

Conference Proceedings

*4th International IEEE EMBS Special Topic Conference on
Information Technology Applications in Biomedicine*

2003



"New Solutions for New Challenges"

24-26 April 2003

Birmingham, United Kingdom

Conference Chair & Co-Chair

Ronald Summers
Ewart Carson

Programme Chair & Co-Chair

Raouf Naguib
Robert Istepanian

Publications Chair

Rajeev Bali



Copyright © 2003 by The Institute of Electrical and Electronics Engineers, Inc. All Rights Reserved

Copyright and Reprint Permissions: Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For other copying, reprint or republications permission, write to IEEE Copyrights Manager, IEEE Operations Center, 445 Hoes Lane, Piscataway, New Jersey USA 08855-1331.

All IEEE Engineering in Medicine and Biology Society Conferences are peer-reviewed by a Technical Program Committee.

The papers in this book comprise the proceedings of the meeting mentioned on the cover and title page. They reflect the authors' opinions and, in the interests of timely dissemination, are published as submitted and without change. Their inclusion in this publication does not necessarily constitute endorsement by the editors, the IEEE Engineering in Medicine and Biology Society, or the Institute of Electrical and Electronics Engineers, Inc.

IEEE Catalog Number: 03TH8655
ISBN: 0-7803-7667-6
Library of Congress: 2002113322

Additional copies of this publication are available from:

IEEE Service Center
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331

Phone: (800) 678-IEEE
(732) 981-1393
Fax: (732) 981-9667
E-mail: customer.services@ieee.org



Table of Contents

	<u>Page</u>
<i>Editor's Notes</i>	<i>xi</i>
<i>Welcome from the Conference Chair</i>	<i>xii</i>
<i>Welcome from the Programme Chair</i>	<i>xiii</i>
<i>Conference Committees</i>	<i>xiv</i>
<i>Sponsors</i>	<i>xv</i>
<i>Keynote Speaker</i>	<i>xvi</i>
<i>Listing of All Papers</i>	
1.1.1 Bioinformatics, Genomics and Neuroinformatics	
Chair: Dr Elebeoba May, Sandia National Laboratories, USA	
1.1.1-1 <i>HPLC/ESI-MS Identification of Common Peptides in Amphibian Skin Secretions,</i> Zheng, H.; Ojha, P.; McClean, S.; Hutchinson, R.; Black, N. D.; Hughes, J. G.; Shaw, C. – University of Ulster, UK (60).	1
1.1.1-2 <i>Binding Motif Based Code Models for Prokaryotic Translation Initiation,</i> May, E. E.; Vouk, M. A.; Bitzer, D. L.; Rosnick, D. I. – Sandia National Laboratories and North Carolina State University, USA (100).	5
1.1.1-3 <i>Xiphoidal Sounds Analysis by the Way of Audio Signal Codings and Global</i> <i>Parameters Extraction,</i> Dellandrea, E.; Makris, P.; Boiron, M.; Vincent, N. – University of Tours, France (118).	9
1.1.1-4 <i>A Novel Biometric Approach in Human Verification by Photoplethysmographic</i> <i>Signals,</i> Gu, Y. Y.; Zhang, Y.; Zhang, Y. T. – The Chinese University of Hong Kong, China (142).	13
1.1.1-5 <i>Microarray Image De-Noising Using Stationary Wavelet Transform,</i> Wang, X. H.; Istepanian, R. S. H.; Song, Y. H. – Brunel University, UK (18).	15
1.1.1-6 <i>Improving Expression Data Mining through Cluster Validation,</i> Bolshakova, N.; Azuaje, F. – Trinity College Dublin, Ireland (14).	19

2.1.1	Mobile Healthcare Technologies Chair: Dr Robert Istepanian, Brunel University, UK	
2.1.1-1	<i>Clinical Validation of a Mobile Patient-Expert Tele-Echography System Using ISDN Lines</i> , Smith-Guerin, N.; Al Bassit, L.; Poisson, G.; Delgorge, C.; Arbeille, Ph.; Vieyres, P. – University of Orleans and University of Tours, France (25).	23
2.1.1-2	<i>Horizontal versus Vertical Development of the HCI in the Wardinhand Project</i> , Ancona, M.; Coscia, E.; Rubattino, C.; Megliola, M. – Università di Genova, Italy (46).	27
2.1.1-3	<i>3G Network Oriented Mobile Agents for Intelligent Diabetes Management: A Conceptual Model</i> , Li, M.; Istepanian, R. S. H.; Zou, Y.; Ibidun, K. – Brunel University and Orange Personal Communications Services Ltd, UK (13).	31
2.1.1-4	<i>An Ambulatory System to Quantify Bradykinesia and Tremor in Parkinson's Disease</i> , Salarian, A.; Russmann, H.; Vingerhoets, F. J. G.; Burkhard, P. R.; Blanc, Y.; Dehollain, C.; Aminian, K. – Swiss Federal Institute of Technology, Centre Hospitalier Universitaire Vaudois, and Hôpitaux Universitaires de Genève, Switzerland (61).	35
2.1.1-5	<i>Practical Evaluation of GPRS Use in a Telemedicine System in Cyprus</i> , Voskarides, S. Ch.; Pattichis, C. S.; Istepanian, R. S. H.; Michaelides, C.; Schizas, C. N. – Higher Technical Institute and University of Cyprus, Cyprus, Brunel University, UK, and Cyprus Telecommunication Authority, Cyprus (147).	39
2.1.1-6	<i>Wireless Telemedicine: The Next Step?</i> , Woodward, B. – Loughborough University, UK (114).	43
3.1.1	E-Health Internetworking and Home Healthcare 1 Chair: Dr Donna Hudson, University of California, San Francisco, USA	
3.1.1-1	<i>The Evaluation of Information and Communications Technologies in Health Care: The Role of a Multi-Dimensional Value Criterion Model</i> , Cramp, D. G.; Carson, E. R. – City University, UK (50).	47
3.1.1-2	<i>Implementation of a Home Monitoring Network for Patients with Congestive Heart Failure</i> , Alaoui, A.; Levine, B. A.; Beauchene, P.; McAlinden, E. M.; Hu, M. J. T.; Choi, J.; Welsh, J. C.; Mun, S. K. – Georgetown University and Georgetown University Medicare Demonstration Project, USA (136).	51
3.1.1-3	<i>Connect Nodes of the Patient Informing Process to Conventional Software Modules for Supporting the Doctor Patients Relation</i> , Gerlach, K.; Kaeding, A.; Henning, G.; Kottmair, S. – Technische Universität Ilmenau, Germany (31).	55
3.1.1-4	<i>Development of an Online Database System for Remote Monitoring of Artificial Heart Patient</i> , Choi, J.; Kang, W. Y.; Chung, J.; Park, J. W.; Lee, H. S.; Min, B. G. – BIOMEDLAB Co. and Seoul National University, South Korea (126).	59

