Preface

Within the last years a variety of new healthcare concepts for supporting and assisting users in technology-enhanced home environments emerged. These so-called “Smart Healthcare Technologies” are characterized by a combined use of information and communication technologies and health monitoring devices in the home domain. The spectrum of emerging technical applications covers a broad variety of developments, reaching from internal technologies (implants for monitoring physiological signals) over devices integrated into clothes (wearable technologies) to healthcare robots or smart home technologies, which support older people in keeping up their independent life at home. Nevertheless, practical experience shows, that the brilliance and novelty of technical solutions does not guarantee the successful diffusion of these innovations. The success of (future) healthcare technologies depends decisively on the extent to which technical developments meet the specific needs and demands of users and their willingness to use and integrate the devices into their personal spaces.

In order to fully exploit the potential of smart healthcare technologies, not only aspects of technical feasibility have to be considered. Innovative health technologies substantially depend on the patients’ acceptance to use them. But technology acceptance is a complex phenomenon, which is assumed to be influenced by a number of factors: the diversity of users, the way technology is embedded into the environment, the extent to which technology respects feelings of intimacy and dignity, and the extent to which health technologies provoke feelings of trust, respect and safety. In order to meet these needs in the design process of new technologies, an integrative and multidisciplinary approach is required, which combines engineering and medical knowledge with theoretical and methodological contributions from the social sciences and humanities. This book will address this challenge by providing an in-depth introduction into medical, social, psychological, and technical aspects of smart healthcare applications as well as their consequences for the design, use and acceptance of future systems.

The knowledge and insights provided in this book will help students as well as systems designers to understand the fundamental social and technical requirements smart healthcare technologies have to meet. By providing a well-rounded introduction within one single volume, this book is equally suited as a library reference and upper-level course supplement, but also represents a first-class resource for independent study.

The book consists of 14 chapters, which are clustered in three sections: System Design, Frameworks and Applications, and Prototypes and Research Infrastructures.

The first section on System Design hosts five chapters addressing different design aspects of smart healthcare systems. In Chapter 1 entitled Wireless Networking Credibility, Device Interoperability & Other Important Issues to Take into Consideration for the Deployment of a Homecare Service Provision Model, Konstantinos Perakis and Dimitris Koutsouris of the National Technical University of Athens,
Greece discuss the utilization of wireless sensor technologies for unobtrusive patient monitoring. The chapter provides a discussion on the utilization of wireless technologies, for the deployment of monitoring wireless personal area sensor networks for the unobtrusive monitoring of patients. The chapter answers some fundamental questions, including which is the most appropriate technology for such a networking architecture, what is the best topology for home monitoring wireless sensor network solutions, and what is the performance of the wireless networking technologies. In addition, the chapter initiates some brainstorming regarding the questions of how many interoperability protocols we actually need, presenting the strong and weak points of most of the current interoperability standards utilized in the field of homecare, with emphasis on the encoding and formatting of ElectroCardioGram (ECG) waveforms. The chapter closes by pointing out other important issues in the field of homecare, such as legal and safety issues.

Chapter 2, Sensor Networks in Pervasive Healthcare Computing authored by Zhilbert Tafa from the Belgrade University, Serbia, outlines the technical design space of wireless sensor networks and highlights technical as well as non-technical aspects implied by the integration of technology into medical environments. Advances in wireless sensor networking (WSN) have opened up new opportunities in distributed informatics. Pervasive healthcare, based on WSN, is an emerging technology area with great potential of future applicability. Small-size devices capable of sensing, computing and communicating, enable pervasive platforms; while opening up a large number of technical, medical, social and ethical questions and challenges. Though mostly focused on technical issues, this chapter also addresses some non-technical aspects implied by the technology implementation in medicine. It presents the general philosophy of the technical design space of wireless sensor networks, mostly highlighting: energy conservation, communication aspects, security, and software implementation. The state-of-the-art in ubiquitous healthcare, challenges, open questions, as well as the non-technical aspects of the system implementations are also presented here. As such, the chapter gives an insight on most important WSN-based pervasive computing issues, the multidisciplinary application-driven design of these systems, and their position in pervasive healthcare computing.

