The Challenge of Ubiquitous Computing in Health Care: Technology, Concepts and Solutions

Findings from the IMIA Yearbook of Medical Informatics 2005

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Summary

Objectives: To review recent research efforts in the field of ubiquitous computing in health care. To identify current research trends and further challenges for medical informatics.

Methods: Analysis of the contents of the Yearbook on Medical Informatics 2005 of the International Medical Informatics Association (IMIA).

Results: The Yearbook of Medical Informatics 2005 includes 34 original papers selected from 22 peer-reviewed scientific journals related to several distinct research areas: health and clinical management, patient records, health information systems, medical signal processing and biomedical imaging, decision support, knowledge representation and management, education and consumer informatics as well as bioinformatics. A special section on ubiquitous health care systems is devoted to recent developments in the application of ubiquitous computing in health care. Besides additional synoptical reviews of each of the sections the Yearbook includes invited reviews concerning E-Health strategies, primary care informatics and wearable healthcare.

Conclusions: Several publications demonstrate the potential of ubiquitous computing to enhance effectiveness of health services delivery and organization. But ubiquitous computing is also a societal challenge, caused by the surrounding but unobtrusive character of this technology. Contributions from nearly all of the established sub-disciplines of medical informatics are demanded to turn the visions of this promising new research field into reality.

Keywords

Medical informatics, health informatics, International Medical Informatics Association, ubiquitous computing, pervasive computing, mobile computing, yearbook

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Introduction: Ubiquitous Computing in Health Care

Ubiquitous computing, even though often used synonymous to pervasive computing, combines mobile and pervasive computing with the objective of surrounding the user with technology that unobtrusively provides them with information and services dependent on their environment and relevant to them in a particular context [1]. The computer as a single device with its rather cumbersome user interface consuming almost full attention of its user will vanish in this vision. Instead, intelligent user interfaces far beyond today's graphical user interfaces will enable the user to interact with their environment while simultaneously using IT-services. Since the introduction of ubiquitous computing as a new visionary paradigm of computing in the late eighties by Mark Weiser, Chief Technology Officer at Xerox's Palo Alto Research Center at that time [2], miniaturization and improvement of computer, sensor and networking technology, development of new materials like intelligent textiles, smart paper, etc. and improvements of power supply helped to bring this vision at least partly into reality (e.g. [3-6]).

Health care seems to be an ideal application field for ubiquitous computing. Where else is the paradigm of "getting the right information at the right time at the right place" of greater importance than in health care? Scenarios for application of ubiquitous computing are home care and monitoring (e.g. [7-9]), assistance for health professionals (e.g. [10-12]), and the self-organization of health care institutions (e.g. [13]). Wearable systems and especially new man-machine interfaces are key technologies of ubiquitous computing in health care [15-17]. Another key technology, namely RFID chips (Radio Frequency Identification) [18], useful for realizing context-awareness of ubiquitous computing solutions is already available and in use in several domains.These miniaturized chips allow the wireless transfer of data within a limited area around a special RFID reader and can be used to identify nearby people and objects.

The special section "Ubiquitous Health Care Systems" of the recent Yearbook 2005 of the International Medical Informatics Association (IMIA) takes a closer look at current research in ubiquitous computing in health care. In this paper we summarize its contents and discuss how the selected research contributes to the development of ubiquitous computing in health care.

The IMIA Yearbook of Medical Informatics 2005

The IMIA Yearbook of Medical Informatics has been annually published by the International Medical Informatics Association

