MODEL FOR AN INTEGRATED DESIGN OF SMART FURNITURE FOR THE ELDERLY

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Abstract - The traditional view of the furniture as a static object of beauty and utility has been surpased with the advent of the new technologies, the concept of Ambient Assited Living and the fast paced changes in the social relations. The society is aging and the elderly are more willing to stay at their home, thus, the static furniture which they have been using is no longer able to adress their needs. Hence, the concept of Smart Furniture is gaining more importance because it offers solutions for improving the living conditions of the elderly, monitor their health and assist them throughout their aging. The aim of this research is to establish a model for a participatory and integrative approach for the design of Smart Furniture in order to alleviate the production obstacles and increase its production. Therefore, a literature review on the state of the art of Smart Furniture design is undertaken in order to investigate the key design aspects needed for the delivery of a succesfull product. A survey is conducted among furniture production companies for assessing the available capacities, knowledge and issues for design production of Smart Furniture. The identification of behavioral, ergonomical, psychological and physical needs of users will significantly contribute towards the creation of sustainable product solutions. Further, a set of defined criteria for assessment of a Smart Furniture product is proposed and validated by a team of experts, followed by ranking of their relevance. With the research a model is established for an Integrated Universal Design and a tool for a qualitative and quantitative assessment of a Smart Furniture product. Such a model will enable the development of novel research ideas that willl produce smart furniture based on the concepts of Universal Design, Ambient Assited Living and Ubiquitous Computing. The Authors would also like to acknowledge the contribution of the COST Action CA16226 – Indoor living space improvement: Smart Habitats for the Elderly.

Keywords - Smart Furniture, Ambient Assited Living, Information and Communication Technologies, Sustainability, Ubiquitous Computing

I. INTRODUCTION

The society is ageing and and it is estimated that in 2020, one fifth of the European population will be over 65 years old [1]. It is noted that there is a tendency in elderly people to stay at home instead of moving into residential care. This in turn requires certain assistance to them in order to conduct their daily activities. According to the World Health Organization, this tendency will generate difficulties to cover the home assistance needs in the near future because of the lack of health workers and doctors [2]. As it is stated, "falls are a really important problem for our ageing society. More than a third of older people fall each year, and in nursing and residential homes it is much more common than that" [1].

Because of the growing average age of the population, the concept of the Ambient Assisted Living (AAL) is gaining more importance. This stresses the need for developing smart furniture solutions that will assist the elderly towards a healthy and active aging.

In the contemporary society, many older people are willing to remain independent at home [2]. The Information and communication technologies (ICTs) offer solutions to such needs of the elderly. Hence, the inclusion of Information and Communication Technologies is gaining even more relevancy in the concept of Smart Buildings and Smart Furniture. However, it is stated that, often, the domains of data, information, and knowledge about buildings and how people inhabit them are excluded from the pespective of the stakeholder in the built-environment [3].

One such technology under development is an Ambient Assisted Living (AAL) monitoring system that provides individualized support services and health care within the home [4]. AAL technologies are under development by several consortiums, due to the fact that there is a high degree of acceptance of AAL among elderly [5], [6].

Also, the way we live and behave is constantly changing throughout the decades. The concept of the home/building has evolved as well as the needs of the occupants. Today, the buildings are no longer a simple and passive place but a dynamic one that needs to satisfy multiple demands of the users, such as the need to be comfortable, secure, easy to use and maintain, to be ergonomical, energy efficient etc. The new technologies, offer solutions to achieve the occupants needs with their integration in smart buildings and smart furniture. The identification of the needs and the creation of an participatory design process is a must in order to make life more comfortable and functional.

The idea of universal design (UD) is based on seven key principles, such as: equitable use, flexibility in use, simple and intuitive, perceptible information, tolerance of error, low pysical effort and size and space for approach and use.

Therefore, the objective of this research is to identify the available technologies, the needs of the elderly, their behavior, psychological and ergonomical needs

in order to define key design aspects that need to be implemented in the design of smart furniture and its integration into a smart habitat. The aim is to establish a model for a participatory and integrative design when designing smart furniture which will be based on defined design criteria. This would enable the development of novel research ideas that generate fixed and moveable furniture. Also, this would help the elderly to define their expectations and needs clearly, which will greatly help to identify design and performance issues at the earliest stage of design projects. The output of the research will provide furniture designers with valuable guidelines on the needs of the elderly which will enable them to design smart furniture. The identification of behavioral, ergonomical, psychological and physical needs of users will also significantly contribute towards the creation of sustainable solutions. Also, considering that furniture design is an important factor in the European economy and industry, it is necessary to identify its direction for future development.

