Design and Automation for Seniors

Robot aided design of an environment for the elderly and disabled.

Karolina Dąbrowska-Żółtak¹, Jerzy Wojtowicz², Stefan Wrona³
¹,²,³ Warsaw University of Technology
¹,³ {karolina.dabrowska|wrona}@arch.pw.edu.pl
² jerzy@post.harvard.edu

The changing social structure and the development of new technologies in the emerging Society of Knowledge makes possible the development a new kind of living space or habitat that adapts and responds to the needs and problems of elderly. The exponential growth of the aging population in EU, US and Japan is well proven and it urgently calls for the innovative solutions. Today use of automated and robotic elements in design opens the new possibilities for architecture. This paper offers the background of the problem, presents few precedents of assisted by mechatronics solutions, review the four experimental design projects from Warsaw University of Technology and in conclusion propose the agenda for further design research.

Keywords: mechatronic, architecture, seniors

AGING SOCIETY PROBLEM
Seniors - who they are and when the old age begins - it is still not clearly defined. With the development of medicine, the average life expectancy increases. According to the Central Statistical Office data, in 2015 there were 4,456 centenarians in Poland. On the other hand, financial institutions in Poland names as a seniors people who have turned 50, reverse-mortgage funds refer to people over 60. From the point of view of retirement, this limit is currently set at 60-65 years depending on gender. These data mean that we can be seniors almost through the half of life. This entails the necessity to consider a group of seniors not as a single set, but to separate additional divisions delimited by additional age limits, or what seems more adequate, conditioned by the degree of fitness and social and professional activity.

Different needs and disables
The elderly people who are professionally active will have different needs than the old pensioners living alone. The needs of seniors may vary also as result of the place of residence - the size and location of the town, contacts with the family and non-professional activities or hobbies cultivated before the retirement.

In the group of people over 65, the percentage of people with temporary or permanent disability increases. Studies showing how the percentage of people with disabilities increases with age (Kalache and Kickbusch 1997). At the same time, the percentage of economically active people is decreasing, with age. In addition to problems caused by the physical difficulties, there are those related to psychological issues, like the limited ability to occupy free time and the consequences resulting from the limited contact.
with family and society.

Regardless of the exact age and living environment of the seniors, the research indicates three basic types of their needs that are biologically, psychologically and socially conditioned (Kędziora-Kornatowska et al. 2010). A well designed residential environment in the XXIc should support seniors in each of the mentioned areas.

Challenges for architecture and technology
The architecture augmented by inormation technology can support a growing population of elderly people in many areas of life. Engineers and architects face the challenge of creating a safe and friendly environment that provides support or stimulation, depending on changing needs. It should at the same time support both for seniors and for those who look after them. Solution can be drawn from Industry 4.0 that goes beyond the automated factories and shapes now the human environment in new areas of life (Olszewski et al. 2017).

Frequent occupational passivity among seniors raises the challenge to designed facilities that are cheap to use and possible inexpensive to produce, while adapting to the individual needs of residents.

An important postulate is at the same time constant monitoring of the health of people, often living alone and navigating seniors moving in urban structures, as they are often struggling with memory problems and spatial orientation.

MECHATRONICS AND DESIGN FOR ELDERLY
Problems faced by elderly and disabled are challenging for contemporary architect. Apart from those above the several subtypes could be isolated and related to the range of technologies and used in the design.

In the biological zone associated with physical disability in seniors, the demand for:

- motor support systems - incl. exoskeletons,
- robots and actuators for seniors supporting in performing everyday activities,
- robots and actuators replacing and supporting carers of people with disabilities,
- treatment devices, accelerating, for example, changing dressings, in patients,
- active rehabilitation devices,
- health monitoring systems,
- quick access diagnostic devices,
- systems controlling and optimizing the environmental parameters of a senior apartment, humidity, temperature, air purity, etc.,
- simulators and systems encouraging you to do physical exercises,
- kinetic systems allowing to improve the ergonomics of the senior’s living environment while ensuring optimal use of space.

In the psychological zone, where there are problems like mood disorders, anxiety, memory problems and concentration, all kinds of systems activating and supporting the orientation of seniors in the environment may play an important role, including:

- computers and stimulation robots for intellectual exercises,
- technological facilitations in the implementation of remote work, including computers and equipment facilitating communication at a distance,
- systems using augmented reality, facilitating the movement of seniors, among others in crowded urban spaces and navigating in a safe way to reach your destination,
- energy-efficient solutions reducing the cost of living a senior home,
- systems ensuring security against external factors.