Table 1 Table of contents of IMIA Yearbook of Medical Informatics 2005

Preface	Schek HJ. Ubiquitous Computing and Pervasive Health Care.
Editorial	Haux R, Kulikowski CA. Ubiquitous Health Care Systems
Review Section	Lorenzi NM. E-Health Strategies Worldwide. Jai Mohan A, Suleiman AB. E-Health Strategies for Developing Nations. Teasdale S. A review of Primary Care Informatics: past progress, present reality, future prospects. Tröster. G. The Agenda of Wearable Healthcare.
Research and Education Section	Hersh W. The Full Spectrum of Biomedical Informatics Research and Education at OHSU. Jaspers MWM, Gardner RM, Gatewood LC, Haux R, Schmidt D, Wetter T. The International Partnership for Health Informatics Education: Lessons Learned from Six Years of Experience Knaup P, Frey W, Haux R, Leven FJ. Medical informatics specialists: what are their job profiles? Results of a study on the first 1024 medical informatics graduates of the Universities of Heidelberg and Heilbronn. Methods Inf Med. 2003; 42 (5): 578-87. Okada M, Yamamoto K, Kawamura T. Health and Medical Informatics Education in Japan. Pinciroli F, Masseroli M, Bonacina S. New e-Health Tracks in the Engineering Education of the Politecnico di Milano. Wright G, Betts H, Murray P. Health Informatics Masters Education, Online Learning and Student Support.
Special Section: Ubiquitous Health Care Systems	Bott O. Ubiquitous Health Care Systems: a New Paradigm for Medical Informatics? Synopsis. Carroll AE, Tarczy-Hornoch P, O'Reilly E, Christakis DA. The effect of point-of-care personal digital assistant use on resident documentation discrepancies. Pediatrics 2004 Mar;113 (3 Pt 1):450-4. Coiera E, Clarke R. e-Consent: The design and implementation of consumer consent. J Am Med Inform Assoc 2004 Mar-Apr; 11 (2): 129-40. Lukowicz P, Kirstein T, Tröster G. Wearable systems for health care applications. Methods Inf Med. 2004; 43 (3): 232-8. Maiolo C, Mohamed EI, Fiorani CM, de Lorenzo A. Home telemonitoring for patients with severe respiratory illnes: the Italian experience. J Telemed Telecare 2003;9:67–71. Marks IM, Mataix-Cols D, Kenwright M, Cameron R, Hirsch S, Gega L. Pragmatic evaluation of computer-aided self-help for anxiety and depression. Br J Psychiatry. 2003 Jul;183:57-65.
Section 1: Health and Clinical Management	Lovis C. Health and Clinical Management. Synopsis. Kuperman GJ, Gibson RF. Computer physician order entry: benefits, costs, and issues. Ann Intern Med 2003; 139 (1): 31-9. Park WS, Kim JS, Chae YM, Yu SH, Kim CY, Kim SA, Jung SH. Does the physician order-entry system increase the revenue of a general hospital? Int J Med Inform 2003; 71 (1):25-32. Ruland CM, Ravn IH. Usefulness and effects on costs and staff management of a nursing resource management information system. J Nurs Manag 2003; 11 (3): 208-15. Samore MH, Evans RS, Lassen A, Gould P, Lloyd J, Gardner RM, Abouzelof R, Taylor C, Woodbury DA, Willy M, Bright RA. Surveillance of medical device-related hazards and adverse events in hospitalized patients. JAMA 2004; 291 (3): 325-34.
Section 2: Patient Records	Beale T. The Health Record – why is it so hard? Synopsis. Hippisley-Cox J, Pringle M, Cater R, Wynn A, Hammersley V, Coupland C, Hapgood R, Horsfield P, Teasdale S, Johnson C. The electronic patient record in primary care – regression or progression? A cross sectional study. BMJ 2003; 326 (7404): 1439-43. Nilsson G, Ahlfeldt H, Strender LE. Textual content, health problems and diagnostic codes in electronic patient records in general practice. Scand J Prim Health Care 2003; 21 (1): 33-6. Rotich JK, Hannan TJ, Smith FE, Bii J, Odero WW, Vu N, Mamlin BW, Mamlin JJ, Einterz RM, Tierney WM. Installing and implementing a computer-based patient record system in sub-Saharan Africa: the Mosoriot Medical Record System. J Am Med Inform Assoc 2003; 10 (4): 295-303. Wang SJ, Middleton B, Prosser LA, Bardon CG, Spurr CD, Carchidi PJ, Kittler AF, Goldszer RC, Fairchild DG, Sussman AJ, Kuperman GJ, Bates DW. A cost-benefit analysis of electronic medical records in primary care. Am J Med 2003; 114 (5): 397-403.
Section 3: Health Information Systems	Gómez Aguilera EJ. Health Information Systems. Synopsis. Jacklin PB, Roberts JA, Wallace P, Haines A, Harrison R, Barber JA, Thompson SG, Lewis L, Currell R, Parker S, Wainwright P; Virtual Outreach Project Group. Virtual outreach: economic evaluation of joint teleconsultations for patients referred by their general practitioner for a specialist opinion. BMJ 2003; 327 (7406): 84-8. Tsui FC, Espino JU, Dato VM, Gesteland PH, Hutman J, Wagner MM. Technical description of RODS: a real-time public health surveillance system. J Am Med Inform Assoc 2003; 10 (5): 399-408. Van Der Meijden MJ, Tange HJ, Troost J, Hasman A. Determinants of success of inpatient clinical information systems: a literature review. J Am Med Inform Assoc 2003; 10 (3): 235-43. Winter A, Brigl B, Wendt T. Modeling hospital information systems. Part 1: The revised three-layer graph-based meta model 3LGM2. Methods Inf Med 2003; 42 (5): 544-51.
Section 4: Medical Signal Processing and Biomedical Imaging.	Barillot C. Medical Signal Processing and Biomedical Imaging. Synopsis. Armoundas AA, Feldman AB, Mukkamala R, He B, Mullen TJ, Belk PA, Lee YZ, Cohen RJ. Statistical accuracy of a moving equivalent dipole method to identify sites of origin of cardiac electrical activation. IEEE Trans Biomed Eng. 2003 Dec; 50 (12): 1360-70. Cachia A, Mangin JF, Riviere D, Kherif F, Boddaert N, Andrade A, Papadopoulos-Orfanos D, Poline JB, Bloch I, Zilbovicius M, Sonigo P, Brunelle F, Regis J. A primal sketch of the cortex mean curvature: a morphogenesis based approach to study the variability of the folding patterns. IEEE Trans Med Imaging 2003; 22 (6): 754-65. Chabanas M, Luboz V, Payan Y. Patient specific finite element model of the face soft tissues for computer-assisted maxillofacial surgery. Med Image Anal. 2003 Jun; 7 (2): 131-51. Ganser KA, Dickhaus H, Metzner R, Wirtz CR. A deformable digital brain atlas system according to Talairach and Tournoux. Med Image Anal. 2004 Mar; 8 (1): 3-22. Tilg B, Fischer G, Modre R, Hanser F, Messnarz B, Roithinger FX. Electrocardiographic imaging of atrial and ventricular electrical activation. Med Image Anal. 2003 Sep; 7 (3): 391-8.

