaging, he is credited for a number of novel MR phase contrast velocity imaging and computational modelling techniques that have transformed in vivo blood flow quantification and visualization. These include the development of locally focused imaging combined with real-time navigator echoes for resolving respiratory motion for high-resolution coronary-angiography, as well as MR dynamic flow pressure mapping for which he received the ISMRM I. I. Rabi Award. He pioneered the concept of perceptual docking for robotic control, which represents a paradigm shift of learning and knowledge acquisition of motor and perceptual/cognitive behaviour for robotics, as well as the field of Body Sensor Network (BSN) for providing personalized wireless monitoring platforms that are pervasive, intelligent, and context-aware. Professor Yang is a Distinguished Lecturer for IEEE Engineering in Medicine and Biology Society and Editor-in-Chief, *IEEE Journal of Biomedical and Health Informatics*.

Contents

Contributors

Javier Andreu-Perez The Hamlyn Centre, Imperial College London, London, UK

Omer Aziz The Hamlyn Centre, Imperial College London, London, UK

Anthony E.G. Cass Department of Chemistry and Institute of Biomedical Engineering, Imperial College London, London, UK

Timothy G. Constandinou Department of Electrical and Electronic Engineering, Imperial College London, London, UK

Jonathan M. Cooper School of Engineering, University of Glasgow, Glasgow, UK

David R.S. Cumming School of Engineering, University of Glasgow, Glasgow, UK

Ara Darzi The Hamlyn Centre, Imperial College London, London, UK

Joshua Ellul The Hamlyn Centre, Imperial College London, London, UK

Javier Espina Philips Group Innovation, Eindhoven, The Netherlands

Thomas Falck Philips Group Innovation, Eindhoven, The Netherlands

Paul A. Hammond Dialog Semiconductor, Edinburgh, UK

Henry Higgins Caldicot, Monmouthshire, UK

Xiaopeng Hu School of Computer Science and Technology, Dalian University of Technology, Dalian, China

Kamen Ivanov Institute of Biomedical and Health Engineering, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, PR China

Erik A. Johannessen Førsteamanuensis, Department of Micro- and Nanosystems Technology (IMST), Vestfold University College, Tønsberg, Norway

Christopher J. Johnson Department of Chemistry and Institute of Biomedical Engineering, Imperial College London, London, UK

Richard Kwasnicki The Hamlyn Centre, Imperial College London, London, UK

Thao T. Le Department of Chemistry and Institute of Biomedical Engineering, Imperial College London, London, UK

Benny Lo The Hamlyn Centre, Imperial College London, London, UK

Robert Merrifield The Hamlyn Centre, Imperial College London, London, UK

Paul Mitcheson Department of Electrical and Electronic Engineering, Imperial College London, London, UK

Oliver Mülhens Philips Group Innovation, Eindhoven, The Netherlands

Danny O'Hare Department of Bioengineering, Imperial College London, London, UK

Athanasia Panousopoulou The Hamlyn Centre, Imperial College London, London, UK

Institute of Computer Science, Foundation for Research and Technology – Hellas (FORTH), Heraklion, Crete, Greece

Lars Schmitt Philips Group Innovation, Eindhoven, The Netherlands

Leila Shepherd DNA Electronics Ltd, London, UK

Surapa Thiemjarus National Electronics and Computer Technology Center, Pathumthani, Thailand

Chris Toumazou Department of Electrical and Electronic Engineering, Imperial College London, London, UK

Jakub Trzebinski Department of Chemistry and Institute of Biomedical Engineering, Imperial College London, London, UK

Lei Wang Institute of Biomedical and Health Engineering, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, PR China

Guang-Zhong Yang The Hamlyn Centre, Imperial College London, London, UK

Eric Yeatman Department of Electrical and Electronic Engineering, Imperial College London, London, UK

Zhiqiang Zhang The Hamlyn Centre, Imperial College London, London, UK