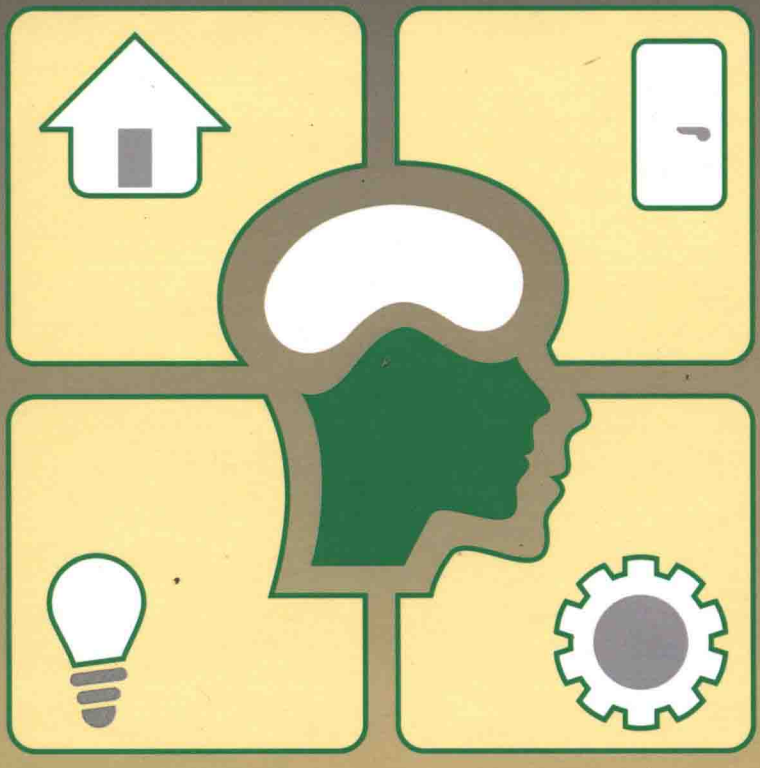
# Smart Technologies in Healthcare



Editor
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# Preface

Assistive Technologies in Smart Environments can help, transform, and enhance the way people with disabilities manage their daily lives and activities that would otherwise be difficult or impossible for them to do. However, despite the developments of a lot of new assistive technologies, much need to be done, especially concerning the establishment of standards and guidelines for the field. Users' impairments and particularities are so diverse that implementing complex technological solutions—mandatory for user adaptation—represents a major challenge in terms of universal design. Also, despite the rapid evolution of the field in the last decade, it is still considered as an emerging one. In this context, the main objective of this book is to investigate the most recent solutions to problems occurring in various aspects of assistive technologies specifically applied to the domain of smart environments.

This volume contains chapters covering the main aspects in the field of assistive technologies. The introductory chapter aims to show the historical evolution of the notion of assistive technologies in smart environment and to present it in the current context. It also presents the new paradigm of *open innovation* constituting the key to the success of the most prolific research teams around the world. The following chapters aim to throw light on the state of the progress in fields, such as: human activity recognition, automatic learning of the user's profile, human perspective of the technologies, physiological and cognitive monitoring, context awareness, user interface, security aspects, etc.

Activity recognition and automatic learning of human activities represent a core issue for developing useful assistive technologies. To be able to help a user, the system must first need to know what he is doing and how, in order to provide an adapted assistance. That is why a complete chapter on how applying data mining in smart homes has been included in this book. This part of the book is the most technical aspect of the problem in

regard to computer science. It is also one of the subjects that have been the researched and published.

The human perspective constitutes another key aspect of assistive technologies. However, it has largely been overlooked and only been treated superficially in most papers. Nevertheless, this is a fundamental element of assistive technology for the acceptance of the developed new devices by the users and the caregivers. Therefore, the technologies must be developed for the people, according to the human perspective. Technology must adapt itself to its user, not the other way around. For that reason, we decided to include a full chapter presenting the core elements of the human aspects, which are fundamental to the development of assistive technologies.

Context awareness refers to the ability of a system to capture, model and use specific information about the environment surrounding the system, such as location, time, user profile, etc. Using contextual information to adapt the assistive services to the user constitutes a formidable challenge. In this book, a comprehensive chapter on this issue has been included. This chapter also includes a real case study.

Interfaces are the link between the system and the user. Therefore, they must be easy to use, be intuitive and efficient. To address this aspect of the problem, a chapter has been added that presents a case study with senior people on the usage and design of user interfaces. The results of the study can be used as guidelines for creating good interfaces.

