Co-adaptation of robot systems, processes and in-house environments for professional care assistance in an ageing society

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Abstract

The recruitment of new workforce for the field of care taking is difficult in highly industrialized countries and the gap between demand and availability of care takers will further increase with the expected increase in aged populations in the future. In particular, service robot systems are able to enhance the capabilities of assisted environments significantly as they add critical capabilities and thus allow environments to actively support care givers and care takers with the full bandwidth of necessary processes, tasks and services. Service robot systems add to assisted environments besides the aspect of hard physical assistance capabilities with flexibility, increased intelligence and situational awareness and provide new ways of intuitive man-machine-interaction. However, the integration of service robot systems into real world assisted environments has been difficult due to the usually separate development of environment and stand-alone robot systems. In this paper, the authors present a conceptual approach for a robotic care environment in which care environment (including room layouts, furniture and distributed sensors), service robot systems and care processes are fully synchronized and co-adapted. The conceptual approach borrows further ideas and methods developed in a series of large research projects (GEWOS, LISA, PASSAge, USA², LISA habitech) in the field of Ambient Assisted Living (AAL) by the authors and integrates them into a new research direction. The ultimate goal of the authors is to systematically investigate tradeoffs related to the distribution of complexity between environment, service robot systems and process structures and identify performance optimized and cost efficient solutions that will boost implementation and commercialization of service robot systems in ambulant and stationary care.

Keywords: Robotics, Care, Robot Oriented Design, Structured Environments, Ambient Intelligence

1. Background

In highly industrialized countries, aging society (Robine et al., 2005; Doblhammer et al., 2005; Staudinger & Kessler, 2007), shrinking work force (Burgiavini et al., 2012), demand for increased productivity in working and private life (Börsch-Supan, 2005) as well as the development towards a society for which scientists predict for the next decades the increased emergence of Centenarians, Super-centenarians (and the enlarging of the average life span by another 20 years, see Jeune & Vaupel, 1995; Maier et al., 2010), necessitate novel technological approaches, in-home services and support for ambient assisted living that are fully and invisibly integrated into our daily activities (see, for example, Wichert & Eberhardt, 2011).

Already today the recruitment of new workforce for the field of care taking is difficult in highly industrialized countries and the gap between demand and availability of care takers will further increase with the expected increase in aged populations in the future. This is true for both the field of care taking in institutions as care homes and supervised accommodation as well as in the field of home care. Reasons for the ongoing image damage and unpopularity of the care taking profession are, amongst others, low salaries, tough work schedules, high physical burdens, the execution of hygiene critical tasks (washing and cleaning of elderly, etc.), repetitive and monotonous tasks and the increase of documentary administrative work. The often honored personal contact of the care takers to the care givers (which is often used as an argument against the extensive use of technology in the care field) in current care taking reality is already missed out on due to the aforementioned aspects and burdens on the care takers. The situation can be expected to become more severe with the increase in the gap between demand and availability of care taking workforce.

With our research in co-adaptation of robot systems and in-house environments for professional care assistance in an ageing society presented in this paper, we aim to dramatically change the image and performance of the professional and non-professional care taking field and, at the same time, improving the life situation of the care takers in care homes, supervised accommodation and home care. We are not aiming at the substitution of care taking workforce by capital investment in technology but at the substitution and redistribution of individual tasks making care taking a creative, technology-oriented, high-level profession that is attractive for skilled and motivated people. Assisted living environments in which a multitude of assistive subsystems and service robots
operate seamlessly allow a complete redesign of the processes and task structures leading to the fact that the care takers become more self-dependent (which enhances life quality and decreases the burden on care takers). On the other hand, such environments allow that the care takers can be relieved, to a large extent, from the aforementioned challenging mental and physical burdens and instead concentrate on increasing the quality of service, personal care and mental and physical treatment and training of the elderly, which definitely demands intensive personal contact.

In particular, service robot systems are able to enhance the capabilities of assisted environments significantly as they add critical capabilities and thus allow environments to actively support care givers and care takers with the full bandwidth of necessary processes, tasks and services. Service robot systems add to assisted environments, besides the aspect of hard physical assistance, capabilities such as flexibility, increased intelligence and situational awareness and provide new ways of intuitive man-machine-interaction. However, the integration of service robot systems into real world assisted environments has been difficult due to the usually separate development of environment and stand-alone robot systems, high cost of highly dexterous service robot systems and lack of seamless integration and user acceptance. Therefore, with our research in this field, we aim at creating the scientific basis for the integration of service robot systems into assisted environments, considering the ultimate goal of creating care and home-care environments that allow a radical restructuring of processes and tasks for dramatically changing the image and performance of future technology-oriented care taking.

