

Contents

1	Introduction	1
	Guang-Zhong Yang, Omer Aziz, Richard Kwasnicki, Robert Merrifield, Ara Darzi, and Benny Lo	
1.1	Wireless Sensor Networks	1
1.2	BSN for Healthcare and Wellbeing	6
1.2.1	Monitoring Patients with Chronic Disease	7
1.2.2	Monitoring Hospital Patients	9
1.2.3	Monitoring Elderly Patients	11
1.2.4	Life Style and Wellbeing	12
1.3	The Need for Pervasive Health Monitoring	13
1.4	Technical Challenges Facing BSN	17
1.4.1	Improved Sensor Design	18
1.4.2	MEMS and BioMEMS	19
1.4.3	Biocompatibility, Integratability and Resorbability	21
1.4.4	Energy Supply and Demand	23
1.4.5	Wireless Data-Paths, Antenna Design, System Security and Reliability	29
1.4.6	Context Awareness	31
1.4.7	Integrated Therapeutic Systems	33
1.5	From Wellbeing to Personalised Healthcare	34
1.6	Finding the Ideal Architecture for BSN	36
1.7	The Future: Going from “Micro” to “Nano”	38
1.8	The Scope of the Book	42
	References	46
2	Biosensors and Sensor Systems	55
	Danny O’Hare	
2.1	Introduction	55
2.2	Bioanalysis	57
2.2.1	Some Jargon	57

2.2.2	Bioanalysis – What Does Chemical Concentration Mean in Biology?	59
2.3	Molecular Recognition	61
2.4	Electrochemical Sensors	65
2.4.1	Potentiometry	66
2.4.2	Amperometry and Voltammetry	79
2.4.3	Instrumentation	94
2.4.4	Signal Processing and Data Analysis	97
2.5	Multiple Sensors and Microsensor Arrays	99
2.5.1	Microelectrode Arrays for Primary Mammalian Cell Culture	101
2.5.2	Assessing Biocompatibility	102
2.6	New Materials	106
2.7	Future Perspectives and Research Challenges	108
	References	109
3	Biosensor Design with Molecular Engineering and Nanotechnology	117
	Thao T. Le, Christopher J. Johnson, Jakub Trzebinski, and Anthony E.G. Cass	
3.1	Introduction	117
3.2	Biomolecular Engineering for Biosensors	118
3.2.1	Engineering Proteins by Rational Design	118
3.2.2	Engineering Proteins by Evolutionary Design	121
3.2.3	Nucleic Acid Aptamers	121
3.3	Biosensor Applications	123
3.3.1	The Signal Transduction Module	124
3.3.2	The Molecular Recognition Module	125
3.3.3	Immobilisation Module	127
3.4	Nanotechnology	130
3.4.1	Miniaturisation and Scaling Laws: Nanoscale Devices and Performance Enhancements of Biosensors	131
3.4.2	Graphene	134
3.4.3	Nanoelectrochemical Sensors	136
3.4.4	Graphene Electrochemical Sensors	139
3.5	Biocompatibility and Implantable Biosensors	141
3.6	Conclusions	147
	References	148
4	Wireless Communication	155
	Henry Higgins	
4.1	Introduction	155
4.2	Inductive Coupling	156
4.3	RF Communication in the Body	157

4.4	Implanted Transceiver	159
4.5	Antenna Design	161
4.6	Antenna Testing	165
4.6.1	Antenna Impedance and Radiation Resistance Measurement	165
4.6.2	Quarter Wave Line Impedance Measurement	166
4.7	Matching Network	168
4.7.1	Transmitter Tuning	168
4.7.2	The L Network	170
4.7.3	The π Network	171
4.7.4	The T and $\pi - L$ Networks	172
4.7.5	Parasitic Effects	173
4.7.6	Network Choice	174
4.7.7	Radio Frequency Losses in Components and Layout Issues	175
4.7.8	Receiver Tuning	176
4.7.9	Base Station Antennas	177
4.8	Propagation	177
4.9	Materials	179
4.10	Environment	180
4.11	External Transceiver (Base Station)	180
4.12	Power Considerations	181
4.13	Miniaturised Construction	181
4.13.1	Battery Challenges	182
4.14	Defibrillation Pulse and X-rays	183
4.15	Link Budget	184
4.16	Electro-stimulation: A Non-MICS Example	184
4.17	Conclusions	187
	References	187
5	Network Topologies, Communication Protocols, and Standards	189
	Javier Espina, Thomas Falck, Athanasia Panousopoulou, Lars Schmitt, Oliver Mülhens, and Guang-Zhong Yang	
5.1	Network Topologies	189
5.2	Body Sensor Network Application Scenarios	192
5.2.1	Stand-Alone Body Sensor Networks	192
5.2.2	Pervasive Sensor Networks	195
5.2.3	Global Healthcare Connectivity	197
5.3	The Standardisation of Wireless Personal and Body Area Networking	198
5.3.1	The Wireless Regulatory Environment	199
5.3.2	Wireless Communication Standards	201
5.3.3	IEEE 802.15.1: Medium-Rate Wireless Personal Area Networks	202