Table 1 Continued

Section 5: Decision Support, Knowledge Representation and Management	Hripcsak G. Decision Support, Knowledge Representation and Management. Synopsis. Abu-Hanna A, de Keizer N. Integrating classification trees with local logistic regression in Intensive Care prognosis. Artif Intell Med 2003; 2 9(1-2): 5-23. Heckerling PS, Gerber BS, Tape TG, Wigton RS. Entering the black box of neural networks. Methods Inf Med 2003; 42 (3): 287-96. Plougmann S, Hejlesen O, Turner B, Kerr D, Cavan D. The effect of alcohol on blood glucose in Type 1 diabetes – metabolic modelling and integration in a decision support system. Int J Med Inform 2003; 70 (2-3): 337-44. Tamblyn R, Huang A, Perreault R, Jacques A, Roy D, Hanley J, McLeod P, Laprise R. The medical office of the 21st century (MOXXI): effectiveness of computerized decision-making support in reducing inappropriate prescribing in primary care. CMAJ 2003 Sep 16; 169 (6): 549-56.
Section 6: Education and Consumer Informatics	Gammon D. Education and Consumer Informatics – patient involvement and health outcomes. Synopsis. Bearman M. Is virtual the same as real? Medical students' experiences of a virtual patient. Acad Med 2003; 78 (5): 538-45. Hofmann M, Rosler A, Schwarz W, Muller-Spahn F, Krauchi K, Hock C, Seifritz E. Interactive computer-training as a therapeutic tool in Alzheimer's disease. Compr Psychiatry 2003; 44 (3): 213-9. Liu CT, Yeh YT, Chiang IJ, Chen HY, Lee TI, Chiu WT. Development and evaluation of an integrated pharmaceutical education system. Int J Med Inform 2004; 73 (4): 383-9. Palermo TM, Valenzuela D, Stork PP. A randomized trial of electronic versus paper pain diaries in children: impact on compliance, accuracy, and acceptability. Pain 2004; 107 (3): 213-9.
Section 7: Bioinformatics	Yao. T. Bioinformatics and Systems Biology – towards Integrative Biology. Synopsis. Covitz PA, Hartel F, Schaefer C, De Coronado S, Fragoso G, Sahni H, Gustafson S, Buetow KH. caCORE: a common infrastructure for cancer informatics. Bioinformatics 2003;19(18):2404–12. Lambrix P, Habbouche M, Perez M. Evaluation of ontology development tools for bioinformatics. Bioinformatics 2003;19(18):2404–12. Martin-Sanchez F, Iakovidis I, Norager S, Maojo V, de Groen P, Van der Lei J, Jones T, Abraham-Fuchs K, Apweiler R, Babic A, Baud R, Breton V, Cinquin P, Doupi P, Dugas M, Eils R, Engelbrecht R, Ghazal P, Jehenson P, Kulikowski C, Lampe K, De Moor G, Orphanoudakis S, Rossing N, Sarachan B, Sousa A, Spekowius G, Thireos G, Zahlmann G, Zvarova J, Hermosilla I, Vicente FJ. Synergy between medical informatics and bioinformatics: facilitating genomic medicine for future health care. J Biomed Inform 2004; 37 (1): 30-42. Mitchell JA, McCray AT, Bodenreider O. From phenotype to genotype: issues in navigating the available information resources. Methods Inf Med 2003; 42(5):557-63.