Physiological and cognitive health monitoring constitute a prolific and important field of assistive technologies. Achieving efficient and effective monitoring is, however, not so easy. Which device or sensor to use? How to use it? How to design the device to be accepted by the user? How to process and presents the data in order to be useful? To answer these questions, two chapters have been included in the book to cover aspects related to health monitoring.

Finally, the security perspective of the technology should not be neglected. This issue is generally overlooked, in more attention is paid to mostly neglected in published literature technical or human aspects of the technology. However, the security issues are essential if it is to be deployed. What about fault tolerance? What about reliability of the system? What about the decisions taken by the intelligent system that may put the user in danger? In this book, we have included a full chapter on a new approach to address this important issue based on the Discrete Controller Synthesis

(DCS). This new intuitive approach allows for formally ensuring the security aspect of an intelligent system.

This book will serve as a reference for researchers, practitioners and engineers that seek to have a complete portrait of the field of assistive technologies.

# Contents

# 1

# Ambient Smart Assistive Technologies

## Challenges and Perspectives

*Bruno Bouchard*[1,2,*] and *Sébastien Gaboury*[2]

## 1. Introduction

Today, most Western countries face an unprecedented demographic crisis caused by accelerated ageing of its population (United Nations 2013). This is made worse by a lack of resources and shortage of qualified home-care workers. Senior citizens, many of whom suffer from the loss of autonomy caused by cognitive or physical disorders, or both, wish to remain at home as long as possible. Staying in the home is clearly desirable not only from an economic point of view (Oderandi et al. 2012), but also because it offers a better quality of life by allowing the deinstitutionalization that is consistent with societal values: people should live as normal a life as possible without segregation and enjoy a dignified existence with full access to autonomy. For many seniors with moderate to severe functional dependence, however, ageing at home entails coping with numerous risks and practical challenges. The home environment has to be adapted, if not technologically enhanced, using intelligent technologies and sensors to offset cognitive and physical

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deficiencies, to provide assistance and guidance, to ensure safety and to support natural caregivers and professionals in their work. This vision of the future, which has now become a reality, originated in 1988 at the Xerox Palo Alto Research Center (PARC), resulting in the work entitled *'The Computer for the 21st Century'* by American scientist, Mark Weiser (Weiser 1991). From the early 1990s, a large community of scientists developed around this specific research niche (Blackman et al. 2015), actively seeking technological solutions for these very human problems by employing such concepts as ubiquitous sensors, ambient intelligence (AmI) and assistive technologies to keep people in their homes. The idea achieved maturity in the mid-2000s and we have since seen the fruits of this research develop into tangible innovations, technologies to promote autonomy and quite substantial economic spinoffs. For instance, in the United States alone, the market for assistive technologies based on ambient intelligence will reach approximately $60 billion (US) a year by 2018, with expected annual growth of nearly 6 per cent over the next decade (BCC Research 2013).

## *1.1 What is Ambient Assisted Technologies?*

In general, Ambient Assisted Technologies (AAT) refer to the use of an array of electronic devices—sensors and actuators or effectors—incorporated into everyday objects, such as cabinet doors, stoves, lamps, screens and so on in a transparent way, meaning that they are not visible to the user, in order to monitor the user's status and provide assistance as needed, such as advice, feedback, guidance or warning—of a stove left on, for example, based on information collected and historical data (Ramos et al. 2008). In the scientific literature (Queirós et al. 2015), the interdisciplinary challenges related to this area are regarded as hugely complex and many key questions require investigation. For instance:

- What technologies should be developed and applied in order to meet the needs of the people in need, natural caregivers and practitioners?
- What kinds of sensors and actuators are better used?
- How should the necessary models of artificial intelligence be developed in order to implement these technologies?
- How are they to be adapted to user profiles?
- How are they to be deployed and maintained?
- Can technology improve the ability of the people with diminished autonomy to perform day-to-day activities?
- What new skills will practitioners need to acquire?
- What are the productivity gains for the healthcare system?

- How to develop marketing strategies and ensure the transfer of technology to enterprises?
- What is ethically acceptable and what is not?

