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Towards a vision controlled robotic home environment

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ABSTRACT

Ergonomics concern the creation of a product or an environment, where the connection between human skills and the surrounding is optimized. The aim of the proposed paper focuses on the implementation of a novel furniture system, offering ergonomy, by automatically adjusting its height relative to the user needs. The proposed robotic furniture system provides an integrated solution, comprising reduced space utilization, modularity, and intelligent operation while maintaining ergonomy. A set of electrical motors is used to position the various sections of the system into the correct height level, and to displace them towards the horizontal axis, to allow a rotational motion path. A vision system was integrated on the prototype to perform object recognition, in order to efficiently classify objects stored into the various system sections, and in order to assist the user in retrieving a specific previously stored object, by moving the appropriate section of the furniture into the correct height.

1. Introduction

Furniture is designed to adapt to specific needs, supporting various human activities. According to the application, a set of guidelines or rules is followed during design, in order to provide ergonomic features. Small or large sized furniture can be found within a household environment, each comprising individual modules, placed at a specific height, based upon the desired functionality [1]. A close look at the fixed and loose components of our environments shows that all components of the housing environment are gradually integrated with electronics and micro-systems. "Miniaturization" and "Downscale" as basic trends of our technological development today enable a seamless integration of sensors, actuators, control components and microelectronic systems into all subsystems, components and appliances, in a pervasive but somehow invisible way.

Today, robots and distributed robotic sub-systems start to permeate our everyday surrounding, enhancing it with services and additional features. At the same time, this permeation is on the way to transform our perception of what robots are, robot technology, robots' possibilities and the environment they are merged with. This transformation which has to be understood as a natural part of the evolution of robotics, will especially become visible when robots enter the field of service and assistance.

Aging society faces numerous challenges in performing simple tasks in Activities of Daily Living (ADLs) [2]. ADLs represent the everyday tasks people usually need to be able to independently accomplish. Nowadays caring of elderly people becomes more and more important. Originally children were taking care of their older generation, but this changed especially in industrial countries. In China and Japan the children used to care their parents when they were becoming older. Nowadays it is often not followed anymore. Additionally, the care system in many countries varies, contributing more or less to the aging society. For example in China, there is no global state care system establishment. Only 1% of the 80 + generation is found in private health care facilities. The aging society is required to cover on their own their caring expenses in private facilities. Nowadays, the majority of population worldwide focuses more on their professional career, rather than to their own family. That means not only that people increasingly used to pass on the responsibility of caring the elderly, but also a lower birth rate is recorded since more couples tend to have no children. Since the young generation is gradually decreasing, demographic change increases with rapid rates, and the definition of a strategic approach efficiently dealing with this problem becomes even more essential [3]. A demographic change measure within the past century and an estimated growth in the next 20 years in Europe are presented in Fig. 1.

An environment populated with robotic elements and micro-systems can undoubtedly contribute in enhancing their independence, by introducing a degree of ambient assistance. Monitoring people movements in complex environments, analyzing the resulting motion patterns and understanding people gestures correspond to a high level of visual competence that can most appropriately be identified

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as ambient intelligence (AmI) [4]. AmI research builds upon advances in sensors and sensor networks, pervasive computing, and artificial intelligence. Because these contributing fields have experienced tremendous growth in the last few years, AmI research has strengthened and expanded, revolutionizing daily human life by making people's surroundings flexible and adaptive. In AmI, technologies are deployed to make computers disappear in the background, while the human moves into the foreground in complete control of the augmented environment. AmI is a user-centric paradigm, supporting a variety of artificial intelligence methods and works pervasively, nonintrusively, and transparently to aid the user. It supports and promotes interdisciplinary research encompassing the technological, scientific and artistic fields creating a virtual support for embedded and distributed intelligence. AmI will eventually become invisible, embedded in our natural surroundings, present whenever we need it, enabled by simple and effortless interactions, attuned to all our senses, adaptive to users and context-sensitive, and autonomous. The basic idea consists of a distributed layered architecture enabling omnipresent communication, and an advanced human–machine communication protocol. The AmI paradigm sets the principles to design a pervasive and transparent infrastructure capable of observing people without interfering into their lives, adapting to the needs of the user. It must be noted though that populating a home environment with robotic elements must be performed following a space-efficient utilization scheme. Elderly people, and especially the ones using assistive devices such as wheelchairs and rollators, require increased barrier-free space for mobility purposes.

In this paper, the design and implementation of novel robotic furniture system which serves as an intelligent storage space, health assistant, and communication terminal for elderly people are proposed. Additionally, an integrated vision system implements the human–machine interaction assisting in detecting stored items in the robotic furniture, and aiding in efficiently retrieving them upon user queries issued by vocal commands. Thus, a compact terminal assisting the aging society in ADLs by enhancing their independence, as well as offering extended ergonomy is proposed. The proposed module can be applied to introduce a certain degree of an ambient intelligence into the home environment, including high-speed tracking, object recognition, biometrics, vision-guided operation, and many more.