since 1992 [19] with the objective to provide an overview of the latest outstanding research contributions in the field of health and medical informatics [20-23]. The yearbook is subdivided into its major part, the presentation of selected publications of the last year, a review section, a section on research and education and comprehensive information on IMIA's organizational structure and activities. The main section of selected papers is subdivided into the sections on health and clinical management, patient records, health information systems, medical signal processing and biomedical imaging, decision support, knowledge representation and management, education and consumer informatics as well as bioinformatics. Every year a special section is dedicated to a current area of research. This year's special section is on ubiquitous health care systems. Each paper section includes up to five selected publications and a synopsis.

The papers chosen for a yearbook have passed a thorough process of selection and reviewing. Included in the selection process were scientific papers in the area of medical informatics originally published between April 2003 and March 2004. They were ranked according to criteria like topic significance, coverage of literature, quality of research, results and presentation [24].

In the following sections we summarize the content of the IMIA Yearbook 2005 and discuss it in the context of ubiquitous health care systems. Table 1 gives an overview of the papers and authors.

Preface

The preface "Ubiquitous Computing and Pervasive Health Care" by Hans-Jörg Scheck from the Institute of Information Systems at UMIT (Austria) and the ETH Zurich (Switzerland) gives introductory definitions of ubiquitous and wearable computing and enumerates several recent scientific or industrial initiatives on ubiquitous computing in health care. Discussing possible application fields Scheck identifies the demographic development, especially in western countries, with an expectedly increasing number of elderly people as an important challenge. The resulting demand for new ways of health care services including health control and management could be supplied by means of ubiquitous computing. Scheck also emphasizes reliability and security as core requirements on ubiquitous health systems.

Information on IMIA

The International Medical Informatics Association (IMIA) is an independent organization established in 1979 with the objective to play "a major global role in the application of information science and technology in the fields of healthcare and research in medical, health and bioinformatics" [25]. The IMIA yearbook 2005 gives an overview of its organizational structure and its goals and objectives. A progress report is provided by Nancy M. Lorenzi, the IMIA president in 2005. Descriptions of 40 IMIA societies from all continents as well as the 19 IMIA Working Groups are given. Structure, objectives and activities of IMIA regional members are presented for APAMI (Asian Pacific) by Yun Sik Kwak, for EFMI (European) by Arie Hasman, for HELINA (African) by Sedick Isaacs, for IMIA-Lac (Latin-

American and Caribbean) by Lincoln A. de Assis Moura Jr., and for NAMI (North American) by Elizabeth Di Chiara and Don E. Detmer. Finally, the Healthcare Information and Management Systems Society (HIMSS) is represented as institutional member.

