The Engineering Handbook of Smart Technology for Aging, Disability, and Independence

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The Engineering Handbook of Smart Technology for Aging, Disability, and Independence
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Foreword

The disability and aging fields are dynamic. We are in a transition period, moving away from an old vision for disability to a new one. Older adults and people with disabilities were viewed as dependent and in need of consistent professional guidance. Increasingly, they are viewed as people with abilities, much like other people. The old model of disability focused solely on the individual level, and on approaches to disablement only at the body level. The new model of disability is universal, integrative and expansive. Technology innovation and the international human rights movement have provided much of the energy driving transition to a new integrative model of disability and aging. The Engineering Handbook of Smart Technology for Aging, Disability and Independence provides a comprehensive introduction to the new model and related challenges for research and development.

The integrative model is embodied in the World Health Organization’s (WHO) International Classification of Functioning, Disability and Health (ICF), adopted in 2001. Disablement is approached at the body, functional, social and environmental levels. The ICF components, body, activities, participation and environment, are in dynamic relationship to one another, therefore, generating interesting challenges for research and development (R&D) and measurement. Assessment measures assume a real world context of school, family and employment.

The integrative model is participatory. Participation of end users and stakeholders has implications for R&D and the education and training of professionals. Throughout the world, people with disabilities and older adults have an expressed preference to live as independently as possible in their communities. As the Handbook illustrates, they often need technological supports to realize their everyday living objectives. End users of technology will be more involved in the planning and implementation of studies that generate quality of life outcomes. The technology development process must become proactive in initiating participatory design that receives feedback from end users, industry and regulators. Engineering curricula must be adapted to teach our students about the
integrative model of disability, participatory design and the importance of social factors such as end user acceptance and stakeholder markets and regulation.

Breakthroughs in biomedical and technological sciences and their applications are ongoing. Applications have improved the quality of life for some but not all older adults and people with disabilities. Human rights advocacy for full citizenship and community inclusion have permeated the international arena. The World Health Organization has estimated the disability population as approximately one billion, mostly living in lower resource countries. Without commitment to accessibility, affordability, availability and usability, technology will not benefit the many around the world that need it to pursue active lives, to study, to work and live in their communities.

The Handbook sets out a framework in which engineering innovation is complemented by exploration of contextual factors such as human rights, standards, policy and the role of international organizations. While the engineering community may grasp the potential of technology to improve quality of life, it also has an important role in the realization of the new vision for older adults and people with disabilities through its education and advocacy within the technical community. Engineering innovation must be further harnessed to effect social good.

Kate Seelman
2008
Aging and disability have begun to impact our quality of life. Elderly people and those living with disabilities [people with special needs (PwSN)] are loosing their independence and overall wellbeing. The growing PwSN population is too large to be cared for through traditional government programs. The cost associated with such programs and the lack of a skilled caregiver workforce makes it very difficult to meet the needs of this segment of the population. It is therefore inevitable that we resort to technology in our search for solutions to the costly and challenging problems facing PwSN.

This handbook presents a broad overview of multidisciplinary research and development aiming at achieving independence and wellbeing for PwSN. The book covers the user population, the various impairments and disabilities, and state-of-the-art assistive technology, ranging from simple assistive devices to comprehensive assistive environments. A unique aspect of this book is presenting the readers with a uniform and coherent treatment of a large number (over 50) of cross-disciplinary, diverse research topics—all centered around PwSN.

AUDIENCE

This book has been designed for two audiences. The first includes professionals, researchers, and students seeking an understanding of the PwSN population and their needs, and the existing body of research and practice focusing on improving PwSN wellbeing and independence. This audience spans several engineering disciplines, including computer science engineering, electrical engineering, biomedical engineering, and rehabilitation engineering. It also spans geriatricians, occupational therapists, physical therapists, clinical and health psychologists, behavioral scientists, and physicians.

The second audience comprises anyone who has interest in assistive technologies for people with special needs and wants to know what is currently available, and what will be possible in the near and more distant future. This group includes but is not limited to
the public health policymakers, health services professionals, national and state funding agencies, government health departments, and specialized institutions. This audience also includes the PwSN themselves.

BOOK ORGANIZATION

The book is divided into eight parts, each consists of several chapters. The purpose of each part is summarized below:

Part I: Definitions, Classifications, and Policies. This part presents the most important definitions related to disabilities and aging and the technologies dedicated to this population. It also discusses policy-related issues.

Part II: Users, Needs, and Assistive Technology. This part addresses user needs for the elderly and people with disabilities. It covers the various user populations, including statistics, such as population size, growth rate, government spending on population programs, research and development (R&D), and health, among other statistics. This part also introduces devices and systems developed for PwSN in support of communicating, writing, reading, studying, among other things.