Chapter 3, Next Generation Body Area Networks and Smart Environments for Healthcare, by Paul Fergus et al. from Liverpool John Moores University, UK discusses the research challenges currently encountered in the fields of body area networks and smart environments as well as the trends that are likely to emerge from these challenges. The evolution of wireless network protocols such as Bluetooth and ZigBee, and the reducing size, cost (and power consumption) of small-scale sensor devices means that new approaches to healthcare monitoring and provision are now possible. From the technological side, new wireless devices can be envisaged that can monitor patients both externally (in terms of movement, flexibility and mobility) and even internally (in terms of embedded devices). From the health and social care side, such wireless devices enable home monitoring of patients. This can allow more efficient and effective use of health and social care professionals, and also allow patients in remote areas to potentially receive as much healthcare monitoring as patients in urban environments. However, it is important that any use of such new technologies is carefully piloted and integrated with traditional health and social care approaches, especially in terms of the reliability and security of patient data. The authors provide a discussion on the state-of-the-art research initiatives that are trying to address these challenges. A discussion is presented on some of the more recent background work and a view of what future body area networks and smart environments might look like. Throughout the discussion they present the challenges faced by many research communities and the likely trends that will emerge given such challenges.
In Chapter 4 entitled *From Idea to Use - Lessons Learned from a Participatory ICT Healthcare Case Study* Henrik Enquist, Sweden, presents a case study investigating the use of a mobile e-health device for storing personal information and enabling communication with healthcare information systems. The objective of the case study was to develop and investigate the use of a novel e-health technology called the “Memory Stone”. This personal device is intended to be used for storing information and enabling communication with healthcare information systems. It would also serve as an intimate repository during pregnancy, and as such, function as a learning tool during the course of a pregnancy. Using a participatory design approach, the work was performed in collaboration between a multidisciplinary research team, ten pregnant women, and eight healthcare professionals including midwives, general practitioners and medical specialists. In this chapter, some more or less problematic issues encountered during the case study are discussed and put forward as topics to be considered in future research concerning e-health technology. This includes areas such as initiative versus creativity, methodological issues, stakeholder interests, and other difficulties when introducing novel information technology in a healthcare context.

Matthew L. Lee and Anind K. Dey from Carnegie Mellon University, USA discuss the design process for the development and evaluation of a smart lifelogging system in Chapter 5 entitled *Smart Lifelogging Technology for Episodic Memory Support*. Recent episodic memory impairment (EMI) affects over 26 million individuals with Alzheimer’s disease. Smart lifelogging technologies can capture a log of the user’s personal experience using wearable or embedded recording devices and present elements of that log as cues that can support memory recollection for people with EMI. In this chapter, the authors describe their design process for developing and evaluating a smart lifelogging system specifically designed to help people with mild EMI remember their experiences better and reduce the burden on their caregivers. The design process includes two formative field studies to understand both what lifelogging data is most effective for supporting memory and how to present these data. They found that their self-guided approach was more effective at supporting people’s ability to retain a detailed memory of their experiences, to feel more confident about their memory abilities, and to reduce the additional burden placed on the caregiver than a caregiver-guided approach.

The second section addressing Frameworks and Applications comprises four chapters illustrating different examples of smart healthcare frameworks and applications. In Chapter 6, *Resolving and Mediating Ambiguous Contexts in Pervasive Environments* by Nirmalya Roy et al. from the Institute for Infocomm Research in Singapore, an ontology-driven context mediation framework for resource constrained sensor networks is discussed, which employs efficient context-aware data fusion and information theoretic sensor parameter selection in order to achieve optimal state estimations. Pervasive computing applications envision sensor rich computing and networking environments that can capture various types of contexts of inhabitants of the environment, such as their locations, activities, vital signs, and environmental measures. Such context information is useful in a variety of applications, for example to manage health information to promote independent living in “aging-in-place” scenarios. In reality, both sensed and interpreted contexts are often ambiguous, leading to potentially dangerous decisions if not properly handled. Thus, a significant challenge facing the development of realistic and deployable context-aware services for pervasive computing applications is the ability to deal with these ambiguous contexts. In this chapter, the authors discuss a resource optimized quality assured ontology-driven context mediation framework for resource constrained sensor networks based on efficient context-aware data fusion and information theoretic sensor parameter selection for optimal state estimation. It has the ability to represent contexts according to the applications’ ontology and easily composable ontological rules to mediate ambiguous contexts.
In Chapter 7, entitled *Supporting the Ubiquitous Doctor*, Carlos Ferraz (Centro de Informática, Universidade Federal de Pernambuco, Brazil) and Juliana Diniz (Departamento de Estatística e Informática, Universidade Federal Rural de Pernambuco, Brazil) illustrate the design and implementation of a context-aware system named “UbiDoctor”, which offers context, content, and session management for unobtrusive session migration in multi-device scenarios. In health service environments, mobility support is an important issue, given that the mobility of the medical professionals is inherent to the organizational structure of healthcare entities, such as hospitals and medical centers. The concept of the “Ubiquitous Doctor” refers to a doctor that works anytime, anywhere and uses any computer device. For doing this, the doctor needs support to migrate a work session started on a device to another one, either for convenience (more comfort) or forced (e.g. low battery). This so called ‘session migration’ presents some challenges like preventing from disruption and performing quickly, so the Ubiquitous Doctor’s productivity can be improved. This chapter presents the design and implementation of a context-aware system (middleware services and application) to support the Ubiquitous Doctor, as well as experiments that show that the average migration time represents a low impact on the transition time between medical activities, and an assessment carried out with a group of doctors confirmed the importance of supporting the migration process in order to make it fast and reliable. The doctors also agreed on the importance of using the most convenient device based on context variables like user status and location.