5.3.4	IEEE P802.15.3: High-Rate Wireless Personal Area Networks	207
5.3.5	IEEE 802.15.4: Low-Rate Wireless Personal Area Networks	208
5.3.6	IEEE 802.15.6: Wireless Body Area Networks	215
5.3.7	Comparison of Technologies	220
5.4	Interference and Coexistence	222
5.5	Healthcare System Integration	225
5.5.1	ISO/IEEE 11073 Personal Health Device Communication	226
5.5.2	Continua Health Alliance	230
5.6	Conclusions	231
	References	232
6	Energy Harvesting and Power Delivery	237
	Eric Yeatman and Paul Mitcheson	
6.1	Introduction	237
6.1.1	Sensor Node Power Requirements	238
6.1.2	Batteries and Fuel Cells for Sensor Nodes	240
6.1.3	Ambient Energy Sources	241
6.2	Inertial Energy Harvesters: Principles and Performance Limits	242
6.2.1	Energy Extraction Mechanisms for Inertial Generators	242
6.2.2	Performance Limits	247
6.3	Inertial Energy Harvesters: Practical Examples	251
6.3.1	Electrostatic Harvesters	251
6.3.2	Electromagnetic Harvesters	256
6.3.3	Piezoelectric Harvesters	256
6.4	Power Electronics for Energy Harvesters	258
6.4.1	Electrostatic Harvester Interfaces	259
6.4.2	Electromagnetic Harvester Interfaces	260
6.4.3	Piezoelectric Energy Harvester Interfaces	261
6.5	Wireless Power Delivery	262
6.5.1	Near Field Inductive Power Transfer	263
6.5.2	Ultrasonic Power Delivery	266
6.5.3	Radiative Power Transfer	267
6.6	Discussion and Conclusions	268
6.6.1	What Is Achievable in Body-Sensor Energy Harvesting?	268
6.6.2	Future Prospects and Trends	269
	References	270

7	Towards Ultra-low Power Bio-inspired Processing	273
	Leila Shepherd, Timothy G. Constandinou, and Chris Toumazou	
7.1	Introduction	273
7.2	Bio-inspired Signal Processing	274
7.3	Analogue Versus Digital Signal Processing	275
7.3.1	Quantised Data/Time vs. Continuous Data/Time	275
7.3.2	Analogue/Digital Data Representation	276
7.3.3	Linear Operations	278
7.3.4	Non-linear Operations	278
7.3.5	Hybrid System Organisation	279
7.4	CMOS-Based Biosensors	280
7.4.1	Ion-Sensitive Field-Effect Transistor (ISFET)	282
7.4.2	ISFET-Based Biosensors	284
7.4.3	Towards Biochemically-Inspired Processing with ISFETs	286
7.4.4	An ISFET-Based ASIC for Rapid Point-of-Care Gene Detection	290
7.5	Future Outlook	294
	References	296
8	Multi-sensor Fusion	301
	Guang-Zhong Yang, Javier Andreu-Perez, Xiaopeng Hu, and Surapa Thiemjarus	
8.1	Introduction	301
8.1.1	Information Interaction	302
8.1.2	Levels of Processing	303
8.2	Direct Data Fusion	305
8.2.1	Optimal Averaging for Sensor Arrays	305
8.2.2	Source Recovery	307
8.3	Feature-Level Fusion	312
8.3.1	Feature Detection	314
8.3.2	Distance Metrics	315
8.3.3	Instance-Based Learning	316
8.3.4	Distance-Based Clustering	317
8.4	Dimensionality Reduction	320
8.4.1	Multidimensional Scaling (MDS)	321
8.4.2	Locally Linear Embedding (LLE)	322
8.4.3	Laplacian Eigenmaps	323
8.4.4	Isometric Mapping (Isomap)	324
8.5	Feature Selection	326
8.5.1	Feature Relevance	330
8.5.2	Feature Relevance Based on ROC Analysis	333
8.5.3	Feature Selection Based on ROC Analysis	335
8.5.4	Multi-objective Feature Selection	338
8.5.5	Feature Redundancy	341

