Specific issues of the design for the elderly

S B Sebesi¹, H L Groza¹, A Ianoși¹, A Dimitrova¹ and D Mândru¹
¹Faculty of Mechanical Engineering, Department of Mechatronics and Machine Dynamics, Technical University of Cluj-Napoca, Cluj-Napoca, Romania
E-mail: Dan.Mandru@mdm.utcluj.ro

Abstract. The actual demographic studies show that number of the elderly people is increasing constantly. Considering their motor, sensorial and cognitive constrains and restrictions, a new field of Assistive Technology is developing, focussed on the design and development of a wide range of devices, apparatus, equipment and systems dedicated to their independent and safe life. In this paper, a systematisation of existing gero-technical systems is proposed, emphasising the today trends in this field. The specific issues of designing this kind of products are identified and analysed. Two approaches of the authors are finally presented: wearable suits for aging and disabilities simulation and tele-monitoring of the elderly.

1. Introduction
In the current period there are intense efforts of enriching the knowledge in the field of designing for older persons. The increasingly rich experience of the designers leads to the improvement of the user’s outcomes and satisfaction, and increasing the systems efficiency.

The interdisciplinary research of aging and its dedicated technology, for a better life quality of the elderly, defines the dynamic filed of gerotechnology. An appropriate approach in the complex process of the design devices and equipment which belong to the gerotechnology, that assumes the focus on the specific requirements of the elderly, enhances their safety, increases the tasks completion rate, reduces the carrying on time and errors, limits the need for supplementary modifications and adjustments, etc.

The assistive devices and equipment developed for older people may offer various ways to compensate the motor, sensorial and cognitive impairments, functional limitations and disabilities associated with aging, to support frailty specific to very old persons, to provide the ability to complete basic daily tasks without personal assistance and to combat the pain and compensate the fatigue [1].

1.1. Levels, trends and demographic drivers
The world population continues to grow but noticeably a little bit slowly than in the recent past. Ten years ago, the world population was growing by 1.24 % per year but today, it is growing by 1.18 % per year that means an additional 83 million people annually.

The world’s population is ageing and this fact is noticeable in every country in the world. Population ageing is tending to become one of the most significant social challenges of the twenty-first century, with implications for nearly all sectors of society:

- labour and financial markets;
- housing;
- goods and services;
- social protection;
- transportation;
- intergenerational ties;
- family structures;

According to World Population Prospects: the 2015 Revision report the number of persons with aged 60 years or over has increased considerably in recent years, and that growth is projected to accelerate in the coming decades (table 1).

### Table 1. Population aged 60 years or over for the world regions (2000, 2015, 2030, 2050).

| Region         | Persons aged 60 years or over(millions) | Distribution of older persons(percentage) |
|----------------|-----------------------------------------|-----------------------------------------|
|                | 2000 | 2015 | 2030 | 2050 | 2000 | 2015 | 2030 | 2050 |
| Africa         | 42.4 | 64.4 | 105.4 | 220.3 | 7.0 | 7.2 | 7.5 | 10.5 |
| Asia           | 319.5 | 508.0 | 844.5 | 1293.7 | 52.6 | 56.4 | 60.2 | 61.8 |
| Europe         | 147.3 | 176.5 | 217.2 | 242.0 | 24.3 | 19.6 | 15.5 | 11.6 |
| Latin America  | 42.7 | 70.9 | 121.0 | 200.0 | 7.0 | 7.9 | 8.6 | 9.6 |
| Oceania        | 4.1 | 6.5 | 9.6 | 13.2 | 0.7 | 0.7 | 0.7 | 0.6 |
| Northern America | 51.0 | 74.6 | 104.8 | 122.7 | 8.4 | 8.3 | 7.5 | 5.9 |

Globally the number of people with age 60 years or over is projected to grow by 56 % between 2015 and 2030, that means from 901 million to 1.4 billion, and the global population of older persons is projected to reaching nearly 2.1 billion by 2050, that means more than double its size in 2015.

Over the next 15 years, the number of older persons (aged 60 years or over) is expected to grow fastest in Latin America with a projected 71 % increase, followed by Asia (66 %), Africa (64 %), Oceania (47 %), Northern America (41 %) and Europe (23 %) [2].

The older population (60 years or over) is growing faster in urban areas than in rural areas. Globally the number of people with age 60 years or over between 2000 and 2015 increased by 68% in urban areas, compared to a “just” 25 % increase in rural areas. The number of older persons is growing faster than the numbers of people in any other age group. One in eight was aged 60 years or over worldwide in 2015, and this number is projected to account for one in six people by 2030.