In the social zone associated with the activation of the senior, maintaining family and friend relationships, making new acquaintances and stimulating activity, one can distinguish:

- companions work replacing living beings,
- Interactive remote communication systems to facilitate meetings without the need to over-
come distances,
• mobile interiors to host families and grandchildren, while minimizing the space of the senior home,
• mobile units facilitating the movement of seniors, including vehicles and the same residential modules.

In cooperation with a commercial partner, the LISA project created an interactive wall supporting seniors, see figure 1. It was equipped, among others, with an interactive mirror and a system of sliding mechanical elements designed to support the user in performing everyday activities (Brock 2015).

In the robotic laboratory in Munich, research is also underway to detect problems related to physical limitations. Among other things, the trajectory of motion is analyzed, when older people move up stairs, ramps and flat surfaces, which may contribute to further exoskeletal research, supporting the elderly in everyday activities. Research on the Polish exoskeleton is also conducted at the Faculty of Mechatronics of the Warsaw University of Technology under the supervision of prof. Danuta Jasińska-Choromańska, as shown in figure 2. The exoskeleton is to support people struggling with leg paresis.

Exoskeletons are used by both physically handicapped people and their carers. They are to support them in performing operations requiring physical strength, such as lifting a patient. Example of such solution is Hybrid Assistive Limb - HAL (Sankai 2010). The Asian solution allows you to increase the user’s lifting capacity and protect it against injuries. In the case of carers of the elderly, who are often unable to move independently, this solution allows to increase efficiency and help both professional caregivers and family members of the disabled.

Humanoid robots are also designed to replace guardians completely. The first humanoid robots used in caring for people have been used in Japan[1]. Despite years, it has still not been decided to implement this solution commercially.

Support systems also include robots and devices supporting or replacing them in everyday activities, such as cleaning, cooking or hygiene. Robots are gradually entering not only the world of production or confectioning, but also services.

An example of a prophylactic device in medicine is the Assistive Robotic Table - ART (Threatt 2014). The object combines the functions of a piece of furni-
ature that facilitates the performance of basic medical procedures with functionality that allows measuring blood pressure and making it easier to put on dressings. ART (figure 3) allows you to save the work of a nurse or a doctor while ensuring the correct quality of dressing change or health measurement.

Quick detection of life and health threats is the basis for effective response to sudden emergencies, hence, next to the mechanical support of seniors, intensive work is underway on health monitoring systems and detecting hazardous situations. The basis of their operation are the sensor sets. They may be sensors of various types located in rooms, and their additional function may be monitoring of the senior’s living environment, including air cleanliness control, humidity level or daylight intensity (Zouba et al. 2007), as shown in figure 4.

In addition to cameras and point sensors, floors with a grid of pressure sensors are also used. They allow the detection of the user’s downfall by information about the pressure forces and surface area to which forces are currently distributed [2].

Sensors that monitor the health status that can be worn on the body enable constant, non-invasive monitoring of the patient’s state of health. Currently, tests are underway on prototype solutions, where sensors would be permanently worn by the senior. Thanks to the flexible, ultra-thin electronic systems, it is possible to create an electronic tattoo that works like a sensor that you can always have with you (Gibney 2015).

Modern machines are not only purely mechanical devices. Software, including those using artificial intelligence, allows it to become a stimulant for physical and intellectual exercise, becoming an alternative to passive spending time in front of the TV screen (Hirano et al. 2013). Among the robotic exercise instructors, solutions are proposed where the robot conducts group classes for seniors [3].

Works manufactured today, according to producers, can become companions for single people. It is not their role only to help in the performance of physical work, but above all to satisfy the need for contact with others.

One of the first robot robots to fall into human memory was the robotic dog introduced to the market in 1999 by Sony. To this day, he is a companion of many Japanese, and after the departure of such a pet, for which the company no longer produces spare parts, in the country of blooming cherry can meet real mourners.

In 2014, the Japanese company Aldebaran, presented a humanoid robot that is to read human emotions and respond to them. A robot named Pepper can speak, move and do not need care, and has been programmed to display positive qualities such as kindness and caring [4]. Thanks to them, despite the lack of mechanical functionality beyond moving, he quickly found buyers.

Assistance in activation, including the implementation of physical exercises and remote contacts, can also be carried out using classical computers, and an important role can be played by a properly designed interface, dedicated to people with visual and...
hearing impairments.

One of the first works on the involvement of older people to work with computers took place in the mid-70s at the University of Illinois (Whitcomb 1990). Research conducted on a group of seniors, who during the five-week course were to gain the ability to use a computer database with the results of their doctor’s research, show that a properly designed digital environment allows to increase the independence of seniors and increase their self-confidence (Chu et al. 2009). In the era of the evolving Internet of Things (IoT), the ability to use and access to digital tools can become one of the key improvements in everyday life. Remote ordering of purchases, arranging medical appointments or checking the efficiency of home appliances already contributes to lowering the threshold of independence from physical fitness, according to the above mentioned research results presented by the WHO in 2000.