Part III: Human–Machine Interaction and Alternative Communication. This part addresses research experiences focused on improvement of the human–machine interaction in terms of aging and disabilities. It also covers innovative systems, generic interfaces, systems adaptations, and virtual reality. This part also covers speech prosthesis, talking calculators, and tactile or voice output measuring devices. Communication boards or books, multilevel voice output devices with levels, dynamic displays, icon sequencing, among other systems are also discussed.

Part IV: Assistive Robotics. This part discusses robotic solutions and the latest advances in assistive devices. Such systems can now, or will in the future, serve many of the “personal assistance” needs of older persons with disabilities. This part covers robots that assist people in daily life tasks (eating and drinking, applying makeup, etc.), robots for therapy, robots for training, and robots for sport rehabilitation.

Part V: User Mobility. This part discusses user mobility issues and solutions that could help users overcome their lost mobility. It also addresses issues and approaches to driver safety, testing, and remediation, and the role of technology in enabling mobility and providing alternatives transportation systems. Finally, this part outlines many domains related to user mobility such as new wheelchair designs, smart wheelchairs, driving dilemmas, and adaptation of public transportation systems.

Part VI: Technologies for Smart Environments. This part discusses technologies that enable the creation of smart environments. It covers: home networking, home automation, middleware technologies, service infrastructures, context-aware frameworks, tracking, behavior analysis, among others technologies.

Part VII: Smart Environments and Cyberinfrastructures. This part discusses the integration of advanced technologies into the daily life of user environments (home, work, public places, public administrations, etc.) that enable the creation of an assistive environment. It also addresses issues and approaches to smart technology
applications. This part also covers the use of Information and Communication Technology (ICT) and services to promote organizational performance and quality of life, telehealth applications and patient monitoring, information, and education.

Part VIII: Emerging Standards, Guidelines, and Design Methods. This part discusses methods related to designing products that fit the user’s needs and capacities. It also discusses new tools and concepts, and other issues related to the provision of usable and accessible technology that promotes independent and safe living. This part also discusses emerging standards and guidelines to build accessible devices, tools, and environments.

HOW TO USE THIS BOOK

The book is a compendium of a broad set of research areas, all centered around PwSN. The main intended use of the book is as a field reference for “one-stop shopping” by researchers and practitioners. The book has been organized into parts to enable readers to use it as a supplemental material in many courses on engineering and the health professions. Policymakers, governments, and health service professionals can use the book as a source for the latest information on PwSN and the related technologies available to them.

We hope that you find the book both valuable and interesting.

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Introduction to the Book

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According to the World Health Organization (WHO), there are between 750 million and 1 billion people with special needs (PwSN) in our world today. This includes the growing elder population and people living with disabilities. In 2002 it was estimated that 20% of the US population and 13% of the European population are PwSN. In the United States, over 35 million Americans (12% of the population) are over the age of 65. This 65+ population is expected to double by 2030. In fact, the oldest population (85+) is the most rapidly growing segment of our population. In 1900 there were only 100,000 persons 85+; in 2000, there were 4.2 million; in 2050, there will be 21 million (Fig. I.1). The significance of these numbers is that there is a strong correlation between elders’ disability and age; at least 62% of elders 85+ have difficulty with one or more core activities of daily living. Consider dementia alone and how it degrades the quality of life for elders, adversely impacting their independence. Approximately 10% of people age 65+ have cognitive impairments that impair functional abilities. Alzheimer’s disease is the most common cause of dementia in persons over 65, causing progressive decline in abilities.

Aging and disability pose challenging and costly problems needy of urgent solutions that cannot be solved by traditional government programs alone. This book focuses on technology and its promise in promoting independence for people with special needs. The use of devices, computers, robots, and other established assistive technology (AT) can potentially increase the autonomy of PwSN, by compensating for physical limitations and circumventing difficulties with normal activities of daily living (ADL).
INTRODUCTION TO THE BOOK

I.1 THE POPULATION

Numerous researchers have attempted to define the concept of disability in diverse historical or geographic settings, with regard to attributes or modulating factors such as impairment, health condition, and individual–environment interaction. Since the 1960s, numerous such attempts have led to significantly varying definitions. The first international classification of impairment, disease, and handicap (ICIDH) [1] developed by the World Health Organization (WHO), which has been used worldwide for more than twenty years, defines a handicap as “a disadvantage for a given individual, resulting from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal for that individual” [1].