The ageing process is most advanced in high-income countries. Japan is home to the world’s most aged population: 33 % were aged 60 years or over in 2015. Japan is followed by Germany (28 % aged 60 years or over), Italy (28 %) and Finland (27 %). By 2030, older persons are expected to account for more than 25 % of the populations in Europe and in Northern America, 20 % in Oceania, 17 % in Asia and in Latin America, and 6 % in Africa.

The prediction shows that in 2050 the 44 % of the world’s population will live in aged countries, with at least 20 % of the population aged 60 years or over. Also the prediction shows that one in four people will live in country where more than 30 % of people are above age 60 [2].

Globally the 60 year-old persons in 2010-2015 on average could expect to live in additional 20.2 years. This life expectancy at age 60 years was highest in Oceania (23.7 years), in Northern America (23.5 years), and in Africa (16.7 years).

### 1.2. Analysis of diminished sensorial and locomotion functions

Sensorial and locomotion functions get affected by the passing of time and can be considered part of the ageing process. Ageing and death of living organisms have some common elements with ageing and disappearance of non-living systems. As ageing of the non-living systems can be defined only as deterioration due to the environment factors, the living organisms are affected also by losing the capability to adjust and compensate the deterioration factors. The living systems can only survive thru reproducibility, while the non-living systems can be generated and regenerated by external forces.

The five traditional sensorial perception methods are: taste, sight, touch, hearing and smell. The human nervous system can develop more capabilities to adapt to the environment [3]:

---

1. IOP Conf. Series: Materials Science and Engineering 147 (2016) 012049 doi:10.1088/1757-899X/147/1/012049
2. "World Population Prospects: the 2015 Revision"
3. "Analysis of diminished sensorial and locomotion functions"
“Own reception” is defined as the capability that helps us fill our body position, of each limb. Because of it we can move balanced and coordinate.

“Equilibrium reception” is the capability to maintain our stand up position.

“Thermo reception” is connected to the presence at the skin level of some specialised receptors capable to determine the temperature of the environment.

“Noci reception” is the sensibility to physical pain.

“Chrono reception” is the capability of the body to feel the passing of time. This capability is controlling the physical parameters of the organism for 24 hours.

Internal receptors are also responsible for the adaptation to the environment. Receptors for extension and distension for example present in the intestine. Chemoreceptors present in the blood vessels can determine the concentration of the chemical elements, and send a signal for thirst. This are only a few examples, as every internal organ is equipped with internal receptors connected to the central nervous system that controls and adapts the needs to the environment.

Regarding locomotion functions the most obvious manifestation related to ageing is that the moves are getting slower and eventually the moves will stop [4]. Reduction of the movement amplitude and muscle force affects the daily activities like walking, work space for the hands, etc. Muscle control is also affected and related effects like tremor, precision grasping or standing up strait are present at old age people. Also age related diseases like Parkinson are affecting the locomotion functions.

2. Systematization of gero-technical systems

Nowadays a new field of Assistive Technology is developing, focused on the design and development of a wide range of devices, apparatus, equipment and systems dedicated to their independent and safely life. Table 2 gives a systematization of the assistive systems dedicated to elderly.

| Assistive systems                  | Subcategories                                        |
|-----------------------------------|------------------------------------------------------|
| Walk and posture assist systems   | Canes and crutches                                   |
|                                   | Walkers and Rollators                                |
|                                   | Sit-to-stand transfer assist systems                 |
|                                   | Complex systems with multiple functions              |
| Mobility aids                     | Manual Wheelchairs                                   |
|                                   | Powered Wheelchairs                                  |
|                                   | Scooters                                             |
| Exercisers                        | Stationary exercisers                                |
|                                   | Wearable exercisers                                  |
|                                   | Exercisers for passive mobilization                  |
|                                   | Exercisers for active mobilizations                  |
| Rehabilitation robotic systems    | Robotic systems for gait restoration                 |
|                                   | Robots for upper extremities therapy                 |
|                                   | Robotics for neuro-motor rehabilitation              |
| Assistive robotics                | Robotic mobility and manipulation aids               |
|                                   | Personal assistant                                   |
|                                   | Pet-like social robotic systems                      |
|                                   | Robots for domestic tasks (e.g. vacuuming, floor cleaning, a.s.o.) |
|                                   | Smart living spaces                                  |
| Prosthetic and orthotic systems   | Upper/lower limb passive prostheses/orthoses         |
|                                   | Upper/lower limb active prostheses/orthoses          |
|                                   | Exoskeletons                                         |
|                                   | Orthoses for tremor suppression                      |
### Assistive equipment for sensorial function
- Electronic reading devices
- Electronic travel aids
- Braille displays
- Hearing aids
- Implantable hearing devices
- Assistive listening devices
- Robotic guide for visually impaired