There are numerous games and platforms for seniors on the market to help in memory exercises, communicate at a distance or carry out work that can be done in a digital environment. Taming with the digital environment allows simultaneous work by seniors and extends the period of professional activity.

In addition to programs and applications supporting seniors, there are also projects that shape the physical working environment for people who are not fully functional. Among them, there is robotic architecture and furniture enriched with actuators and sensors. AWE - Animated Work Environment is a project of a robotic workplace, in which the use of new technologies is to support efficiency and improve comfort and ergonomics. The project is dedicated to both healthy people and motor dysfunctions (Green et al. 2005).

The next stage facilitating and supporting the work of seniors in the digital environment may be the use of augmented reality. In order to improve the comfort and safety of seniors struggling with memory problems, it is possible to use solutions that facilitate navigating in the case of pedestrian or car movement. Systems using augmented reality, are to facilitate the movement of seniors, among others in crowded urban spaces and help you reach your destination in a safe way. For this purpose it is possible to use, for example, glasses with a built-in information display function.

Digital solutions that enable communication can have a positive effect on maintaining ties with family and friends who do not live in the neighborhood of a senior citizen. This communication can be implemented both through classic computers as well as screens integrated with a residential unit. They can be both intelligent mirrors as well as flexible OLED screens, which when they are not turned on, are transparent and can function as windows.

In a zone directly related to architecture dedicated to professionally inactive people whose income is often limited, the basis is to provide high comfort, while reducing the cost of buying and maintaining a flat. The standard here are solutions allowing to reduce the demand for housing for energy and to obtain it from renewable sources, an effective way.

To reduce costs, especially for heavily urbanized areas, it may help to minimize the living space, while ensuring the basic functionality of the flat, including easily accessible storage space. For this purpose, it is possible to use mobile walls in order to be able to use the same space in many ways, and to use actuators allowing access to spaces that are difficult to access and which allow storage.

Miniature apartments with a mobile wall are gradually becoming a standard in the highly urbanized cities of China and Japan. An example of an apartment design, which can accommodate up to 4 people is the Compact Project Smart Studio Apartment project of the New York Corcoran studio.

Contemporary visions of future homes for the elderly are proposals combining the provision of individual space for residents, care and monitoring of health and psychophysical activation. It is also a place where seniors can develop their passions and meet with co-residents and visiting their family and friends, and lowering the cost of living through the
use of renewable energy and passive construction become the basic assumptions.

Today’s miniature sensors, including sensors made in MEMS technology, allow minimizing the volume of measurement systems, or integrating them with everyday equipment such as a watch, telephone or items of clothing. Currently, simple solutions of this type, measuring the pulse of the runner, are used, e.g. on sports watches. With the development of techniques it will be possible to extend the diagnostic capabilities of miniature objects. In the literature, ideas of micro-diagnostic capsules, or those capable of performing micro-operations, which the patient will be able to swallow, are also increasingly appearing. For example the Swiss surgical microrobots that can be injected into the patient’s tissue are already used (Nelson et al. 2010).

In the case of direct contact of the user with robots or systems equipped with actuators endangering the safety of users, it is necessary to maintain special security considerations. Current protections are often based on sensor moments that detect unforeseen loads on the mechanism. Such solution has been implemented, among others, in the KUKA robot, which enables safe and direct cooperation with a human being, without the necessity of putting mechanical barriers or safeguards based on sensors that do not allow a person to enter the robot’s working area.

**STUDIO AS RESEARCH BY DESIGN**

During the project’s implementation the research by design method was used. This is a new approach to research in the field of applied sciences, whereas in architecture studio it has been present for a long time. Design research is an investigation method in which design is an essential part of the research process. This process is based on critical questions, suggestions and problems created during project work. Questions may include conceptual schemes or project prototypes and their possible alternatives. Therefore, the test results, when using this method, are typically obtained through practical experience. In ROBOstudio the research and methods based on design, which is a recursive process of questions and proposals was used. In the age of society of knowledge, this process must take into account social participation, making designing a reflective practice. The critical evaluation, comparative methods and prototypical models were part of design problem solving.

In the face of the changing social structure and the development of new technologies, it is possible and perhaps necessary to develop a living space that responds to the needs and problems of older people and with temporary or permanent disability, using automated and robotic elements. During ROBOstudio 2017/2018 - ROBOsenior project concepts of residential units - houses of the future, adapting to the needs of the oldest members of society and allow-
ing integration and finding a place where you can develop your own passions or host relatives.