Chapter 8, *mVITAL: A Standards Compliant Vital Sign Monitor*, authored by Yusuf Ozturk and Jayesh Sharma from the San Diego State University, USA starts by deriving the requirements for a vital sign monitoring solution and then presents an end-to-end medical device networking system named “mVITAL“. Pervasive care and chronic disease management to reduce institutionalization is a priority for most western countries. The realization of next generation ubiquitous and pervasive healthcare systems will be a challenging task, as these systems are likely to involve a complex structure. Such systems will consist of various devices, ranging from resource-constrained sensors and actuators to complex multimedia devices, supporting time critical applications. This is further compounded by cultural and socio-economical factors that must be addressed for next generation healthcare systems to be widely diffused and used. In this study, the requirements for a vital sign monitoring solution are derived and based on these requirements a standards compliant medical device networking solution is presented. mVITAL is an end-to-end solution based on IEEE-11073 framework. IEEE-11073 defines a family of standards and nomenclature for device communication protocol, data format and logical interface between monitoring station and standard compliant medical devices. mVITAL is not only providing medical sensor networking and vital sign monitoring but also closes the loop by signaling alert messages to the caregiver and allowing pervasive access to vital signs of a patient using smart phones over a heterogeneous network. A role based access control mechanism is developed to limit the access to secure data. The end-to-end delay and the variations in delay for both the sensor data collection and the pervasive access are analyzed. mVITAL is developed as a complementary solution augmenting functionality of a hospital information system and can be loosely coupled with the hospital information system using web services.

In Chapter 9, *A Highly-Interactive and User-Friendly PHR Application for the Provision of Homecare Services* by Vasso Koufi et al. from the University of Piraeus (Greece), a prototype of a Personal Health Record (PHR) system is presented that aims at supporting chronic disease management. Homecare is an important component of the continuum of care as it provides the potential to improve quality of life and quality of healthcare delivery while containing costs. Personal Health Record systems constitute a technological infrastructure that can support greater flexibility for healthcare professionals and patients, thereby allowing for more effective homecare services. In particular, PHRs are intended to reach patients
outside of care settings, influence their behaviors and satisfy their demand for greater information and access. Moreover, PHRs can facilitate access to comprehensive real-time patient data for healthcare professionals thus enabling them to identify problems quickly (e.g., prior to scheduled appointments) and steer patients to appropriate facilities when needed. To this ends, PHR technology needs to evolve well beyond providing a consolidated patient record, in ways that make it more widely applicable and valuable to health systems. The development of applications and tools on top of PHR systems can allow the PHR to function as a platform for both patients and healthcare professionals to exchange information and interact with the health system (e.g., scheduling appointments electronically). This chapter presents a prototype PHR-based system that aims at supporting chronic disease management. In particular, it assists healthcare professionals in assessing an individual’s condition and in forming the appropriate treatment plan while it provides individuals with a user-friendly application for step-to-step guidance to their treatment plans. The system has been developed on the grounds of a service-oriented architecture where healthcare process automation is realized by means of dynamic, patient-related workflows.