II. SMART FURNITURE CONCEPT

A. Universal Design and Ambient Assisted Living

The concept of the universal design has been esablished since the 1980`s among the American architects, with the idea that the buildings should be deisgned for all of the potential users, among which the elderly. The definition of the universal design stated that ""the design of products and environment should be made in such a way that it is usable by all the people, to the greatest possible extent, without the need for adaptation or special design" [7]. The universal design is slowly being implemented in many aspects of the society, such as transportation, planning, building, housing, information and communication technology, as well as health and social services, and it is slowly replacing the concepts of accessibility and usability [8]The fast pace of changes in global society is caused by fluctuance in demographics, social structure, income, social relations and networks, changes in the built environment, changes in the outdoor environment etc. The integration of a universally accesible apartment has been implemented in the countries` legislation. It is noted that often these types of appartments are not sold to customers without disabiliy because of the different design, [7]The plurality of the western society and the democratic values are reflected into the demand for products to fully satisfy the changing needs of the end user. The universal design in buildings is gaining more importance and applicability through its regulation in building codes. However, with the this in furniture that is not the case. The idea of the furniture as a fixed and static object of "beauty and status" is transforming towards a more adaptable and flexible element. The design of furniture for the elderly or for people with disabilities should not be only designing of a barrier-free element. The development of smart furniture has been predominantly oriented towards the geriatrics or nursing homes to assist the helthcare workers on monitoring the health of the elderly. These smart systems have not been widely used in privatehomes due to cost issues.

The furniture for the disabled has to be adapted towards their needs and to be designed in a way to make it easy for them to use such furniture and adapting to its needs. One such solution is the production of modular furniture, movable furniture, cargo-cabinets, telescope shelves to make contents easily accesible and etc. Similarly, in terms of mobility aids it is concluded that affordable, safe, visually appealing devices would promote greater acceptance [9]. These notions stress the need for beauty in the design of furniture. According to the AAL philosophy, As it is noted, the older people need to have improved design of the furniture for living, while the industrial designed furniture for them is considered to be dull, with scarce design features, and not a lot of choice (Burke, 2012).Also, the furniture needs to be integrated in the home, and more importantly to establish a connection between them. Smart buildings are a significant evolving trend of an ongoing and broad technological development, frequently termed within Industry 4.0 a convergence of digital technologies. As it is stated, "Smart buildings leverage pervasive wireless connectivity, sensors and IoT technologies to communicate and analyze data that is used to control and optimize building management systems"[10]. This raises the isse of of hierarchical organization of the elements and furniture within the Smart building and the level of autonomy each of them needs to have in order to satisfy the users` needs.

B. Smart technologies and concept integration

Mainly the technologies that could be applied in the design of smart furniture can be grouped in several domains, such as: mechanical, electronical (hardware systems, sensors etc.) and software systems (artificial inteligence etc.). The technologies in the AI domain are Natural Language Analysis, Computer Vision, Machine Learning and Deep Learning.The development of advanced technologies would be assist the elderly and disabled in a case of emergency help, prevention and detection of falls, monitoring of physiological parameters, etc. It is noted that there are certain concerns about the user-friendliness of the devices, lack of human response and the need for training tailored to older learners [5].Also, the concepts of Smart Materials and Smart Building are related to improving the living conditions of the user, but on different scales. An advanced technology that could be used for the creation of an integrated Smart Habitat is the ubiquitous sensing. The growth of computing technology in networking and mobility, brings the possibility for ubiquitous computing [11], for achieving ubquitous sensing, which is a

computing that seeks to develop a distributed and networked computing infrastructure to support user activities, while remaining transparent to the users. Some of the features that are needed for the development of ubiquitous sensing are: self-calibration of the system, networking, distributed computing, optical and audio sensors, mobile sensors, embedded sensors etc. Such technologies combined with the growing field of Artificial Intelligence can be used to sense the activities of the occupants, learn on them, foresee their activities and more importantly monitor their health. Smart Spaces are characterized by following features [12]; (1) identification and detection of activity of users (2) sensing users' and devices' location and (3) control and coordination of devices. For such integration several issues have been pointed out as needed to be resloved to have improved smart device collaboration, such as: a unified communication protocol between a portable device and an embedded computer must be defined and to define a mechanism for finding appropriate devices and services and also providing necessary services to each user [13].