The great difficulty in addressing the scientific issues in a field where the needs are so pressing is attributed to a number of factors—the almost unprecedented interdisciplinarity of the questions to be researched, the substantial infrastructure and equipment requirements for prototyping, the difficulties research teams face in establishing partnerships with the public and private sectors and with users in order to carry out experiments that demonstrate the effectiveness of the proposed technological solutions and so on. A few teams actually have access to this combination of key factors, which are the basis for efficiency in developing ambient assisted technologies.

## *1.2 Assistive Technologies* vs. *Automation*

Often, the term 'assistive technology' is used to describe what is, in fact, an 'automated system'. For the sake of this book, we think it is important to clearly define both the concepts.

- **Automated System.** A system made of sensors and actuators which perform actions on behalf of the person. Most of the time, this kind of system is made for carrying out the task for a person in order to alleviate his workload. It is good in the context of a factory, for instance, where you want to execute a maximum of tasks without human interventions, in order to minimize the number of employees. In the context of assistance, this is actually bad because the system fails to increase the user's autonomy.
- **Assistive System.** An assistive system is also made of sensors and actuators, like the automated one. However, we can say that the assistive system is smarter than the automated one. In this sense, instead of simply performing the task for the user, it will try to provide real-time assistance for completing activities to increase the autonomy of the person. Of course, in case of immediate danger, the system will perform actions directly, but the main purpose of the system is to help the user to carry out his activities; not to perform them on his behalf. This provides physical and psychological benefits to the user.

The difference between both the concepts may seem subtle. In fact, an assistive system is a specific form, or a more evolved form of automated

systems. To be sure to understand correctly, let's conclude this section with a small example. Let's say that Peter, a cognitively impaired user with head trauma, is cooking a chicken on the stove. After 40 minutes, Peter is distracted by the phone and after the call; he goes to his bedroom and forgets the chicken. After a certain delay, let's say 20 more minutes, the smart home system will take some action. The question is: Which action should the system make? In the case of an automated system, it will simply cut the power of the stove. This action is correct in order to preserve the safety of the person, but it does little to help the user in his rehabilitation process of restoring his cognitive abilities. On the other hand, an assistive system would begin by sending cues, hints and reminders to the user. For instance, it could begin by flashing lights in order to draw a path to the kitchen. Once the user is in the kitchen, it would send an audio message telling him that the chicken on the stove is ready. A screen can also show a video example of how to get the chicken out of the stove and how to turn off the power. Of course, if the user is unresponsive to a reasonable amount of prompting, or if there is an immediate danger, the system will cut off the power by itself.

## 2. Assistive Technologies: Open Innovation Model

Developing assistive technologies is not a simple task, especially in the academic field. As we described in Section 1, the challenge is complex because it is hugely interdisciplinary. Most of the universities tend to separate each field of research in different faculties, departments, etc. This approach by fields of research tends to complicate interdisciplinary projects. Moreover, the funding agencies also tend to finance projects by specific field of research. For instance, in Canada, we have a specific national funding agency which supports research projects in the field of engineering and natural sciences. We also have another agency supporting projects in the medical field. But what about us? We are developing assistive systems with sensors and actuators (engineering), with artificial intelligence (computer sciences), which are adapted and tested with cognitively impaired patients (medical field). Another issue is related to the very applicative finality of what we are developing. Assistive technologies are not just concepts; they need to be conceptualized, prototyped and tested with real patients. To be efficient, a lab working in the field needs to be able to cover all those aspects properly. In the last decade, we saw a lot of research done in the field, but only few real assistive products came out of that good research. Often, research teams will only concentrate their efforts on the concept, or on the prototype. Teams often have difficulty in accessing real data, or having access to real users/patients to test their technologies.

To solve these issues, we deployed in our lab an innovative integrated research program covering the entire vertical process of technological development, using the 'Open Innovation' model developed by the renowned Harvard Business School (Cherbourg 2006) and recently adapted for assistive technologies by the British Academy of Management (Oderandi et al. 2012). In that model (Fig. 1), every technology generated by research must go through seven key steps in synergy with all the partners: users, practitioners, researchers, public agencies and private enterprises:

1. Pre-technology (for example, identification of needs)
2. Theoretical bases related to technology (for instance, data mining approaches)
3. Systems development and prototyping
4. Controlled-environment testing (laboratory, ideally with real infrastructure)
5. *In vivo* experiments (real context, with users, on a long period)
6. Promotion, intellectual property and technological transfer
7. Marketing, commercialization and creation of spinoffs and start-up

Obviously, while this area of research is highly interdisciplinary, its gravitational centre and scientific driver is firmly planted in Ambient Intelligence (AmI) (Ramos et al. 2008). The technology—sensors and actuators—required to set up such assistive systems already exists (Bouchard et al. 2014). The scientific challenge is to exploit it successfully using innovative approaches in AmI in order to create intelligent technologies that provide the needed services to users.