3.1.1-5	<i>The Role of Information Technology in Disease Management</i> , Hudson, D. L.; Cohen, M. E. - University of California and California State University, USA (90).	169
3.1.1-6	<i>Telediagnostic Platform for Uterus Cancer Risk Diminution in Mexico</i> , Montesinos, L.; Puentes, J.; Parra, A.; Solaiman, B.; Roux, C. - Instituto Tecnológico y de Estudios Superiores de Monterrey, México, Ecole Nationale Supérieure des Télécommunications de Bretagne and INSERM-ERM, France (38).	66
3.2.1	E-Health Internetworking and Home Healthcare 2 (Posters)	
3.2.1-1	<i>An Intelligent System for the Provision of Personalized Dietary Plans and Health Monitoring</i> , Antoniou, I.; Nanou, T.; Fotiadis, D. I.; Likas, A. - University of Ioannina and Biomedical Research Institute, Greece (79).	70
3.2.1-2	<i>Medical Signal Transmission and Analysis Based on Internet</i> , Ma, Z.; Ng, N. F. - Singapore Polytechnic, Singapore (39).	74
3.2.1-3	<i>Intelligent Monitoring of Elderly People</i> , Tablado, A.; Illarramendi, A.; Bermúdez, J.; Goñi, A. - University of the Basque Country, Spain (58).	78
3.2.1-4	<i>An Internet-Based Cycle Ergometer System by Using Distributed Computing</i> , Wang, Z.; Shibai, K.; Kiryu, T. - Niigata University, Japan (35).	82
4.2.1	Clinical Knowledge Management (Posters)	
4.2.1-1	<i>Framework of a System for the Management and Assistance in Analysis of Medical Images</i> , Pereira, J.; Castro, A.; Arcay, B.; Pazos, A.; Gomez, A. - University of A Coruna, Spain (135).	86
4.2.1-2	<i>Technology Assisted Health Care - An Information Based Approach</i> , Clarke, M.; Jones, R. W. - Brunel University and Chorleywood Health Centre, UK (115).	157
5.1.1	Education and Training Methodologies Chair: Dr Semahat Demir, University of Memphis, USA	
5.1.1-1	<i>Medical Physics E-Learning Training Materials</i> , Tabakov, S.; Roberts, V. C.; Jonsson, B.-A.; Ljungberg, M.; Milano, F.; Lewis, C.; Strand, S.-E.; Lamm, I. L.; Riccardi, L.; Benini, A.; Teixeira, N.; Pascoal, A.; Litchev, A.; Noel, A.; Smith, P.; Musilek, L.; Sheahan, N. - King's College London, UK, and EMERALD Consortium (107).	94
5.1.1-2	<i>CITATION: Semantics-Based Information Modeling for the Healthcare Administration Sector</i> , Sakellaris, G. C.; Anagnostakis, A. G.; Tzima, M.; Fotiadis, D. I.; Likas, A. - University of Ioannina and Biomedical Research Institute, Greece (55).	98

5.1.1-3	<i>Evaluation of Use of Information Technology for the Benefit of Individuals with Spinal Cord Injury</i> , Magjarevic, R.; Jaksic, M.; Bilas, V.; Summers, R. – University of Zagreb, and General Hospital "Sveti Duh", Croatia, and Loughborough University, UK (150).	102
5.1.1-4	<i>Simulation-Based Education and Training Resource: ICELL</i> , Demir, S. S.; Velipasaoglu, E. O. – University of Memphis and University of Tennessee, and Enkata Technologies, USA (141).	106
6.1.1	Advances in Digital Hospitals and EHR/EPR Issues Chair: Dr Rajeev Bali, BIOCORE (Coventry University), UK	
6.1.1-1	<i>Specialized Telepathology Electronic Patient Record Based on JPEG 2000</i> , Montesinos, L.; Puentes, J. – Instituto Tecnológico y de Estudios Superiores de Monterrey, México, Ecole Nationale Supérieure des Télécommunications de Bretagne, and INSERM-ERM, France (36).	110
6.1.1-2	<i>Towards a Practical Healthcare Information Security Model for Healthcare Institutions</i> , Dwivedi, A.; Bali, R. K.; Belsis, M. A.; Naguib, R. N. G.; Every, P.; Nassar, N. S. – BIOCORE and DKERG (Coventry University), and Biotech Associates Ltd, UK (111).	114
6.1.1-3	<i>Use of XML Technology in a Virtual Patient Record Infrastructure</i> , Berler, A.; Konnis, G.; Pavlopoulos, S.; Karkalis, G.; Sakka, E.; Koutsouris, D. – National Technical University of Athens, Greece (59).	118
6.1.1-4	<i>A Secure Identification Access Control Scheme for Accessing Healthcare Information Systems</i> , Chao, H. M.; Twu, S. H.; Hsu, C. M. – De-Lin Institute of Technology, and Chung Yuan Christian University, Taiwan, China (77).	122
7.1.1	Multimedia, Virtual Reality, Visualization and Advanced Imaging 1 Chair: Professor Guang-Zhong Yang, Imperial College of Science, Technology and Medicine, UK	
7.1.1-1	<i>Intra-Ventricular Blood Flow Simulation with Patient Specific Geometry</i> , Long, Q.; Merrifield, R.; Xu, X. Y.; Kilner, P. J.; Firmin, D.; Yang, G. Z. – Imperial College of Science, Technology and Medicine, and Royal Brompton Hospital, UK (66).	126
7.1.1-2	<i>High Speed Technique for Automatic Guidance of Micro-Robotics in Endoscopic Procedures</i> , Lim, C. S.; Tian, H.; Sadana, G.; Srikanthan, T. – Nanyang Technological University, Singapore, and Indian Institute of Technology, India (43).	130
7.1.1-3	<i>Reconstruction of 3D Deformation from 2D MR Velocity Mapping with Incompressibility Constraints</i> , Gao, J. X.; Masood, S.; Deligianni, F.; Yang, G. Z. – Royal Society/Wolfson Foundation Medical Image Computing Laboratory and National Heart and Lung Institute, Imperial College of Science, Technology and Medicine, UK (99).	134
7.1.1-4	<i>Ultrasound Image Quality Evaluation</i> , Loizou, C.; Pattichis, C. S.; Istepanian, R. S. H.; Pantziaris, M.; Kyriakou, E.; Tyllis, T.; Nicolaidis, A. – Intercollege, University of Cyprus, Institute of Neurology and Genetics, Cyprus, and Brunel University, UK (146).	138