**Ring**

Project by L. Czaja, K. Kowalik, T. Ploch, M. Rusak and B. K. Teja.

The basic assumptions of the project were to provide mobility to seniors through the possibility of moving their homes between the Rings (figure 5) - basic hubs, providing access to necessary media and services. Thanks to this, traveling or going to a sanatorium would become simpler and more pleasant for a senior who could retain its familiar habitat while eliminating the need to rent hotels.

The students’ project assumed that the main assumption of a residential unit dedicated to seniors is its mobility, and the dimensions after submission would allow road transport (2.4 x 8.7 m), see at figure 6. The units would have a modular layout and be equipped with rooms such as a living room, a bathroom bedroom and a kitchenette.

The concept assumes the possibility of assembling the unit without the necessity of integrated furniture with the capsule. Both kitchen and bathroom equipment, as well as furniture such as bed, wardrobe and table have the possibility of transport in a complex capsule.

The project provides for the implementation of mini villages for seniors based on the plan of the circle. Mooring rings for mobile accommodation units should be equipped with necessary media connections and the possibility of transferring materials between residential units. In the form of razor blades separating neighboring residential units.

**Smart storage system.** A modular storage system (figure 5) was provided for the residential units. In accordance with the assumption, modules could be displaced depending on the current needs of the user and reaching for high-placed storage places would no longer be needed. The system based on the Internet of Things technology and the marking of consumer goods and clothing using RFID would allow you to easily find the items you need at the moment.

Additionally, it is possible to transport utility objects and waste between residential units and service facilities, such as a cafe or laundry. The transport of objects would be carried out using mobile cubicles moving within the razor blades for docking and below the floor of a residential circle.
The structure of moving cubes is the answer to the need for a compact, yet ergonomic living space and the need to support seniors struggling with memory problems - thanks to the object marking system.

**Multigeneration house - flexible structures**  

A more forward-looking project, based on new material technologies, not currently available, is the design of units consisting of fixed fragments of rooms set on a mobile core and covered with a flexible fabric structure. The concept assumes the possibility of a four-fold increase in the area of a residential unit by dividing the fixed fragments of the object.

The project assumes the creation of universal units dedicated to both elderly people and their families, which may be subject to change as the structure and needs of the family change (figure 8).

The capsule has a permanent kitchen, a bathroom bedroom and a space with built-in storage cabinets. The combination of capsules is possible due to the use of fixed doors. Window openings are located in solid and rigid walls, and the flexible outer shell is not transparent, as shown in figure 9.

The project assumes the possibility of locating units on the roofs of buildings in an intensively urbanized space and at the ground level in areas with a lower construction index.

The futuristic vision of the flexible units of the future includes the possibility of creating an ergonomic space perfectly suited to the needs of the occupant. Questions for the future remain material solutions that should be used to make this project a reality, without giving up all assumptions, and flexible external walls can complement the urban fabric and are not its basic building material.

**Connection network**  
*Project by M. Korotko, S. Szczotka, A. Grzybek, M. Rudnicki, M. Walczak.*

The network of connections is a project carried out both on the scale of a single residential unit as well as the district and connection network facilitating the formation of a friendly and safe space for seniors.

The basic unit is equipped with a network of sensors located in the floor, to enable the detection of dangerous situations such as a fall. The bathroom has an interactive mirror that can monitor the health of the user, and shelves are equipped with a system of simple delivery of the desired item. The center of a residential unit is a kitchen, which can be rotated depending on the needs, which is to facilitate the preparation of meals, by minimizing the way of moving around the kitchen - figure 10.

**CONCLUSIONS**

Our contemporary design for the elderly units involve proposals combining the provision of individual, customizable space for residents, care and monitoring of health and psychophysical activation. The projects are seen as a places where seniors can cultivate their diverse interest and meet with co-residents, visiting their family and contribute to community and friends. The reduction of the cost of living through the use of renewable energy and robotically assisted prefabricated construction resulting in mass-customised units are among the key assumptions.

The works developed during the ROBOstudio project in the academic year 2017/2018 were devoted to the creation of a friendly, flexible and intuitive living environment adapted to the needs of
Figure 9
Multigeneration house - capsula schema

Figure 10
Connection network - Projection of a residential unit and diagrams showing the basic functions of the facility dedicated to the elderly.
the oldest members of our society. Presented works show the individualized approach of team members and the focus on solving various problems of older people connected with both the physical zone as well as psychophysical and social activity. Future solutions, sometimes difficult to implement today, will contribute to the search for new technological and material solutions and should initiate the discussion on how the seniors' living environment may look like in the coming future.

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