The potential from the integration of Smart Buildings, Smart Furniture and Smart Materials would be potentially be of great benefit for the end user Fig. 1 in making his life conditions more comfortable or assist him when in need.

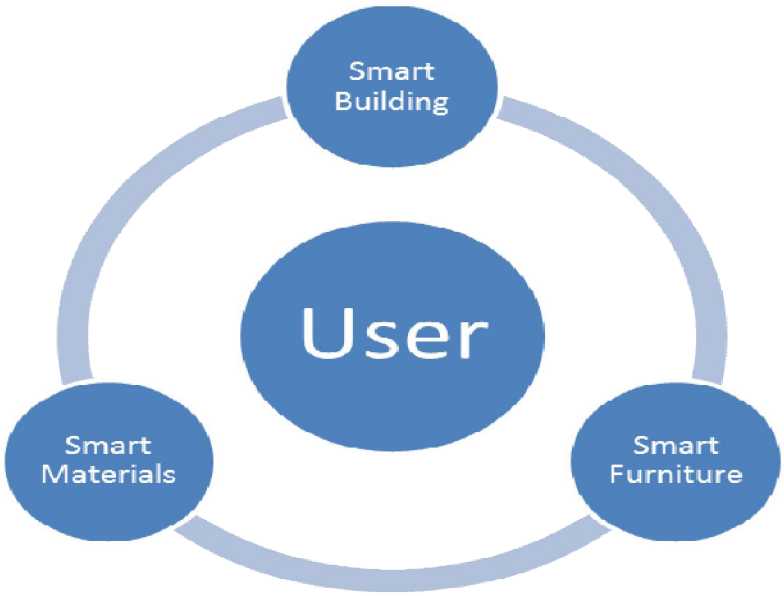


Fig. 1 Creation of Smart Habitats

III. CONTEXT FOR SMART FURNITURE PRODUCTION

In R. of Macedonia there is no long-term approach for creating an environment for the production of furniture for the elderly or for people with disabilities. Several interviews with furniture production companies have been made in the country in order to investigate their experience, practice and challenges in the production of smart furniture. From the interviews a questionaire was developed with aspects that influence the production of smart furniture.

They were assessed by total of 45 employees in furniture companies, of which 23 are designers of furniture, 15 are crafstman and 7 are production managers or owners of the furniture factories. The questions are assessed with a six point Likert scale (1-strongly disagree, 2-disagree, 3-slightly disagree, 4-slightly agree, 5-agree, 6-strongly agree) and the results are shown in Tab 1. From the results shown in Table 1 it could be noted that there is a lack of knowledge on the real needs of the elderly people or people with dissabilities. This means that the government should put more effor in improving such conditions and raising the awareness and knowledge among the designers and production companies on the needs of this category of citizens, and to improve their knowledge on the subjects of Universal Design and Ambient Assisted Living. Of significant importance is the knowledge on the types and degrees of disability and to improve the system solutions that create positive environment for improving their conditions.

The results show that there is a solid body of knowledge on ergonomic requirements for design for the elderly and people with dissabilities, but also a lack of knowledge on behaviroual requirements, while almost half of the surveyed empleyees are not familiar with safety and legal requirements. A significant lack of knowledge among the designers and production employees is noted on the aspects of UD and AAL.

Tab. 1 Assessment of the context for Smart Furniture production

Questions	Avg. points
Familiarity with the needs of the elderly and people with dissabilities	2,26
Knowledge on ergonomic requirements for design fro the elderly and people with dissabilities	4,8
Knowledge on behavioural requirements for design fro the elderly and people with dissabilities	2,1
Knowledge on safety standards for design for the elderly and people with dissabilities	3,1
Knowledge in Universal Design and Ambient Assisted Living	0,25
Applying the principles of Universal Design and Ambient Assisted Living in certain production of the production line	0,1
Skilled workers work production of smart furniture (crafstmen, engineers, system developers etc.)	5,1
Integrated design approach is undertaken during the design of smart furniture (inclusion of different engineering profiles and craftsmen)	1,25
Willingness to improve the knowledge on Smart Furniture and apply it for its production	5,2
There is a market demand for smart furniture	3,8

Further, the employees have stated that there is a sufficient knowledge for the design of accompanying technologies, such as: electronics, mechanics, software, user interface systems and etc. The companies do not have employees for the forementioned engineering profiles, only wood craftsmen, however, the companies in the market are able to deliver such services. The respondents stated that there is a high concordance between them about the willingness to improve the knowledge on Smart Furniture and apply it for its production.This is in compliance with the growing need for a better understanding of building users and the ways in which they might use buildings [4], as well as user–technology interactions, acceptability, and usability. Also, the respondents have stated that there is a relativeliy high demand market for smart furniture products. There are many recent technological innovations which assist the needs of the people with disabilities. The application of the novel technologies in the buildings created the Smart Home system, which allowed a communication and control network, making possible the remote control of almost any electronic appluance in the home.