The paper is organized as follows. In Section 2 related research attempts are mentioned. The ergonomy aspect is introduced in Section 3. The proposed concept realization is given in Section 4. In Section 5 the proposed system architecture is presented in detail. In Section 6 results and further development are discussed and conclusions are given in Section 7.

2. Related work

Some researchers already proposed integrated solutions as e.g. Robotic Rooms [5], Wabot House [6], or Robot Town [7]. The aim of those approaches was to distribute sensors and actuators in the environment which can communicate with the intended robot system, allowing simpler and robust robot designs. Since the 1980s several research groups have created environments and prototype buildings for so-called smart buildings. Based on Ken Sakamura's T-Engine Hardware and a complementary operating system, the Tron House 1, 2 and 3 have been built [8]. The US AwareHome [9] and PlaceLab [10] follow a similar approach and MIT's House_n [11] includes even modular intelligent furniture that can be equipped with various sensor systems. Recently designed German prototypes of assistive homes, such as "Haus der Gegenwart" (house of presence) [12] and "Haus der Zukunft" (house of the future) [13], are exemplarily equipped with a variety of networked pervasive technologies integrated by modern design. Similar to our approach Smart Buildings and Robotic Rooms try to integrate sensor–actuator systems with architectonic elements. Smart Buildings can make these systems quite invisible but their performance is limited to more "passive" services that support cognition, energy control,

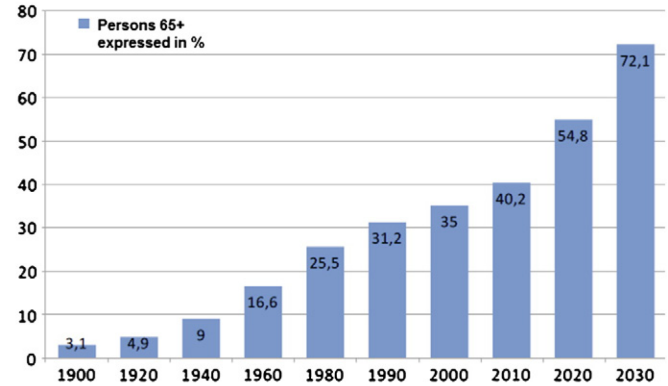

Fig. 1. Projected demographic change in Europe.

logistics, safety and security. However, these approaches integrate mainly sensors, actuators and robots on an informational level. Furthermore, they are presenting implementations that are realized in a controlled experimental environment, and cannot be straightforwardly applied into a regular medium sized apartment. The proposed system focuses on providing a compact ergonomic system that can be easily installed within a home environment, without requiring major re-arrangement procedures and modifications.

A human machine interaction (HMI) interface is required to implement the natural interaction between the user and the intelligent environment. This interaction can be defined through gestures, expressions, and movements, providing users the perception that what they are interacting with is real and usual [14,15]. An AmI environment provides interactive and communication application through natural inputs, such as gestures, sounds, body motion, etc. Other promising directions are facial expressions [16], footsteps inputs [17], and hyper-reality interface [18]. This expands the general concept of multimodal interfaces, where the interaction is based on different modalities such as vision and hearing. The interaction is not anymore dependent on a specific, unique user interface, but on the recognition of the user's actions and behavior. This kind of interaction, known as natural interaction, is defined in terms of experience: people naturally communicate through gestures, expressions, movements, and discover the world by looking around and manipulating physical things [15,19]. The proposed robotic furniture provides a HMI interface by utilizing visual and vocal information exchange between the user and the robotic furniture.

According to [3], the percentage of 65-and-over population in concern to the overall population in the developed countries continuously increases with rapid rates. Hence the need of delivering quality care to a rapidly growing population of elderly while reducing the healthcare costs is an important issue. A promising application in that area is the integration of sensing and consumer electronics technologies which would allow the vital signs of people to be constantly monitored [20]. By integrating "In-home" pervasive networks, inhabitants and their caregivers can be benefited by providing continuous medical monitoring, memory enhancement, control of home appliances, medical data access, and emergency communication [21,22]. Constant monitoring of people's vital signs will enhance the early detection of emergency conditions and diseases for high risk patients and also provide wide range of healthcare services for people with various degrees of cognitive and physical disabilities [23]. Not only the elderly and chronically ill, but also the families in which both parents have to work will benefit from these systems, which can deliver high-quality care services for their babies and little children [24]. A set of vital sign monitoring devices is used in the proposed system, in order to realize a seamless constant monitoring scheme for the