7.2.1	Multimedia, Virtual Reality, Visualization and Advanced Imaging 2 (Posters)	
7.2.1-1	<i>Virtual Reality Extensions into Surgical Training and Teleoperation</i> , Barnes, B. L.; Menon, A.; Mills, R.; Bruyns, C.; Twombly, A.; Smith, J.; Montgomery, K.; Boyle, R. – NASA Ames Research Center and National Biocomputation Center, USA (29).	142
7.2.1-2	<i>A Real-Time Hand Tracking and Multimedia-Based System for Breast Self-Examination: The Simplified 3D Hand Model</i> , Hu, Y.; Naguib, R. N. G.; Todman, A. G.; Amin, S. A.; Oikonomou, A.; Alomishy, H. – BIOCORE (Coventry University) and Walsgrave General Hospital, UK (124).	146
7.2.1-3	<i>Preprocessing and Segmentation of Brain Magnetic Resonance Images</i> , Shen, S.; Sandham, W.; Granat, M. – University of Strathclyde, UK (42).	149
7.2.1-4	<i>Computer System for Three-Dimensional Anatomic-Physiological Correlation during Stereotactic and Functional Neurosurgery</i> , Tejeiro, J.; Macías, R. J.; Morales, J. M.; López, G.; Alvarez, L. M.; Maragoto, C. – International Neurological Restorative Center, Cuba. (131).	153
8.2.1	Integrated-Care Pathways (Posters)	
8.2.1-1	<i>Clinical Knowledge Management for Healthcare</i> , Dwivedi, A.; Bali, R. K.; Naguib, R. N. G.; Nassar, N. S. – BIOCORE (Coventry University) and Biotech Associates Ltd, UK (110).	90
8.2.1-2	<i>Using XML and Controlled Vocabularies to Achieve Unambiguous Knowledge Acquisition from Multiple Heterogeneous Medical Data Sources</i> , Kontaxis, K. M.; Sakellaris, G. C.; Fotiadis, D. I. – University Of Ioannina and Biomedical Research Institute, Greece (78).	161
9.1.1	Intelligent Systems in Diagnosis, Prognosis and Patient Management 1 Chair: Dr Adel Elmaghraby, University of Louisville, USA	
9.1.1-1	<i>A Hybrid Intelligent Closed-Loop Model for Exploration of Cardiovascular Interactions</i> , Elsamahy, E. A.; Mahfouf, M.; Linkens, D. A. – University of Sheffield, UK (12).	165
9.1.1-2	<i>CHILDCARE: A Collaborative Environment for the Monitoring of Children Healthcare at Home</i> , Starida, K.; Ganiatsas, G.; Fotiadis, D. I.; Likas, A. – University of Ioannina and Biomedical Research Institute, Greece (65).	62
9.1.1-3	<i>A Multicriteria Decision Based Approach for Ischaemia Detection in Long Duration ECGs</i> , Goletsis, Y.; Papaloukas, C.; Fotiadis, D. I.; Likas, A.; Michalis, L. K. – University of Ioannina and Biomedical Research Institute, Greece (44).	230

9.1.1-4	<i>Automatic Discovery of the Number of MUAP Clusters and Superimposed MUAP Decomposition in Electromyograms</i> , Katsis, C. I.; Fotiadis, D. I.; Likas, A.; Sarma, I. – University of Ioannina, Biomedical Research Institute, and University Hospital of Ioannina, Greece (45).	177
9.1.1-5	<i>Prognostic Prediction of Bilharziasis-Related Bladder Cancer by Neuro-Fuzzy Classifier</i> , Ji, W.; Naguib, R. N. G.; Macall, J.; Petrovic, D.; Gaura, E.; Ghoneim, M. – The Robert Gordon University, BIOCORE (Coventry University), UK, and Mansoura University, Egypt (48).	181
9.1.1-6	<i>Discovering Acute Myocardial Infarction Markers in Body Surface Mapping</i> , Lopez, J. A.; Nugent, C. D.; Black, N. D. – University of Ulster, UK (54).	184
9.1.2	Intelligent Systems in Diagnosis, Prognosis and Patient Management 2 Chair: Dr Alison Todman, BIOCORE (Coventry University), UK	
9.1.2-1	<i>Visual Search in Chest Radiology: Definition of Reference Anatomy for Analysing Visual Search Patterns</i> , Dempere-Marco, L.; Hu, X.-P.; Yang, G. Z. – Imperial College of Science, Technology and Medicine, UK (96).	187
9.1.2-2	<i>Modeling of the Brainstem Evoked Response for Objective Automated Interpretation</i> , Davey, R. T.; McCullagh, P. J.; Mcallister, G.; Houston, G. – University of Ulster and Royal Victoria Hospital, UK (81).	191
9.1.2-3	<i>Multimethod Machine Learning Approach for Medical Diagnosing</i> , Lenic, M.; Povalej, P.; Zorma, M.; Podgorelec, V.; Kokol, P.; Lhotska, L. – University of Maribor, Slovenia (57).	195
9.1.2-4	<i>Increasing Hemodialysis Efficiency by a Recirculating Dialysate System Managed by a Telehealthcare Center</i> , Prado, M.; Roa, L. M.; Reina-Tosina, J.; Palma, A.; Milan, J. A. – University of Seville and H.U. Virgen Macarena, Spain (68).	199
9.1.2-5	<i>An Evolvable Software Framework for an Internet-Based Telediagnostic System</i> , Mitsa, T. – Research Corporation Technologies, USA (51).	203
9.1.2-6	<i>Evaluation of the Logarithmic-Sensitivity Index as a Neural Network Stopping Criterion for Rare Outcomes</i> , Ennett, C. M.; Frize, M.; Scales, N. – Carleton University and University of Ottawa, Canada (15).	338
9.1.3	Intelligent Systems in Diagnosis, Prognosis and Patient Management 3 Chair: Dr Monique Frize, Carleton University, Canada	
9.1.3-1	<i>Characterization of Ultrasonic Images of the Placenta Based on Textural Features</i> , Linares, P. A.; McCullagh, P. J.; Black, N. D.; Dorman, J. – University of Ulster and Royal Jubilee Maternity Service, UK (82).	211
9.1.3-2	<i>Building Optimal Statistical Deformable Surface Models</i> , Horkaew, P.; Merrifield, R.; Yang, G. Z. – Imperial College of Science, Technology and Medicine, UK (83).	215
9.1.3-3	<i>Blind Study for the Prediction of Attendance to a UK Breast Cancer Screening Unit</i> , Arochena, H. E.; Naguib, R. N. G.; Todman, A. G.; Wheaton, M. E.; Wallis, M. G. – BIOCORE (Coventry University) and Coventry and Warwickshire Hospital, UK (113).	219