Review Section

The review section of the IMIA Yearbook comprises invited articles concerning current topics of medical informatics or contributing to the yearbook's special topic. Two of the four review papers are concerned with e-health strategies. N. M. Lorenzi from Nashville, Tennessee (USA) presents an overview of worldwide e-health strategies with a closer look at a sample of e-health efforts from the Asia-Pacific area, Europe, South America, the Middle East, Africa and North America. A. J. Mohan and A. B. Suleiman from Kuala Lumpur (Malaysia) focus on e-health strategies for developing countries considering Malaysia as an example. The government of Malaysia has declared telehealth as one of seven flagship applications initially constituted of four applications: a national consumer health portal, a lifetime health plan project, a continuing medical education portal and a teleconsultation network. The example of Malaysia demonstrates how even comprehensive and ambitious e-health strategies can be set up and realized consistently by developing countries. S. Teasdale from Nottingham (UK) draws with her review on primary care informatics as an own scientific discipline within health informatics and confirms this claim with a review of more than a hundred scientific papers reflecting past progress, present reality and future prospects of primary care informatics. She concludes that the experiences of primary care informatics are a valuable source for setting up and realizing e-health strategies. Bad news for fragmented health care systems is her impression that "the more fragmented the health care system, the less likely it seems to be that information solutions are implemented and used". The last review of G. Tröster from the ETH Zurich (Switzerland) is about an agenda of wearable healthcare and draws heavily on this year's special topic "Ubiquitous Health Care Systems". He gives an impressive introduction in the field of wearable computing and sketches the vision of a "Personal Health Assistant" (PHA) that continuously acquires the biometric and contextual status of a person and maps it onto a so-called Life Balance Factor that depicts the health status of a person in a way understandable even for medical laypersons. Based on a review of recent projects and developments he concludes that first PHAs will be available in two to three years.

Education and Research in Medical Informatics

Every IMIA Yearbook comprises current contributions regarding educational, training and research approaches in medical informatics throughout the world. This year's issue includes six articles starting with W. Hersh's presentation of the biomedical informatics program at Oregon Health & Science University in Portland (USA). M. Jaspers presents experiences and lessons learned after six years of International Partnership in Health Informatics Education (IPHIE). The IPHIE is an association of currently six universities with the aim of promoting education through international collaboration of graduate and undergraduate training programs in medical and health informatics [26]. P. Knaup et al. report the results of a study on the first 1024 medial informatics graduates of the universities of Heidelberg and Heilbronn concerning their job profiles. Health and medical informatics education in Japan is subject of the contribution of M. Okada. F. Pinciroli from the Laboratory of BioMedical Informatics, Distributed Bioinformatics Systems, and TeleMedicine of Politecnico di Milano (Italy) presents new e-health tracks in the engineering education at his university. G. Wright et al. from CHIRAD (UK) report on health informatics masters education, online learning and student support. CHIRAD is a non-profit organization concerned with research and development in the field of health informatics, "probably the first virtual R&D center for Health Informatics" [27].

Selected Papers and Synopses

For the IMIA Yearbook 2005, 34 original papers from 22 different international journals were selected. After the completion of the review process, experts in each field were invited to be guest editors for the corresponding section and write synopses based on the papers selected. We now briefly summarize the content of each section.

The guest editor for the special section *Ubiquitous Health Care Systems* is O. Bott from Braunschweig (Germany). He identifies different scenarios of ubiquitous computing in health care and relates the selected papers to these scenarios. The section starts with a paper concerning the assistance of health professionals by mobile computing. The before-and-after trial in a neonatal intensive care unit explores changes in documentation discrepancies when a resident is using a personal digital assistant instead of paper-based progress notes. The second paper suggests a concept to implement electronic consent of a patient for information exchange in a ubiquitous computing environment. The third paper gives an overview of wearable technology, a basic technology of ubiquitous computing. One of the most promising visions of ubiquitous computing in health care is the unobtrusive surveillance of patients with severe chronic diseases at home reducing the need for face-to-face medical visits or hospitalization. The last two papers of this section can be related to this scenario. A study concerning the application of this approach for patients with respiratory illness compared with traditional health surveillance is followed by a pragmatic evaluation of extending the psychiatric face-to-face therapy of a clinician by means of computer applications. Bott concludes that health care is an extremely promising application field for ubiquitous computing with several chances to improve quality and outcome of health services.

The section on *Health and Clinical Management* is guest edited by C. Lovis from Geneva (Switzerland). He relates the four articles of this section to three important characteristics of effective IT in health care: availability at affordable costs, extension of clinical decision support to management

and the ability to detect, prevent and correct undesirable events. The first two papers of this section address computer physician order entry (CPOE) with its potential effects and problems. One is a comprehensive review of current CPOE systems and discusses important aspects of their deployment and use. The second paper demonstrates that a CPOE can have a positive effect on the revenue of a general hospital for both inpatient and outpatient cases. The study is based on an analysis of all general hospitals in South Korea in a period of four years. The third paper of this section evaluates a nursing resource management information system with respect to its ability to provide decision support for nurses in charge of managing ward staff. The resulting improvements in terms of a reduction in expenditures for overtime and extra hours are impressive evidence for the usefulness of such systems. The last paper of this section evaluated systems for the surveillance of medical device-related hazards and adverse events in hospitalized patients. Interestingly, all methods examined have only limited ability to provide a true image of device-related incidents.