## 3. Conclusion

In conclusion, we can say that the field of assistive technologies is currently one of the most important research and development areas of the future. This leading-edge sector target four main objectives: (1) to generate benefits for society and individuals by preserving autonomy and quality of life for people with cognitive or physical disorders and their natural caregivers through the creation of assistive technologies that can be efficiently integrated within the living environment (home or seniors' residence); (2) to achieve scientific advances in the form of formal models, artificial intelligence algorithms, rehabilitation practices based on conclusive data, changes in working methods and so on, through the rigorous *in vivo* testing and development of the aforesaid assistive technologies; (3) to build bridges between research, practice, users and industry by bringing

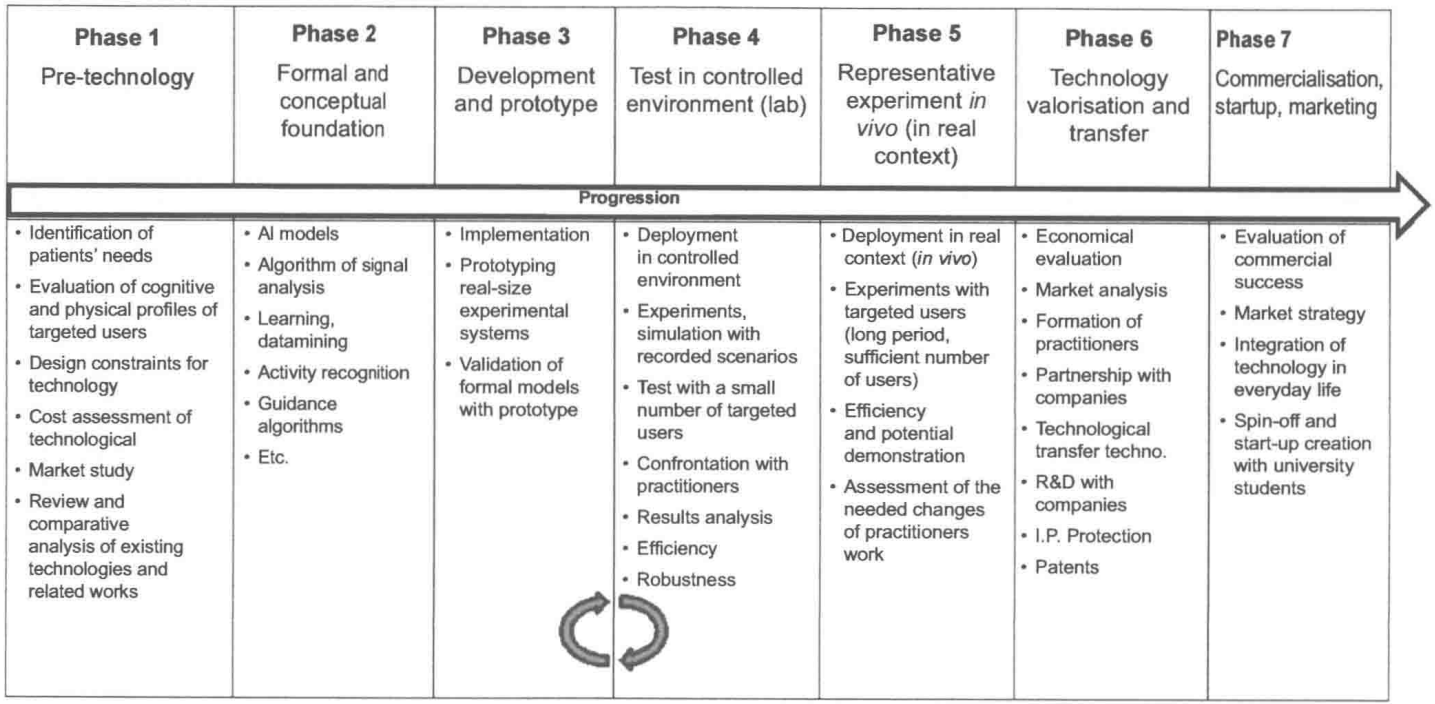


**Fig. 1.** Open innovation model applied to the field of assistive technologies.