In the third section on Prototypes and Research Infrastructures, several examples of prototype systems and research infrastructures for smart healthcare systems are presented. John F. Duncan et al. from Indiana University, USA present an event-driven monitoring system designed for elder care in Chapter 10 entitled The Portal Monitor: A Privacy-Aware Event-Driven System for Elder Care. The Portal Monitor is an example of privacy-aware design that addresses specific risks based on gerontology literature and confirmed by focus groups with representations of the target group. The design emphasizes data transparency, minimizes data collection and storage, and balances elder control with elder risks. By being event-driven, this monitor enables a caregiver to react more efficiently than with passive monitoring technologies such as traditional security cameras. By reducing cognitive load, the system empowers caregivers, and allows them to provide a higher quality of care – thus allowing the elder to remain in their home as long as possible. The authors make innovative use of arguably the most pervasive communications infrastructure – the cellular network – to enhance elder autonomy without sacrificing their privacy.

In Chapter 11, Interactivating Rehabilitation through Active Multimodal Feedback and Guidance, Bert Bongers (University of Technology, Sydney, Australia) and Stuart Smith (Prince of Wales Medical Research Institute, Australia) present a novel rehabilitation solution for patients with neurological damage. The chapter outlines a Human-Computer Interaction inspired approach to rehabilitation of neurological damage (e.g., spinal cord injury) that employs novel, computer guided multimodal feedback in the form of video games or generation of musical content. The authors report an initial exploratory phase of a project aimed at gaining insight into the development of spinal cord injury (SCI) rehabilitation tools. This exploration included observation of a number of patient interactions in their current rehabilitation routines, the development of initial prototype proposals, and finally through to the development of rapid prototypes which can be used in rehabilitation settings. This initial phase has yielded an understanding of the issues surrounding the development of novel technologies for rehabilitation that will direct further research in the area of rehabilitation engineering. Through the integration of novel methods, in particular the use of interactive physical devices, to the rehabilitation of SCI patients, larger scale research into efficacy of the devices can be undertaken. These developments may eventually beneficially impact upon the instruments used, the training methods applied and the rehabilitation routines undertaken for individuals living with neurological damage.

In Chapter 12, Mapping Input Technology to Ability, Ainara Garzo et al. from the Fatronik Foundation (Spain) present the design process of an alternative input system for persons with motor disabilities. Accessibility is a critical aspect of health care system design, particularly e-health systems. Ability to access
services may change as ones abilities vary, by situation as in the use of a cell phone while driving, by condition, as during an illness or as a result of an accident and in the process of aging. As the population becomes increasingly skewed towards elders, the ability to communicate with and via computers will become more and more important. Communication consists of two processes: presenting information in an accessible manner and receiving input from the user in a mode that fits the users skills and needs. This chapter describes the design process in providing an alternative to a keyboard for input by persons with motor disabilities.

Chapter 13, Restoring Balance: Replacing the Vestibular Sense with Wearable Vibrotactile Feedback, by Maria Benini et al. (Eindhoven University of Technology, The Netherlands) reports on the iterative user-centered design process of different wearable prototypes of a vibrotactile feedback system for substituting the balance sense. Bilateral vestibular loss (BVL) is a disorder of the balance sensory organs in the inner ear and can cause falls, which may have grave consequences, particularly among elderly. This paper presents the iterative user-centered design of vibrotactile feedback mechanisms for substituting the balance sense. Six wearable prototypes were created to compare the suitability of different body parts (foot, ankle, knee, waist, shoulder, upper arm) for perceiving this type of feedback and to compare different encoding mechanisms (number, intensity, rhythm of vibrations). In a second iteration, two of these wearable devices (for the ankle and the waist), in two feedback styles (directional and non-directional) were improved and evaluated. Based on the combined studies and interviews conducted with patients and specialists, it is argued that vibrotactile non-directional balance feedback should be applied to ankles, and that such devices should be integrated in training systems.

The section closes with Chapter 14, A Home-Based System to Support Delivery of Health and Social Care, authored by Kenneth J. Turner, University of Stirling, UK, which demonstrates a research infrastructure for supporting care delivery to the home. The world-wide problem of an ageing population is introduced. This will require older people to be looked after for longer in their own homes. A brief overview is given of care delivery in the home, focusing on computer-based home care as a likely component of future solutions. The challenges faced by home care technology are discussed. It is explained how the Match project (Mobilizing Advanced Technologies for Care at Home) is addressing these issues. The philosophy, architecture and approach of this project are discussed.

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