Guest editor of the *Patient Record* section is T. Beale from London (UK). He gives an impressive introduction into the immense complexity of patient records and especially their trans-institutional instantiation as electronic health records. Additionally, he refers to several standardization and research initiatives and open source activities. The first paper of this section reports on a cross-sectional study in a primary care setting in the UK that has the objective to determine if paper-based medical records contain more information than electronic records and if this information is easier to retrieve. The second paper examines the content of electronic patient records in general practices with the objective to determine the amount of textual content and the rate of coded diagnoses related to health problems and their completeness and correctness. Implementing a computer-based patient record system in a developing country with Kenya as an example is the subject of the third paper of this section. The system was implemented using a rather simple database management system and revealed impressive effects in reducing consultation time and hence improving efficiency. The last paper demonstrates the results of a cost-benefit analysis of electronic medical records in primary care in the US revealing significant financial benefits of electronic records in ambulatory settings.

The *Health Information Systems* section is guest edited by E. J. Gómez Aguilera from Madrid (Spain). A thorough economic evaluation of real-time teleconsultation of specialists by general practitioners in a primary care setting in UK is the subject of the first paper. In addition to examining the total costs of this telemedical service the randomized controlled study also – and this is rather seldom – focuses on patient-related costs in terms of time and absence from work. The second paper focuses on public health surveillance i.e. detecting disease outbreaks as early as possible. The presented system impressively demonstrates how to handle this complex task by reusing data that was already collected by health care providers. A comprehensive literature review on evaluations of patient care information systems that require entry of data by health professionals is subject of the third paper of this section. The authors suggest a framework to assess the success of such systems based on the work of Delone and McLean and discuss its appropriateness. The last paper of this section is devoted to the issue of modeling hospital information systems. A sophisticated meta-model and tool environment is presented that is especially suitable to support strategic information management in hospitals.

The section *Medical Signal Processing and Biomedical Imaging* is guest edited by C. Barillot from Rennes (France). He emphazises that advances made in digital image and signal processing are accompanied by a growing societal pressure for the cost-effective use of equipment. The classical way of interpreting the resulting data by health professionals becomes less and less feasible and needs to be supported by sophisticated algorithms and tools. The five papers of this section can be related to this necessity. The first paper focuses on catheter ablation procedures for treating ventricular arrhythmias and presents an algorithm that uses the single equivalent moving dipole model in an infinite homogeneous volume conductor to guide the catheter to the site of origin of the arrhythmia. The accuracy of the algorithm has been evaluated in computer and animal studies. The second paper proposes a representation of the cortical surface that can be used to study the cortex folding process and to exhibit potential stable anatomical cortical landmarks that are usually hidden in the depth of the brain. The third paper introduces a generic 3D finite element model of the facial soft tissue to address the problem of predicting deformations of this tissue resulting from bone repositioning in maxillofacial surgery. Expert surgeons have qualitatively evaluated the approach. Overcoming the limitations of classical paper-based medical atlas books is the objective of the fourth paper of this section. The proposed digital atlas enhances the well-known stereotaxic brain atlas of Talairach and Tournoux by a 3D-representation of the most brain structures contained in the paper version, a nonrigid matching capability which warps the atlas anatomy to an individual MRI dataset, the integration of knowledge from several neuroanatomical sources, and an interface to a navigation system. The last paper is concerned with inverse electrocardiography. An imaging approach is proposed that uses a bidomain theory-based surface heart model applied to single-beat data of atrial and ventricular activation. The approach can be used e.g. for the guidance of catheter ablation therapy during a right coronary artery procedure.