### Smart home (home modifications)
- Communications means
  - Control systems of the doors and windows
  - Automat control of temperature, humidity, light, TV, a.s.o.
- Adapted bathroom; bathing and washing devices
- Equipped kitchen
- Activity and sleep monitoring systems
- Fall detection systems
- Alert systems
- Reminders and prompts for daily tasks
- Home security and surveillance
- Monitoring and telemonitoring systems

### Others
- Functional electrical stimulation systems
- Devices for cognitive impairments
- Incontinence products

### 3. Specific issues of the design for the elderly

In accordance with [5], [6] and [7], the specific issues in designing for elderly are determined by the triangle user – tasks – system.

Particularities of older people as users of Assistive Technology are low technical knowledge, potential anxiety towards technology, reduced motivation, unrealistic expectations, limited perception concerning the functions and capabilities of own equipment, wide personal attitude and diverse education and culture. For a large range of potential users, a broad variety of abilities and disabilities have to be taken into account as well as different anthropometric data.

The systems have to be designed in terms of how well they respond to the user expectations and how easy is to learn and use. Through its adaptability properties, must fit into the living patterns of the user. The assistive gero-systems must be designed so that they can be personalized for each user’s needs. Among the features of the assistive devices and equipment dedicated to old users, must be also comfort, easy maintainability and servicing, aesthetics, hygiene requirements, affordability, easy storage and transportation.

Any such user wishes to minimize the time and effort for practice and training. For an intermittent use, a reduced relearning time is important. Few parameters, like task carrying out rate and time as well as number of errors, give the elderly performance on an assistive problem.

The design of gerotechnology systems must consider safety characteristics. Thus, because assistive systems work in close proximity to humans, share their operating environment. Safety features include safe operating regimes and fail-safe behavior, analysis of failure modes and user hazards, sensing for proximity detection and environmental changes, collision detection and avoidance.

In terms of autonomy, is important to provide an energetic autonomy as well as a functional autonomy (if possible, the assistive systems must self-improve their operation, repeated errors being detected, anticipated and avoided).

For a better usability, any complexity must be hidden, the systems must have very acceptable controls and operational modes, the user interfaces must be minimal, with intuitive and responsive inputs. By using available components in a modular structure of the systems low costs can be ensured.
4. Two different approaches

4.1 Aging suit

An “Ageing suit” is a system that simulates the loss or diminishes of the locomotion and sensorial functions and allows the user to experience the effects of ageing or different associated illnesses.

These systems find use in different fields of activity like:

- Research and development
- Studies regarding the needs of the elderly
- Development of helping systems for old age people and persons with disabilities
- Development of bio mechanisms
- Development of household items having in mind the needs of the elderly
- Usage by life insurance companies
- Development of cars.

AGNES (figure 1) is a suit worn by students, product developers, designers, engineers, marketing, planners, architects, packaging engineers, and others to better understand the physical challenges associated with aging. Developed by AgeLab researchers and students, AGNES has been calibrated to approximate the motor, visual, flexibility, dexterity and stren gth of a person in their mid-70s. AGNES has been used in retail, public transportation, home, community, automobile, workplace and other environments [8].

![Figure 1. AGNES Ageing suit.](image)

Another example of an Ageing suit is R70i (figure 2) produced by Applied Minds LLC for Genworth. Within this suit a virtual reality is created with the help of 3D goggles, a helmet with headphones and an exoskeleton. All is controlled by a computer installed in a backpack, operated remotely.

The simulated effects of the suit as described in the facts sheet [9] are:

**Hearing impairments:** Sensorineural hearing loss; Tinnitus (ringing of the ears); Aphasia (loss of speech). Immersive audio processing system to simulate the hearing impairments associated with aging. Includes a special mode to demonstrate the experience of speech loss (aphasia).

**Vision disorders:** Glaucoma; Macular degeneration; Cataracts; Floaters. Fully immersive, real-time “Augmented Reality” vision and image processing system to allow the user to experience four visual impairments associated with aging. Video signals are sent to a very high-speed computer that digitizes them and processes the images to create the desired effects.