The Disabled People’s International (DPI) organization defines disability as “the loss or limitation of opportunities to take part in the normal life of the community on an equal level with others due to physical and social barriers” [2].

People with disabilities (also referred to as disabled persons) are “persons who are atypical in body, intellect, or emotions and who are categorized by society as disabled by a process of examination, explanation for their difference, and legitimization of their role in society and the resources that society puts at their disposal” [3].

The WHO revision of the ICIDH, the International Classification of Functioning, Disability and Health (ICF), provides a handicap with medical and contextual dimensions. Further, the handicap is seen as a result of an interaction between personal characteristics (health condition) and social and environmental factors [4].

I.1.1 Handicap and Wellbeing

Wellbeing or quality of life is an important concern for PwSN, who, like every person, is seeking to be well, happy, healthy, and prosperous. PwSN have several important components of wellbeing. A key activity is independent living with convenient access to goods and services, as well as being socially active and enjoying self-esteem and dignity. In modern societies, PwSN can attain some components of wellbeing such as access to services using assistive technology (AT). Other components, such as freedom of navigation and travel, are much more difficult because of environmental obstacles encountered by the disabled.
I.1.2 Handicap and the International Classification of Functioning, Disability, and Health (ICF)

The World Health Organization (WHO) ICF addresses the situation of being handicapped, in a diverse way. The WHO classification adopts a functional approach [4], focusing on the level of health and functional capacity, without limiting consideration to the deficiency–incapacity–disadvantage chain, where handicap results from physical deficiency or disease [1]. Since an individual’s functioning and disability occurs in a social and environmental context, ICF also includes environmental factors.

In summary, ICF combines two approaches: medical and social. The medical approach is traditional, where the handicap is perceived as an endogenous congenital problem, or as a direct consequence of a disease or disorder that requires medical care. The social approach focuses on the patient’s environment. Here, a handicap is perceived as a problem created by society or the individual’s environment, where the handicap represents incomplete social integration of the handicapped individual.

Social classification stresses models of human operation (Fig. I.2), where a handicap results from dynamic interaction between a patient’s health condition (diseases, trauma, wounds, etc.) and other contextual factors. Examples of contextual factors include personal and environmental factors, which are considered concurrently. To summarize, the ICF defines a person with a disability as “a person with one or more impairments, one or more activity limitations, one or more participation restrictions or a combination” [4].

I.1.3 Needs of People with Special Needs (PwSN)

Analyzing the human beings, Maslow has identified five categories of needs, with different priority levels (Fig. I.3), in the following order: survival (physiological), safety, social needs, esteem, and self-actualization (fulfillment). Maslow’s model is also valid for PwSN, whose needs are similar to those of ordinary persons. Nevertheless, many of
these needs are not fulfilled, so PwSN seek to fulfill these need and reach a state of well-being. Initially, PwSN attempt to fulfill the first level of needs (survival). The survival needs are formed by the physiological needs and include the biological requirements for feeding, performing hygiene, sleeping, ADL, and so on. When PwSN fulfill their survival needs, they will look for situations that keep them safe, before moving up the chain and fulfill their needs to be part of society and to achieve [5].

As an example of needs in terms of safety, consider a person with visual impairment who wishes to cross the street safely. In contrast, for the elderly, safety might represent the ability to obtain emergency help after falling and not being able to stand again. Social need is a key element that PwSN would like to develop continuously [6]. For example, a person with a hearing impairment suffers from a diminution of social contact, while someone with a motor disability feels excluded from social activities.

The third level of the pyramid relates to esteem, both self-esteem and being favorably recognized by others. Esteem is often related to the capability of achieving things, contributing to a work activity and being autonomous. In particular, PwSN in a dependent situation feel the need for increased autonomy, as well as the opportunity to prove their worth to themselves and others through work or other activities [6].

I.1.4 Types of Impairment

PwSN live with impairments that impact their abilities to conduct activities of daily living (ADL). An impairment can limit or restrict one or more ADLs, including moving from one place to another (e.g., navigation, locomotion, transfer), maintaining a position (e.g., standing, sitting, sleeping), interacting with the environment (e.g., controlling systems, gripping objects), communicating (e.g., speaking, writing, hand gestures), feeding (chewing, swallowing, etc.), and perceiving the external world (by movement of the eyes, the head, etc.).

Many older persons face one or more impairments. Their situation is often similar to that of people with disabilities. Their needs are similar to those people with multiple handicaps with a decrease in the muscular, vision, hearing and cognitive capacities [7].

A review of all impairments and handicaps of PwSN is not possible in a single chapter. We briefly describe the most common and known handicaps and impairments.