9.1.3-4	<i>Electroencephalogram Analysis with Approximate Entropy to Help in the Diagnosis of Alzheimer's Disease</i> , Abásolo, D.; Hornero, R.; Espino, P.; Alonso, A.; de la Rosa, R. – University of Valladolid and Hospital Universitario de Valladolid, Spain (49).	222
9.1.3-5	<i>Early Detection of Masses in Digitized Mammograms Using Texture Features and Neuro-Fuzzy Model</i> , Youssry, N.; Abou-Chadi, F. E. Z.; El-Sayad, A. M. – Mansoura University, Egypt (32).	226
9.1.3-6	<i>An Intelligent Hybrid Neuro-Fuzzy Rule-Based System for Prognostic Decision Making in Prostate Cancer Patients</i> , Seker, H.; Odetayo, M. O.; Petrovic, D.; Naguib, R. N. G.; Hamdy, F. C. – University of Bradford, BIOCORE (Coventry University) and University of Sheffield, UK (117).	173
9.1.3-7	<i>Processing Thermal Images to Detect Breast Cancer and Assess Pain</i> , Frize, M.; Herry, C.; Scales, N. – Carleton University and University of Ottawa, Canada (26).	234
9.1.3-8	<i>Interface for Digital Medical Image Databases</i> , Konkachbaev, A. I.; Elmaghraby, A. S. – University of Louisville, USA (93).	238
9.2.1	Intelligent Systems in Diagnosis, Prognosis and Patient Management 4 (Posters)	
9.2.1-1	<i>A Toolkit to Aid Clinical Decision Support</i> , Thornton, K.; Lazzarini, A. – Durham University, UK (94).	242
9.2.1-2	<i>Non-Invasive Clinical Screening of Diabetes and Coronary Heart Disease</i> , Jacobson, M. L. – United Arab Emirates University, United Arab Emirates (33).	246
9.2.1-3	<i>Study of Raman Spectrum Characteristic for Stomach Cancer</i> , Li, X.; Jin, H.; Ding, C.; Lin, J. – Dalian University of Technology, Liaoning University, and Shenyang Institute of Technology, China (103).	250
9.2.1-4	<i>Classification Accuracy of a Frequency Analysis Method: Comparison Between Supervised SOM and KNN</i> , Hannula, M.; Laitinen, J.; Alasaarela, E. – University of Oulu, and Oulu Polytechnic, Finland (112).	254
9.2.1-5	<i>Evaluation of a Statistical Prediction Model Used in the Design of Neural Network Based ECG Classifiers: A Multiple Linear Regression Approach</i> , Finlay, D. D.; Nugent, C. D.; McCullagh, P. J.; Black, N. D.; Lopez, J. A. – University of Ulster, UK (86).	258
9.2.1-6	<i>Hot Spot Detection Based on Feature Space Representation of Visual Search in Medical Imaging</i> , Hu, X.-P.; Dempere-Marco, L.; Yang, G. Z. – Imperial College of Science, Technology and Medicine, UK (98).	261
9.2.1-7	<i>Clinical Applications of Myoelectric Signal Processing by Neural Network and Spectral Analysis</i> , Azzerboni, B.; La Foresta, F. – Università di Messina, Italy (80).	265

9.2.1-8	<i>Evaluation of the Index Quality Image Analysing Microcalcifications in Digitized Mammographic Images</i> , Mayo, P.; Rodenas, F.; Verdú, G.; Villaescusa, J. I.; Campayo, J. M. – Universidad Politécnica de Valencia, La Fe University Hospital, and Radiological Protection Technical Unit of LAINSA, Spain (133).	269
10.1.1	Special Session: Wearable Health Management Systems Chair: Dr Andreas Lymberis, European Commission, Belgium	
10.1.1-1	<i>Smart Wearables for Remote Health Monitoring, from Prevention to Rehabilitation: Current R&D, Future Challenges</i> , Lymberis, A. – European Commission, Information Society Directorate-General, Belgium (138).	272
10.1.1-2	<i>A Wearable Intelligent System for Monitoring Health Condition and Rehabilitation of Running Athletes</i> , Glaros, C.; Fotiadis, D. I.; Likas, A.; Stafylopatis, A. – University of Ioannina, Biomedical Research Institute, and National Technical University of Athens, Greece (88).	276
10.1.1-3	<i>Advanced Insulin Infusion Using a Control Loop (ADICOL)</i> , Vering, T.; Dudde, R. – Fraunhofer Institute Silicon Technology, and Itzehoe Disetronic Medical Systems, Germany (127).	280
10.1.1-4	<i>Wearable Health Care System for Vital Signs Monitoring</i> , Paradiso, R. – Milior S.P.A. and Smartex S.R.L., Italy (119).	283
10.1.1-5	<i>Wearable Sensing Garment for Posture Detection, Rehabilitation and Tele-Medicine</i> , Lorussi, F.; Scilingo, E. P.; Tesconi, M.; Tognetti, A.; De Rossi, D. – University of Pisa, Italy (130).	287
10.1.1-6	<i>Smart Devices for the Early Detection and Interpretation of Cardiological Syndromes</i> , Gouaux, F.; Simon-Chautemps, L.; Adami, S.; Arzi, M.; Assanelli, D.; Fayn, J.; Forlini, M.-C.; Malossi, C.; Martinez, A.; Placide, J.; Ziliani, G.-L.; Rubel, P. – INSERM, France, Elettronica Trentina, University of Brescia and ST Microelectronics, Italy, and INSA-LISI, France (129).	291
10.1.1-7	<i>The Proliferation of Patient-Worn Wireless Telemetry Technologies Within the U.S. Healthcare Environment</i> , Gieras, I. A. – Beaumont Services Company and William Beaumont Hospital, USA (52).	295
10.1.1-8	<i>VTAM - A New "Biocloth" for Ambulatory Telemonitoring</i> , Weber, J.-L.; Blanc, D.; Dittmar, A.; Comet, B.; Corroy, C.; Noury, N.; Baghai, R.; Vaysse, S.; Blinowska, A. – TAM-Télésanté, LPM-INSA, MEDES, ITECH Entreprise, Faculté de Médecine, RBI, MEDIAG, and INSERM, France (121).	299
11.1.1	Student Paper Competition 1 Chair: Dr John Puentes, ENST Bretagne, France	
11.1.1-1	<i>Self-Organizing Maps for Masking Mammography Images</i> , Rickard, H. E.; Tourassi, G. D.; Elmaghraby, A. S. – University of Louisville, and Duke University Medical Center, USA (92).	302
11.1.1-2	<i>Biomedical Pattern Discovery and Visualisation Based on Self-Adaptive Neural Networks</i> , Haiying, W.; Azuaje, F.; Black, N. D. – University of Ulster, UK (62).	306