G. Hripcsak from New York (USA) is the guest editor of the section *Decision Support, Knowledge Representation and Management.* All of the four papers of this section can be related to clinical decision support. The first paper addresses the problem of prognosis prediction in intensive care in the context of quality of care programs. The prediction of patient mortality is used to monitor the quality of care delivered by institutions. A method is presented and compared to a traditional global logistic regression model that applies a hybrid learning approach to improve prognosis prediction. Artificial neural networks are often criticized for failing to explain upon which information they base their predictions. Paper

two of this section addresses this problem by using methods of relevance and sensitivity analysis to determine the most important predictor variables. The approach is applied to a validated neural network for predicting community-acquired pneumonia. Using simulation tools for predicting the development of blood glucose values to help diabetics or diabetologists tailor the right insulin dose and diet is a common approach, but enhancing the accuracy of these simulation models is an ongoing research effort. The third paper enhances an existing simulation approach by considering the effect of alcohol on diabetes patients. The approach was evaluated based on data from a clinical study. The last paper examines the effects of computerized decision-support for prescribing in primary care. The randomized controlled study reveals interesting effects on the reduction of the rate of potentially inappropriate prescriptions when using computerized decision-support. Hripcsak concluded in his synopsis that explanation and creditability remain important success factors for these kinds of systems.

The section *Education and Consumer Informatics* is guest edited by D. Gammon from Tromsø (Norway). One paper of the section is devoted to the education of medical students; the remaining three papers are about supportive tools for patients. The first paper related to medical education examines the question if a computer-based virtual patient is useful for teaching communication skills to medical students and how the students experience a virtual patient. The first of the patient-oriented papers focuses on interactive computer training as a therapeutic tool in Alzheimer's disease. The objective of the system is to improve the patient's ability to remember how to perform tasks of everyday life. Supporting patients in understanding their current medications in terms of their effects and how to use them, their potential side effects or the effects of combining certain drugs is subject to the third paper. The presented integrated pharmaceutical information system was evaluated and led to a better understanding and knowledge of the participating patients concerning their individual medication. The last paper presents the results of a randomized trial in children suffering from headaches or juvenile idiopathic arthritis with the aim to compare paper-based pain diaries with electronic diaries. The results of the study are an impressive indicator that improving compliance and accuracy in patient disease diary recording is possible with mobile computing technologies like personal digital assistants.

The last section *Bioinformatics* is guest edited by T. Yao from Yokohama (Japan). The papers in this section span a wide variety of subjects starting with the presentation of a common infrastructure for data management and integration that support advanced biomedical applications. The system called caCORE was developed for cancer research and has been used to develop scientific applications that use data from different genomic and clinical science sources. The second paper evaluates four current tools for developing and maintaining ontologies in terms of performance and user-friendliness with the gene ontology as a test case. The third paper authored by 30 researchers is concerned with the analysis of possible synergies between medical informatics and bioinformatics. Besides recommending realistic research items for collaborative projects the role of biomedical informatics as a "connector" of both research fields is discussed. The last paper assesses the availability and nature of data of several biological databases for the use case of navigating from phenotype to genotype. As a result many problems and informatics issues are pointed out.

Conclusions and Outlook

The IMIA Yearbook 2005 again bears witness to the magnitude of facets of medical informatics. Its contributions impressively demonstrate progress within each subdiscipline of medical informatics as well as progress in integrating technologies and methods from different disciplines towards solutions of ever increasing complexity. Medical informatics therewith is on its way to meet the challenges that the continuous and dramatic process of change of our health care systems is posing on it. The special topic of this Yearbook "Ubiquitous Health Care Systems" reflects a transition into a new era of information processing in health care corresponding to these challenges. Impressive examples demonstrate chances to reduce consultation or hospitalization rates and costs by intensifying home care and monitoring as well as chances to reduce the workload on health care professionals. Intensifying the presence of information technology in the immediate vicinity of a person by simultaneously reducing its perceptibility stimulates fantastic new opportunities but also is a massive societal challenge. The circumspectly combination of biomedical sensors, new ways of man-machine interaction, information and knowledge bases, decision support systems, integrative and transinstitutional health information systems is needed to turn the vision of ubiquitous health care systems into reality. Consistently, all of the established sub-disciplines of medical informatics are demanded to contribute to this promising new research field. The ongoing evaluation of the resulting technology concerning their compatibility with user requirements, safety and security concerns and other technology-oriented design criteria but also with societal and economical constraints should have highest priority especially in the sensitive context of ubiquitous computing in health care. The next yearbook 2006 (which is to appear in March, 2006) will take care of this issue and focus on "Health Technology Assessment" as its special topic. It will stress the necessity of assessing the clinical, economical and social effects of health technology and provides an overview on current techniques and results in the field of medical informatics.

Up-to-date information about current and future issues of the IMIA Yearbook is available at http://iig.umit.at/yearbook/.

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