2. Research question and research method

Our research focuses on the redesign and structuring of care environments (at home as well as in care facilities) and the processes taking place within them for the creation of modular and mass-customizable robot-compatible assisted living and service environments as well as the redesign and adaptation of existing service robot systems. In an interdisciplinary approach, we will develop optimized care environments in which service robot systems seamlessly interact with the physical environment, embedded medical sensors and systems, various sets of standardized and non-standardized processes and human beings (care takers as well as care givers) to provide multidimensional assistance and a broad set of modular and customizable services. The basic premise consists of a distributed layered architecture enabling omnipresent communication, and an advanced human–machine communication protocol. The Ambient Intelligence (AmI) paradigm sets the principles to design a pervasive and transparent infrastructure capable of observing people without interfering with 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 those using assistive devices such as wheelchairs and rollators, require increased barrier-free space for mobility purposes.

A particular focus in our research is on the co-adaptation and creation of compatibility (in a physical and informational sense) of assistive environments and service robot systems. In contrast to usual service robot development (see, for example, Care-O-Bot, Patient Transfer Assist, RI-MAN), the complexity of functions (hardware, software, tasks, etc.) will not be concentrated solely in the robot system but distributed strategically between the robot system and the environment. Previous research by the authors showed that such an approach has the potential for significantly reducing the complexity and cost of the service robot system, enhancing their reliability/robustness and above all, creating completely new service and assistance capabilities (Georgoulas, et al., 2012).

In this paper, the authors present a conceptual approach for a robotic care environment in which furniture and robot systems are fully synchronized and co-adapted. The conceptual approach borrows further ideas and methods developed in a series of large research projects (GEWOS, LISA, PASSAge, USA², LISA-habitech) in the field of Ambient Assisted Living (AAL) by the authors. Furthermore, within these research projects, the authors were already able to test individual sub-systems of the now suggested, more comprehensive approach. Primarily in experimental, user oriented approaches, and in these research projects, sub-system prototypes of robot-compatible interiors and building “infill” compatible service robots were developed, and their interaction was demonstrated, evaluated and developed further in several development cycles within relevant use cases. The ultimate goal of the authors is to systematically investigate the tradeoffs related to the distribution of complexity between environment and service robot system and identify optimized effective and cost efficient solutions that will boost implementation and commercialization of service robot systems.

The paper is structured as follows. First, the authors outline the background, need and general direction of our research. Following this, the authors define and outline influencing factors and building blocks for robot adapted care environments. Third, the authors present an analysis of processes taking place in professional care environments, build process categories and relate those to the possible task for robot systems that could potentially be used to support or carry out those tasks. Fourth, the authors present their comprehensive approach for a robotic care environment in which a variety of co-adapted robot systems (mobile robots, manipulators, etc.) interact with human beings and the co-adapted the physical environment. The authors then present – as a proof of
concept – exemplarily two individual sub-systems, which they could develop, test and optimize within ongoing research projects. Finally, the authors show the impact their research can have on strategies and business models in the care taking field.

3. Robot Oriented Design for care environments: definition of influencing factors and building blocks for co-adaptation of service robots, processes and environments

Following the methodology developed by the authors in Robot Oriented Design (Bock, 1989) and Robotic Micro-Rooms (Linner et al., 2014) functions can be arranged in a three-dimensional architectural space so that a smooth and optimum operation of processes and activities is possible: a highly structured care environment can be realized that enables the automation of assistive functions and the efficient integration of robotic subsystems. In this space:

1. Processes and activities widely known and partially standardized are possible.
2. The geometric and functional configuration of the environment is known.
3. Distributed sensor systems are able to recognize and locate robots, objects, persons, vital signs, etc. in a robust way.

This creates, similar to a factory environment for industrial robots, a comparatively structured space for care environments. In this sense, factors that influence the co-adaptation of robots and environments are the environment category, the type of service robot, the type and amount of the embedded system distributed in the environment, the service robot complexity reduction function and, last but not least, the type and composition of the process in which the service robot is embedded.

4. Processes, tasks and robots

In previous research, the authors have developed methods for the systemic development of assistive home environments that support elderly people to live independent based on an analysis of processes that result from activities of daily living (see, for example, Linner et al., 2011, Linner & Bock, 2012). Care processes, both in ambulant and stationary settings, are different as the focus, on one hand, is on people that demand a higher level of care but on the other hand, include in some way professional and non-professional care personnel. In particular, in stationary care processes, room layouts and furniture are highly standardized and thus, present a solid opportunity for automation and robotisation. Based on analysis of care processes and discussions with professional care takers and care managers, the authors of this paper have identified the major process categories, related tasks with a high potential for automation and robotisation and robot system suitable for those tasks.