11.1.1-3	<i>Throughput Performance of a WCDMA System Supporting Tele-Echography Services</i> , Yao, W.; Istepanian, R. S. H.; Salem, A. Z.; Zisimopoulos, H.; Gosset, P. – Brunel University and Vodafone Group, UK (144).	310
11.1.1-4	<i>Web-Based Telemedical System for Collaborative Pacemaker Follow-Up</i> , Kollmann, A.; Kastner, P.; Schreier, G.; Rotman, B.; Lercher, P.; Scherr, D.; Klein, W. – ARC Seibersdorf Research GmbH and Karl-Franzens University, Austria (70).	314
11.1.1-5	<i>Ubiquitous Real-Time Monitoring of Critical-Care Patients in Intensive Care Units</i> , Lamberti, F.; Montrucchio, B. – Politecnico di Torino, Italy (97).	318
11.1.1-6	<i>A Prototype XML-Based Implementation of an Integrated 'Intelligent' Neonatal Intensive Care Unit</i> , Catley, C. A.; Frize, M. – Carleton University and University of Ottawa, Canada (91).	322
11.1.2	Student Paper Competition 2 Chair: Mr Pierre Vieyres, Université d'Orléans, France	
11.1.2-1	<i>ROVIMAS: A Software Package for Assessing Surgical Skills Using the Da Vinci Telem manipulator System</i> , Dosis, A.; Bello, F.; Rockall, T.; Munz, Y.; Moorthy, K.; Martin, S.; Darzi, A. – Imperial College of Science, Technology and Medicine, and St.Mary's Hospital, UK (41).	326
11.1.2-2	<i>A Parallel Implementation of a Genetic Algorithm for Colonic Tissue Image Classification</i> , Filippas, J.; Amin, S. A.; Naguib, R. N. G.; Bennett, M. K. – BIOCORE (Coventry University) and Royal Victoria Infirmary, UK (125).	330
11.1.2-3	<i>HCRA: A Hand Configuration Recognition Algorithm for Use in Breast Self-Examination</i> , Hu, Y.; Naguib, R. N. G.; Todman, A. G.; Amin, S. A.; Alomishy, H. – BIOCORE (Coventry University) and Walsgrave General Hospital, UK (123).	334
11.1.2-4	<i>EASYG - Electrocardiogram Analysis System</i> Graz, Peer, C.; Schreier, G.; Kastner, P.; Marko, W.; Messmer, J.; Rotman, B.; Lercher, P.; Klein, W. – ARC Seibersdorf Research GmbH and Karl-Franzens University, Austria (73).	207
11.1.2-5	<i>Low-Cost Home Monitoring Using a Java-Based Embedded Computer</i> , Lamberti, F.; Demartini, C. – Politecnico di Torino, Italy (95).	342
11.1.2-6	<i>Contour Detection by Using Radial Searching for CT Images</i> , Xu, W.; Amin, S. A.; Haas, O. C. L.; Burnham, K. J.; Mills, J. A. – BIOCORE and CTAC (Coventry University), and University Hospitals of Coventry and Warwickshire N.H.S. Trust, UK (149).	346
13.2.1	Late Posters 1	
13.2.1-1	<i>Implementation Solutions and Issues in Building a Personal Sensor Network for Health Care Monitoring</i> , Krco, S. – Ericsson Systems Expertise, Ireland (151).	350

13.2.1-2	<i>Using Decision Tree Algorithms as a Basis for a Heart Sound Diagnosis Decision Support System</i> , Stasis, A. C.; Loukis, E. N.; Pavlopoulos, S. A.; Koutsouris D. – National Technical University of Athens and University of the Aegean, Greece (153).	354
13.2.1-3	<i>Management of Discharge Summaries Based on XML</i> , Román, I.; Roa, L. M.; Vozmediano, J. M.; Corrales, L. – Universidad de Sevilla, Spain (156).	358
13.2.1-4	<i>IST VIVAGO - An Intelligent Social and Remote Wellness Monitoring System for the Elderly</i> , Särelä, A.; Korhonen, I.; Lötjönen, J.; Sola, M.; Myllymäki, M. – IST International Security Technologies Oy, VTT Information Technology and University of Tampere, Finland (159).	362
13.2.2	Late Posters 2	
13.2.2-1	<i>On the Use of Single-Channels for Sensing Multisource Activity in Biomedical Signals</i> , James, C. J. – Aston University, UK (154).	366
13.2.2-2	<i>Direct Sequence CDMA Based Wireless Interface for an Integrated Sensor Microsystem</i> , Aydin, N.; Arslan, T.; Cumming, D. R. S. – University of Edinburgh, Institute for System Level Integration and University of Glasgow, UK (155).	370
13.2.2-3	<i>Audio Assessment of the Peripheral Microcirculation</i> , Crabtree, V. P.; Smith P. R. – Loughborough University, UK (161).	374
13.2.2-4	<i>Survey of Medical Data - From Data Acquisition to High Quality Patient Treatment</i> , Steil, H.; Kirchgessner, J.; Moscardo, V.; Mitteregger, A.; Chang, M. P.; Klinkner-Hughes, G.; Marcelli, D.; Gatti, E. – Fresenius Medical Care, Germany (158).	378
13.2.2-5	<i>Information System for Computer-Aided Interventions</i> , Coussaert, O.; Schoovaerts, F.; Joly, A.; Levivier, M.; Wikler, D. – Free University of Brussels, Belgium (157).	382
<i>Author Index</i>		384