- 8.6 Decision-Level Fusion 343
- 8.7 Methods for Computing with Large Datasets 345
- 8.8 Fusing Datasets in Parallel Using MapReduce 346
- 8.9 Alternatives and Beyond MapReduce 347
- 8.10 Conclusions 347
- References 350
- 9 Context Aware Sensing 355**
- Surapa Thiemjarus and Guang-Zhong Yang
- 9.1 Introduction 355
- 9.2 Application Scenarios 357
- 9.3 Preprocessing for Context Sensing 360
 - 9.3.1 Sources of Signal Variations 360
 - 9.3.2 Data Normalisation 361
 - 9.3.3 Information Granularity 362
- 9.4 Context Recognition Techniques 363
 - 9.4.1 Artificial Neural Networks (ANNs) 363
 - 9.4.2 Hidden Markov Models (HMMs) 373
 - 9.4.3 Factor Graphs (FGs) 380
 - 9.4.4 Other Techniques 383
- 9.5 From Context Sensing to Behaviour Profiling 385
 - 9.5.1 Behaviour Profiling 385
 - 9.5.2 Transitional Activities 387
 - 9.5.3 Concurrent and Interleaving Contexts 390
 - 9.5.4 A Distributed Inferencing Model for Context
Recognition 391
- 9.6 Conclusions 395
- References 397
- 10 Autonomic Sensing 405**
- Benny Lo, Athanasia Panousopoulou, Surapa Thiemjarus,
and Guang-Zhong Yang
- 10.1 Introduction 405
- 10.2 Autonomic Sensing 409
- 10.3 Fault Detection and Self-Healing 411
 - 10.3.1 Belief Networks 412
 - 10.3.2 Belief Propagation Through Message Passing 414
 - 10.3.3 Self-Healing with Hidden Node 420
- 10.4 Networking and Self-Organisation 424
 - 10.4.1 Medium Access Control Sub-layer 425
 - 10.4.2 Network Layer 431
 - 10.4.3 Application Layer 434
- 10.5 Security and Self-Protection 439
 - 10.5.1 Bacterial Attacks 439
 - 10.5.2 Viral Infection 442

10.5.3	Secured Protocols	444
10.5.4	Self-Protection	451
10.6	Conclusions	455
	References	456
11	Wireless Sensor Microsystem Design: A Practical Perspective	463
	Lei Wang, David R.S. Cumming, Paul A. Hammond, Jonathan M. Cooper, Erik A. Johannessen, and Kamen Ivanov	
11.1	Introduction	463
11.2	The Endoscopic Capsule	465
11.3	Applications for Wireless Capsule Devices	469
11.4	Technology	471
11.4.1	Design Constraints	471
11.4.2	Microsystem Design	472
11.4.3	Integrated Sensors	474
11.5	Electronics System Design	478
11.5.1	Analogue Electronic Front-End Acquisition Design	479
11.5.2	Digital System Design	481
11.6	Wireless Transmission	482
11.7	Power Sources	484
11.8	Packaging	487
11.9	Conclusions	489
	References	489
12	Wearable Sensor Integration and Bio-motion Capture: A Practical Perspective	495
	Zhiqiang Zhang, Athanasia Panousopoulou, and Guang-Zhong Yang	
12.1	Introduction	495
12.1.1	Optical Tracking Systems	495
12.1.2	Mechanical-Based Tracking Systems	497
12.1.3	Wearable Inertial-Sensor Based Tracking Systems	498
12.2	Orientation Representation: Quaternion	500
12.2.1	Quaternion Definition	500
12.2.2	Quaternion Algebra	501
12.2.3	Quaternion and Rotation Matrix	503
12.2.4	Quaternion Integration	505
12.3	Bayesian Fusion for Orientation Estimation	506
12.3.1	Bayesian Fusion Theory	507
12.3.2	Dynamic and Measurement Model	508
12.3.3	Kalman Filtering	510
12.3.4	Temporal Interference and Processing	513

- 12.4 Human Body Motion Reconstruction 515
 - 12.4.1 Human Biomechanical Model 517
 - 12.4.2 Posture Estimation 518
- 12.5 Applications of Bio-motion Analysis 519
- 12.6 Network and Quality-of-Service for Bio-motion Analysis 521
- 12.7 Conclusions 524
- References 524

- Appendix A: Wireless Sensor Development Platforms 527**
Benny Lo and Guang-Zhong Yang
 - A.1 Introduction 527
 - A.2 System Architecture 528
 - A.2.1 Processor 537
 - A.2.2 Wireless Communication 537
 - A.2.3 Memory 538
 - A.2.4 Sensor Interface 538
 - A.2.5 Power Supply 539
 - A.3 Conclusions 540
 - References 540

- Appendix B: BSN Software and Development Tools 543**
Joshua Ellul, Benny Lo, and Guang-Zhong Yang
 - B.1 Introduction 543
 - B.2 BSN Requirements and Issues 544
 - B.3 Operating Systems for BSNs 545
 - B.4 BSNOS – An Operating System for BSN 547
 - References 550

- Index 551**



<http://www.springer.com/978-1-4471-6373-2>

Body Sensor Networks

Yang, G.-Z. (Ed.)

2014, XX, 564 p. 246 illus., 113 illus. in color.,

Hardcover

ISBN: 978-1-4471-6373-2