![Figure 2. R70i Genworth Ageing suit.](image)
Joint challenges and mobility loss. The suit’s high performance computer, monitors sensors in eight major body limb joints and selectively applies mechanical resistance to restrict motion and increase effort needed to perform everyday tasks, such as walking. LED lighting on joints displays areas of impairment to onlookers.

Muscle loss (sarcopenia). The suit exoskeleton’s weight and controllable resistance produce the effects and feeling of increasing levels of muscle loss (sarcopenia) and decreased endurance.

Contribution to modular design of ageing/disabilities simulation suit

The simulation suit integrates the sensorial disorder (marked in red) and the locomotion functions disorder (marked in blue) into four modules for each body part. As presented in the block diagram of a simulation suit in figure 3, the Head, Torso, Arms and Legs modules are integrated to simulate ageing or disabilities.

The Head module has the following components: Vision module – that simulates eye related diseases; Hearing module – that simulates diminished hearing and tinnitus; Neck mobility reduction

The Torso module integrates a vest that reduces spine mobility, pelvis mobility and adds weight to the system.

The Legs module includes: a device for knee mobility reduction; special shoes for unsteady walking and weight adding devices.

The Arms module includes: a device for elbow mobility reduction; weight adding devices; gloves that simulate tactile disorder; A tremor module that simulates diseases like Parkinsons.

---

**Figure 3.** Block diagram of a simulation suit.

4.2 Tele-monitoring

Telemonitoring is a way of responding to new needs of home care in an aging population. Using modern communication and information technologies, telemonitoring combines the needs of “patients” with technological progress, beyond the frontiers of traditional home security systems.

The telemonitoring home systems can allow older persons to live in the environment of their choice and protect them against institutionalization or placement in a nursing home. Telemonitoring solutions give a new opportunity for diagnosis, education, and treatment and make it possible to monitor patients with a number of chronic diseases. We consider relevant for the domain of independently
living of elderly generation to telemonitoring: (a) vital signs, (b) to detect non-medical emergencies, (c) to monitor activities of daily living (safety and security monitoring).

(a) Monitoring of vital signs
Researches have demonstrated that many vital signs can be telemoitored successfully. A substantial focus of telemonitoring systems for vital signs focus on measuring cardiovascular activity. Research has been performed into monitoring: blood pressure, pacemaker parameters, heart rate, fetal heart rate, etc. Another strong focus directed on telemonitoring vital signs is to measure aspects of metabolism: physical exercise, basal metabolic rate, blood lactate, blood glucose, blood ethanol, and blood temperature etc. Have been developed measuring equipment to telemonitoring respiratory systems as well as hematologic systems: pulse oximetry, spirometry, and respiratory rate. Have been developed also systems that measure intravesical urological pressure as well as neurologic systems that measure and transfer EMG and EEG [10].

(b) Detecting non-medical emergencies
With non-medical emergency situations we refer to situations: (1) which occurrence cannot be anticipated straightforwardly, (2) of which require immediate care, (3) and of which the required care does not concern specialist medical knowledge. Common instances of such emergency situations are falling, and wandering incidents. Telemonitoring systems for detecting falling incidents are often implemented by means of wearable sensors. An alternative approach is detecting falling incident with vision systems, sensors that are placed in the home environment. Regarding the wandering incidents, numerous telemonitoring systems have been developed for detecting straying and wandering behaviour (wearable sensors, or sensors that are placed in the home environment with alarm) [10].

(c) Monitoring activities of daily living (safety and security monitoring)
Numerous systems have been developed for gathering data on activities of daily living: localisation technologies, vision systems, systems based on accelerometers, infrared motion-sensor, network of sensors, etc. Once the data on the activity of daily living has been gathered, the information is subsequently utilised by pattern recognition methods for classification of the activity that was observed. Telemonitoring technologies refer to solutions that help older people to prolong their independent life at home. The most widespread device for this purpose is the alarm button which may involve notifying emergency services, neighbours, or family. Potentially risky situations can be monitored and managed too. For example, a gas or smoke detector can alert the user and a caregiver to a problem, turning off the gas supply if a cooker is not lit. Another example for avoiding a potentially risky situation is using a flood detector which can report an overflowing sink or bath in the event that the user leaves a tap running. Motion sensors distributed in the house can detect when there is no movement or movement is unusual (based on previous settings), and inform the user, caregiver or the security firm [11].

Contribution for elderly peoples independent and safely life
The objective of the following system by using the current technologies is to provide a specific set of services for elderly people to extend the time in which they can live at home, surrounded by their own comforts and their loved ones (figure 4).