WEARABLE HEALTH CARE SYSTEM FOR VITAL SIGNS MONITORING

R. Paradiso¹.

¹MILIOR SpA and SMARTEX s.r.l., Prato, Italy

Abstract—A new concept in healthcare, aimed at providing continuous remote monitoring of user vital signs, is emerging. An innovative system named WEALTHY is presented, where smart material in fiber and yarn form endowed with a wide range of electrophysical properties (conducting, piezoresistive, etc) are integrated and used as basic elements to be woven or knitted in fabric form. The simultaneous recording of vital signs allows parameters' extrapolation and inter-signal elaboration that contribute to make alert messages and synoptic patient table. WEALTHY system is implemented by integrating computing techniques, smart sensors, portable devices and telecommunications, together with local intelligence and decision support system. The system will assist cardiopathic patients during rehabilitation or subjects working in extreme stressful environment conditions.

Keywords—Wearable, healthcare, integration.

I. INTRODUCTION

A new concept in health care, aimed at providing continuous remote monitoring of patient vital signs, is now emerging. This paradigm shift is both socially driven—the rising cost of assistance, the need to improve early illness detection and medical intervention— and technologically driven. In particular, the advances in sensor technology, as well as in communication technology and treatment of data, constitute the basis on which this new generation of health care systems can consolidate. At the same time systems designed to be minimally invasive for health status monitoring, based on flexible and smart technologies conformable to the human body will help to improve the autonomy and the quality of life of patients. They are also cost-effective in providing around-the-clock assistance, for example in rehabilitation from cardiac disease or for the monitoring of professional workers engaged in extreme environmental conditions. Finally, by providing direct feedback to the users, they improve their awareness and potentially allow better control of their own condition.

In these systems smart materials in fiber and yarn form endowed with a wide range of electro-physical properties (conducting, semiconducting, electrostrictive, piezoresistive, etc) will be integrated and used as basic elements to fabricate woven or knitted fabrics possessing distributed sensor and logic functions. The simultaneous recording of vital signs will allow parameters extrapolation and inter-signal elaboration that contribute to make alert messages and personalized synoptic tables of patient's health.

II. WEALTHY SYSTEM

Strain sensors based on piezoresistive yarns, piezoelectric Polyvinylidene fluoride PVDF pressure

sensors and electrodes realised with fabric containing metal, enable the realization of truly wearable and wireless instrumented garments capable of recording physiological signals and to be used by the patient during the everyday activity. Breathing pattern, electrocardiogram, activity sensors, pressure, temperature, can be listed as physiological variables amenable the monitoring through the proposed system. A miniaturized short-range wireless system can be integrated in the sensitive garment and used to transfer the signals to WEALTHY box/PCs, PDA and mobile phones.

An "intelligent" system for the alert functions, able to create an "intelligent environment" by delivering the appropriate information for the target professional, will be implemented.

The system is addressed for the monitoring of patients with heart disease during and after their rehabilitation and of subjects engaged in extreme stressful conditions

III. WEALTHY FUNCTIONS

An overview of the technology in WEALTHY is shown below in Fig. 1, where the main phases of the process are shown, namely: sensing, pre-processing, transmission, processing and data management.

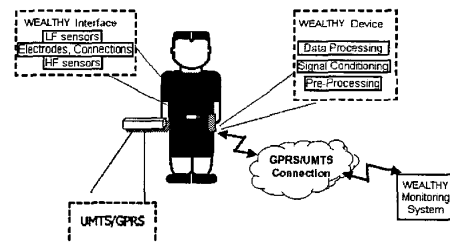


Fig. 1: The processing and communication mechanism

The garment interface is connected with the portable WEALTHY device where the local processing as well as the communication with the network is performed.

The pre-processing and processing locations depend on the selected physiological parameters. One of the main goals of the digital processing stage is to compress or even directly extract the most appropriate features to reduce communication data rates and expenses for the selected physiological parameters.

This processing may typically make use of neuro-fuzzy or other advanced processing techniques like wavelet processing, particularly suited to extract weak biomedical signals from a noisy environment (due to the user movements and activities) and to dramatically reduce the data volume.

The system enable the simultaneous acquisition of differentiated physiological parameters, this feature allows the implementation of an innovative approach to the study of health status by giving a powerful instrument for the definition of new indexes correlated to the whole set of recorded signals.

A "smart" fabric containing insulated conductive wires connected with sensors and electrodes has been used to make the garment. The whole system behaves primarily as a woven circuit port where the electronic signals detected by the electrodes and sensors will be led by means of the conductive threads of the fabric to the reading and processing station. This may either be placed on the garment or the signals may reach it by telemetry.

The intended instrumental set-up will include a number of channels sufficient to guarantee a good acquisition of ECG signals, thus to allow an efficient remote continuous monitoring. This will allow the prevention of critical phase by relaying the information to the doctor (or a suitable medical call centre) in case of alarm and providing feedback to the users and suggestions to the patients about the frequency and intensity of physical activity.

Fig.2 below shows the overall WEALTHY architecture. The system improves user comfort by avoiding wiring harnesses and by using 3G (GPRS/UMTS) wireless communication between the portable communication gateway and the mobile network. This feature allows use of the tele-monitoring system both indoor and outdoor. From the user point of view, the garment and its processing and communication units are miniaturized, and no physical connections with the fixed station for data retrieval will be provided. This helps keep user comfort unaltered. The physiological data to be monitored are transmitted, after suitable processing, to the monitoring system.