IV. INDICATORS FOR THE ASSESSMENT OF SMART FURNITURE DESIGN

In order to establish an operative tool for the assessment of the Smart Furniture product, an indicator list is proposed, derived from the review of the state of the art research in this field. The indicator list is shown in Tab. 2 and the indicators are assessed with a six point Likert scale (1-unimportant, 2-slightly unimportant, 3-somewhat important, 4-slightly important, 5- quite important, 6-very important).

Tab. 2 Indicators for the assessment of Smart Furniture design

Criteria for design of smart furniture	Indicators	Avg. points
Beauty	Esthetics of each element and their integration into the whole	5.8
Comfort	Thermal	4.2
	Acoustic	5.5
	Visual	5.8
Ergonomics	Comfortable	6
	User-friendliness	6
	Functionality	6
	Adaptability	5
	Flexibility	5.2
	Sizing	4.5
	Safety	6
	Stability	6
Costs	Life-cycle costs	5.1

Systems	Electrical Systems	5.2
	Mechanical systems	5.1
	Sensors	5.5
Production	Constructability	4.8
	Simplicity	4.7
Sensors integration	Furniture sensors	5.7
	Wearable sensors	5.7
Materials	Sustianability	5.8
	Texture/Tactility	5.5
	LCA	5.3
	VOC	5.7
	Recyclability	5.4
Legislation	Compliance with building codes	6
User-object interaction	Software systems	5.7
	Artificial inteligence	5.6
	Percpeptibility	5.9

From the results shown in Tab. 2, it could be concluded that the design aspects that are considered very important are: comfortable, user-friendliness, functionality, safety, stability and compliance with building codes. As can be noted, most of these indicators are in the domain of ergonomics. Aspects with least importance during the design and production process are: acoustics, simplicity and constructability.

A. Integrated Design Team for Smart Furniture

Considering that the delivery of a complex system such as a Smart Furniture product demands for an integration of different professions and engineering profiles, it is needed during the design and production phase to have an Integrated Design Team, Fig. 1.

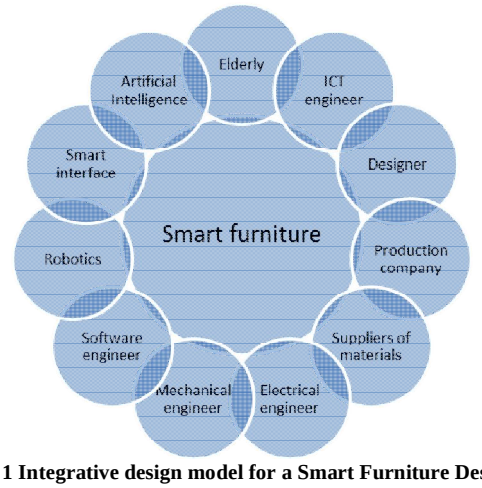


Fig. 1 Integrative design model for a Smart Furniture Design

Integrated Design Process demands Engagement of the whole team inwhole systems and integrated design thinking for every project. As it is stated"The Integrated Design Process (IDP) is a method for realizing high performance buildings that contribute to sustainable communities. It is a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle. The IDP requires a multidisciplinary design team that includes or acquires the skills required to address all design issues flowing from the objectives. The IDP proceeds from whole building system strategies, working through increasing levels of specificity, to realize more optimally integrated solutions." [14].

CONCLUSIONS

This research investigates the production context for a succesfull delivery of Smart Furniture and identifies main issues and concerns that need to be improved.
For asissting the design and production process for the delivery of Smart Furniture products, a toolset of indicators is proposed to be used by the Integrated Design team. The tool is based on the concept of UD, AAL and ubiquitous computing. Also, a model for an Integrative Design process is proposed for the development of Smart Furniture.
Finally, in order to harvest the full potential of novel technologies and create Smart Habitats, it is neceessary to integrate the concept of Smart Materials, Smart Furniture and Smart Buildings.

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