The functional architecture of above system includes three levels of communications:
- *Primary communication* between vital signals and home computer;
- *Secondary communication* between the emergency sensors plus home computer and Central monitoring station;
- *Tertiary communication* between the central monitoring station and the external actors.

As we mentioned in the previous section in our consideration for the elderly people independent living is crucial to telemonitoring: vital signs, emergencies and daily activities (safety and security).
Figure 4. System for elderly people independent and safely life.

The communication between modules is planned to be based on standard protocols and coding systems. Data transmission from the Vital Sensors (blood pressure, respiratory rate, heart rate, blood glucose) to the local computer is performed via Bluetooth, WIFI network and mobile networks (GPRS, 3G, 4G), depends on the device communication protocol. From local computer to the Central monitoring station the grouped data transmission is performed via internet. The emergency and safety security signals are transferred to the Central monitoring station via mobile networks (GPRS, 3G, 4G). Based on the collected information the Central monitoring station can take a decision regarding the next step (e.g.: notify the proper organizations: firemen, policemen, ambulance etc.) For a higher safety and security level the system has embedded three automated action:

1. at gas and smoke alert: warning tone and emergency gas shut-off
2. at flood alert: warning tone and water shut-off
3. at unexpected motion alert: warning tone and a security member safety visit

The presented system can gives the elderly peoples a feeling of reassurance and safety. The described telemonitoring system may not transform the lives of its users, but it can afford benefits with regard to psychological and quality of life outcomes and can allow elderly peoples to live in the environment of their choice.

5. Conclusions
The statistical data justify the need for efficient strategies and high performance equipment which promote independence, safety and improved quality of the life of elderly. Still in the design phase, the question if the assistive systems for old people meet the demands of the elderly who use them, have to be in the attention of the designers. Considering the above-discussed specific issues of the design for the elderly, an important step towards the development of systems with a real value for their users is...
performed. The effects produced by the ageing suits must be reversible, living behind an experience that creates empathy for the elderly and the disabled, and on the other hand it can be an event that can influence the life style of the user. Simulating the locomotion functions, represent only a part of the deficiencies accumulated with age. Loss of the sensorial capabilities represents also a reality, but this is not so easy to simulate in a reversible way for all the senses. The effects of these lost capabilities should be taken under consideration by developers and medical personal for the products and services addressed to elderly people and the disabled. Training of the medical personal that is working with the elder people could be one of the uses of this suit, obtaining this way a more realistic feeling of what their patients are experiencing. With the current technology, it is possible to implement solutions that until recently seemed to be a distant vision of the future as is telemonitoring systems. They provide new opportunities for diagnosis, prevention, education, treatment, rehabilitation, and improve quality of life for older patients. The main objective of the presented telemonitoring system is to allow elderly peoples to live in the environment of their choice and avoid institutionalization or older people's house placement for as long as possible. Using telemonitoring technologies in home environment is still under development, but this method appears to be one of the most promising approaches to facilitate independent living for elderly.

6. References
[1] Mann W C 2005 Smart Technology for Aging, Disability and Independence (John Wiley &Sons, Inc)
[2] Report from Department of Economic and Social Affairs 2015 World Population Ageing 2015 ST/ESA/SER.A/390
[3] http://www.descopera.ro/stiinta/9697033-cate-simturi-au-oamenii
[4] Kirkwood T B 2013 Cell Metabolism 18 pp 303-304
[5] Broadbent E, Stafford R and MacDonald B 2009 Int J Soc Robot 1 pp 319-330
[6] Meng Q and Lee MH 2006 Adv Eng Inf 20 pp 171-186
[7] Demirkan H 2007 Eur Rev Aging Phys Act 4 pp 33-38
[8] Oikonomou T, Votis K, Tzovaras D and Korn P 2009 Universal Access in Human-Computer Interaction. Addressing Diversity (Berlin: Ed Stephanidis C) pp 135-144
[9] Genworth R70i 2015 Facts sheet
[10] Sander B, Richard M and Ben K 2011 Int Conf on Pervasive Computing Tech for Healthcare pp 152 – 159
[11] Bujnowska-Fedak M M and Grata-Barkowska U 2015 Smart Homecare Technology and TeleHealth 3 pp 91-105

Acknowledgments
This research is partially supported by PCCA 180/2012, A Hybrid Fes-Exoskeleton System to Rehabilitate the Upper Limb in Disabled People (EXOSLIM).