5. Conceptual approach

Our concept aims at the co-adaptation of service robots, environment (including floor layouts, furniture, and distributed sensors) and processes to a total system for professional (stationary and ambulant) care environments. Our concept considers, in particular, a seamless relationship and ubiquitous interaction between the user, robotic systems and smart furniture. Every aspect of the care givers’ and care takers’ activities can be influenced and enhanced by implementation of the robotic care environment. Each robotic system will work either individually or as a group in order to provide necessary assistance for the user. The smart furniture is equipped with various sensors, which can communicate with the surrounding environment. For instance, the mobile robot platform will provide efficient logistic service within the living environment, such as delivering shopping from the doorway to the kitchen, or delivering food from the kitchen to the bedside table. The telepresence robot could provide a network interface between the health care provider and the user. It can also be utilized as primary mobile communication platform or social network media. The floor and window cleaning robot will operate in an autonomous manor to carry out cleaning duty only when it is necessary. The lightweight robot arm will assist care givers and care takers with essential tasks such as preparation of food, feeding and personal hygiene operations. The above scenarios provide an excellent opportunity to evaluate and validate the overall concept of an embedded robotic care environment. Figure 1 gives an overview over a fully robot assisted care environment that might be deployed either in a care home (stationary care) in a home to assist ambulant care taking (ambulant care).
6. Proof of concept by implementation and experimentation

The possibility of co-adaptation, the dimensional space layout and furniture systems was tested and validated by the authors in different use cases and by using variety of robot systems in the AAL projects GEWOS, LISA, PASSAge, USA², and LISA habitech. All of these projects were initialized and conducted in the laboratory run by the authors and involved both commercial and industrial partners. The following two examples demonstrate exemplarily how the authors tackled the co-adaptation process.

The research project LISA investigated the possibilities to embed assistive functions and services into wall “terminal” components and, therefore, to enable an autonomous and independent living upon performing activities of daily living by (partially structured environments) robotic micro-rooms (RmRs). The terminal generated a geometrical known and structured environment for the integrated robot systems (Kinova’s JACO robot arm; TurtleBot) and provided them with additional information (for example, example about location of objects to be grasped) through the embedded systems (for example, RFID readers). Details on the LISA project, the developments, experiments and user test conducted within this project are presented in Güttler et al., 2014 and Linner et al., 2014.

In the project USA², assisted workspaces for decentralized high-tech home production of customized goods were developed. The workspaces developed are embedded in larger Cloud Manufacturing systems and will allow companies to utilize a highly skilled workforce (including highly experienced elderly) worldwide. Within the project, the workspace (its functions and design), the embedded sensors distributed in the environments, novel interfaces (for example, leap motion sensors; for further details, see also Georgoulas et al. 2014) and the related work processed were fully co-adapted. Details on the USA² project, the developments, experiments and user test conducted within this project are presented in Linner et al., 2013.
Both in LISA and USA², the TurtleBot mobile rover platform was used to act as the human-machine communication interface. Furthermore, TurtleBot was used to acquire additional visual information (for example, example recognizing dynamic obstacles as human beings) using the Microsoft Kinect Sensor (Biswa & Basu, 2011). The depth sensor consists of an infrared laser projector combined with a CMOS sensor, which captures 3-D real-time data. The sensing range of the depth sensor is adjustable, and the Kinect embedded software is capable of automatically calibrating the sensor based on the user’s physical environment arrangement, accommodating for the presence of furniture or other obstacles. Due to the fact that the Kinect sensor uses an infrared sensor, it can also provide night-vision abilities. Thus, in the proposed architecture, elderly people can be assisted by TurtleBot, in low lighting conditions and even if lights are switched off, i.e. during the night. The TurtleBot tele-operation is based on ROS open-source software (Robot Operating System). The experiments with TurtleBot in LISA and USA² showed that the co-adaptation of environment and mobile platform allows for a multitude of assistive functions (for example, intuitive user interface, transports of goods, detection of emergencies, etc.). The capabilities and technical details of TurtleBot acting in a co-adapted structured environment are presented in detail by Georgoulas et al. (2014).

3-D point cloud of actual interior space generated by TurtleBot

TurtleBot Mobile Platform

The compact mobile platform Lynx (Adept) has a payload of 60 kg

In the next step, the authors will use the generated knowledge and implement and co-adapt care environments and mobile platforms with higher payloads (for example, Lynx), which will increase the range of possible
application significantly. Figures 2 and 3 outline application scenarios for such mobile platforms in professional care settings.

7. Conclusion and future research

The authors have identified the need of and possible use cases for the implementation of service robot technology within professional stationary and ambulant care scenarios. The authors have tested strategies for the adaptation of service robots (for example, example TurtleBot and JACO) in a series of projects in the field of Ambient Assisted Living. In the next step, the authors will apply the knowledge gained so far to create professional care settings in which, in particular, the care takers are heavily supported by a variety of robots. Similar as in the research projects conducted so far, the authors conclude that the co-adaptation of robot systems, physical environment and processes will reduce total system complexity and cost and thus boost implementation and commercialization of service robot systems for ambulant and stationary care.

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