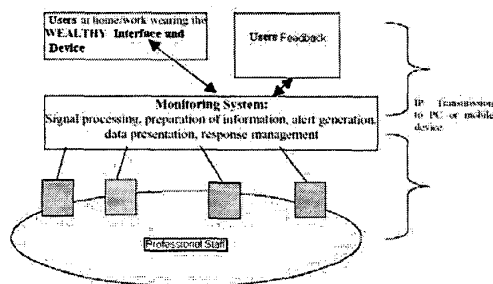


Fig. 2: The overall WEALTHY design

The WEALTHY platform will, therefore, comprise an "intelligent" system for the alert functions. It will be able to create an "intelligent environment" by delivering the appropriate information for the target professional in the most friendly and suitable way by using advanced telecommunications protocols and software development technology and tools.

A strong contribution to medical assistance can be given by the possibility to monitor and assist patients through a remote medical advice service. The use of intelligent -based systems provided to physicians the data to timely detect and manage health risks, early illness diagnose or injury, recommend treatment that would prevent further deterioration and, finally, to make confident professional decisions based on objective information - all in a reasonably short time.

IV: SIGNALS ANALYSIS and RESULTS

The long period analysis of ECG signal performed with several electrodes allows a complete observation of heart functionality, which is of basic importance in many cardiac pathologies, particularly in myocardial ischemia. The most important aspect is the acquisition of the ECG signal from a number of electrodes positioned on the thorax and the limbs. This will allow a quite good mapping of the walls of the heart.

The portable devices for ECG acquisition now commercially available usually only allow 3 acquisition channels and such configuration is enough for a simple analysis of ECG frequency and the identification of arrhythmia but not for monitoring the rehabilitation process. Commonly used holters for long period acquisition of ECG signal perform the acquisition from 3 electrodes so that successive acquisitions with different positions can be performed. Again, such information is useful for the frequency analysis of the signal and the identification of cardiac arrhythmia but is not enough for more complex investigations.

Scientific publications indicate that respiratory rate is the most sensitive respiratory parameter, but non-specific sign of respiratory dysfunction, while tidal volume estimates are sufficiently accurate for clinical decision making in children and adults under resting, sleeping and exercising conditions.

When respiratory function is recorded separately from each hemithorax, it will be useful to detect possible asymmetries in tidal volume and phase relations between right and left sides. Starting from rate and volume indexes, a number of other respiratory parameters can be computed, such as ventilation, fractional aspiratory time, both aspiratory and expiratory flows over mean aspiratory flow as well as the phase and amplitude relation between abdominal and rib cage respiratory patterns. In addition, the same set of sensors will yield a wide series of respiratory indexes useful for diagnosing several clinical conditions affecting respiratory dynamics.

Respiratory drive signifies neural respiratory center activity. The gold standard for measuring this drive is the diaphragmatic electromyogram, an invasive, technically difficult procedure that is not practical for home monitoring. Peak aspiratory flow and peak aspiratory acceleration, which can be easily obtained from the thoracogram, have been found to be a good substitutes for diaphragmatic electromyogram in measuring respiratory drive. Several clinical respiratory phenomena can be characterized by the

ratio of breath-by-breath ventilation divided by respiratory drive. For example, the ratio of ventilation to respiratory drive distinguishes psychogenic from organic causes of breathlessness and this may help to distinguish between a patient with chronic pulmonary and cardiac diseases from a patient with chronic anxiety.

In addition ECG signal can be used to evaluate the time variations of the R-R interval of the QRS component and Respiratory Sinus Arrhythmia (RSA) to study the sympatho-vagal balance [1,2]. In fact, a derivative/threshold algorithm provides the series of RR intervals (tachogram) that are used to provide the power spectral density using an FFT based approach. Two major oscillatory components are usually detectable in RR variability, one of which, synchronous with respiration and related to parasympathetic activity, is described as HF (High Frequency, about 0.25 Hz and varying with respiration), whereas the other, corresponding to the slow waves of arterial pressure and mainly related to sympathetic activity, is described as LF (Low Frequency, about 0.1 Hz). The LF-to-HF ratio can thus be calculated to provide an indication of the sympatho-vagal balance.

Negative emotional stimulus, 3min (such as pictures of mutilations, car crash, etc), was administered to subject following a long lasting (18 min) normal relaxation period. Heart and respiratory rate increase during the negative emotional stimulus with respect to the relaxed period. As shown in Fig.3. The increasing of heart rate (RR distances in the tachogram) was associated to RR spectral indices changes. In particular, is expected sympathetic activity LF was increased and parasympathetic activity HF was reduced during emotional period, as shown in Fig.4.

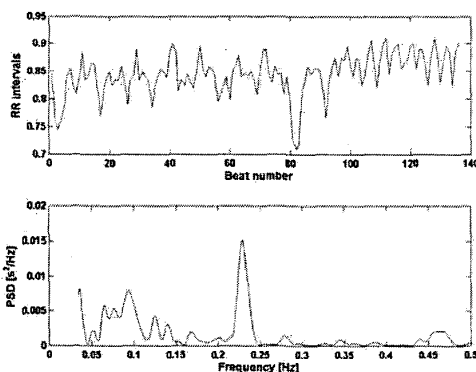


Fig. 3 Tachogram and PSD analysis during relaxation period

From RR signal it is also possible to identify non-linear heart rate dynamics by analyzing entropy measures (E). The reduction of E may be predictive of cardiac disfunctioning.

In addition, Respiratory Sinus Arrhythmia (RSA), computed as the difference between the longest electrocardiographic RR interval during expiration and

the shortest RR interval during aspiration, can be used as an index of the balance between sympathetic and parasympathetic neural activity: high values are linked to an increase of parasympathetic activity, and low values a predominance of sympathetic activity [3,4,5].

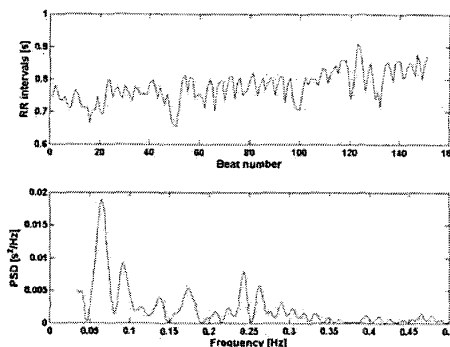


Fig. 4 Tachogram and PSD analysis during emotional period

In some cases, though, physiological parameters cannot be directly interpreted. This is the case, for example, in the monitoring of complex situations (e.g. congestive heart disease), or if one wants to monitor several different conditions with the same system (e.g., cardiac, pulmonary and metabolic disease). Taking the example of cardiac monitoring (using such variables as heart rate, ECG abnormalities, estimates of Central Venous Pressure, estimates of oxygen capillary saturation), the integration of these variables is best done with model-based diagnosis rather than rule-based decision systems.

Model-based diagnosis in clinical medicine can only be implemented when a pathophysiological model is available, but this is generally the case where physiological parameters are monitored, especially in cardiology. Besides, a model-based representation facilitates the generation of explanations, including the generation of causal explanations that are required to give feedback and advice to the patient in non-technical terms.

DISCUSSION

The most innovative character of this system consists in the use of smart materials in form of fibers and yarns which can be knitted or woven into a multifunctional sensing fabric. Preliminary work done by the authors [6] has shown that the basic sensing features on which vital sign recording is based can be implemented using wearable fibers and yarns.

Low frequency mechanical signals of cardiopulmonary origin (respirator signals, ballistogram) or generated by body segments relative motion (kinesthesia) have been faithfully recorded by fiber strain gages made of polypyrrole (a π -electron conjugated conductive polymer) treated cotton/lycra fabric [7,8] or carbon loaded rubber coatings onto cotton/lycra yarns.

High frequency mechanical signals have also been recorded by ferroelectric polymers (PVDF) thin elements which can be spun into wearable yarns. These high frequency signals proved to be essential to detect peripheral pulse (carotid, wrist) and even, under controlled conditions sounds of cardiopulmonary origin.

Finally bioelectric potentials related to cardiac or skeletal muscle activity (ECG, EMG) have been faithfully recorded by woven stainless steel fabrics.

The integration of these different components with appropriate elastic electrical conductors and properly designed connectors to the wearable electronic unit will lead to a truly wearable garment which has no counterpart in any existing monitoring system.

State of the art and advanced textile technology is used in the components integration also considering comfort and form fitting components, leading to new woven or knitted systems enabling applications extending even beyond the clinical area to open new avenues in sport, ergonomics and monitoring operators exposed to harsh or risk conditions (fire fighters, soldiers etc.)

The possibility of simultaneously recording different physiological signals provide an integrated view of normal and abnormal pattern of activity which could be otherwise impossible to detect by recording each signal in different time.

Finally it must be outlined that the possibility of recording physiological variables in a more "natural" environment may help to identify the influence of the psycho-emotional state of the subject in the performance of a physical activity. This is not easily detectable when recording is done within a protected (medical) environment.

A further innovation is the in-context data interpretation. While a simple telemonitoring system would just transmit or record real-time physiological signs, the WEALTHY system will be able to process physiological parameters in context, so that appropriate feedback can be given to the patient.

CONCLUSION

Leveraging the disparate materials, technologies and techniques available within the established electronics and textile industries is leading to a totally new class of large-area, flexible, conformable informative /interactive systems; essential instrumental functions (power supply, sensor, actuator, processor) can be implemented onto fabric substrates [7], as proved by the recent realization of "all-polymer" devices acting as active electronic components (transistors) and "all polymer" batteries.

The innovative approach of this work is based on the use of standard industrial processes to realize the sensing elements. Transduction functions are implemented in the same woven system, where movements and vital signs are converted into readable signals, which can be acquired and tele transmitted.

In others systems, as the Smartshirt system (Sensatex), the sensors are realized by adapting existing technology to the garment, from a technological point of view the innovative idea is given by the use of

optical fibers woven into the fabric, while the sensors are plugged in the connection clips. For the Lifeshirt system (Vivometrics) the innovative aspect is not contained in what it measures and how, but what it can be done with the resulting information.

In our fabric sensors, electrodes and bus structure are all integrated in textile material. Physiological data detected are intrinsically redundant; with this configuration it is also possible to increase the efficiency of the system by reducing motion artifact signals.

ACKNOWLEDGMENT

The author would like to thank all the European partners involved in the project: University of Pisa, Italy; Centre Suisse d'Electronique et de Microtechnique, Switzerland; Atkosoft S.A., Greece; Institut National des Sciences Appliquees de Lyon, France; Istituto Scientifico H San Raffaele, Italy; Centre de Recherches du Service de Sante des Armees, France; Messe Frankfurt GmbH, Germany.

REFERENCES

- [1] Ghelarducci B, and Sebastiani L. Cerebellar contribution to cardiovascular control. *J. Auton. Nerv. Sys.*, 56:149-156, 1996.
- [2] Gemignani A., Santarcangelo E.L., Sebastiani L., Marchese C., Mammoliti R., Simoni A., Ghelarducci B.: Changes in autonomic and EEG patterns induced by hypnotic imagination of aversive stimuli in man. *Brain Res Bull*, 53: 105-111, 2000.
- [3] Angelo Gemignani, Laura Sebastiani, Alfredo Simoni, Enrica Santarcangelo, Brunello Ghelarducci. Hypnotic trait modulation of EEG gamma rhythm and autonomic output during phobic stimulation. Submitted to *Neuroreport*
- [4] Sebastiani, L., Simoni, A., Gemignani, A., Ghelarducci, B., Santarcangelo, E.L. Autonomic and EEG correlates of emotional imagery: evidence for a neo-dissociation theory of hypnosis. Submitted to *Psychophysiology*
- [5] Laura Sebastiani, Alfredo Simoni, Angelo Gemignani, Brunello Ghelarducci and Enrica L.Santarcangelo. Hypnotic susceptibility and relaxation: autonomic and eeg patterns. Submitted to *Cognitive Brain Research*
- [6] M. Pacelli, R. Paradiso, G. Anerdi, S. Ceccarini, M. Ghignoli, F. Lorussi, P. Scilingo, D. De Rossi, A. Gemignani, B. Ghelarducci, "Sensing Threads and Fabrics for Monitoring Body Kinematic and Vital Signs" *Fibres and Textiles for the Future*, August 16-17, 2001 Tampere, Finland
- [7] D. De Rossi, F. Lorussi, A. Mazzoldi, P. Orsini, E.P. Scilingo, Monitoring Body kinematics and gesture through sensing fabrics, 1st Annual International IEEE-EMBS Special Topic Conference on Microtechnologies in Medicine & Biology, October 12-14, 2000, Lyon, FRANCE
- [8] D. De Rossi, A. Mazzoldi, F. Lorussi, R. Paradiso, "From sensitive fabrics to distributed wearable sensors", SPIE's 8th Annual International Symposium on Smart Structures and Materials, 4-8 March 2001, Newport Beach, California USA