The Operation of Autonomous Mobile Robot Assistants in the Environment of Care Facilities Adopting a User-Centered Development Design [1]

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Abstract

The successful development of autonomous mobile robot assistants depends significantly on the well-balanced reconcilements of the technically possible and the socially desirable. Based on empirical research [2] substantiated conclusions can be established for the suitability of "scenario-based design" (Rosson/Carroll 2003) for the successful development of mobile robot assistants and automated guided vehicles to be applied for service functions in stationary care facilities for seniors.

Key-words: User-Centered Technology Development, Knowledge-Transfer, Participative Assessment Methods; Robotics

JEL codes: O31; O33

Introduction

Developments in labor markets and demand for elderly care open an opportunity for innovations in the use of service robots in health services. Microelectronic innovations often proceed, however, without consideration of the needs of either care workers or elderly persons.

Precise scenarios were developed through extensive requirement analysis within a care facility, the specific needs developed by this investigation in alignment with the departments of research and development of mobile robot assistants (RA) and automated guided vehicles (AGV). These scenarios are considered to be the background of further enhancements of the artifacts. This made the exchange of know-how between RA and AGV possible. The connection of these - in other respects separated - development directions of autonomous mobile systems emerged as being very fertile and promising for service applications. Based on the insertion of such scenarios RA and AGV are developed especially for operating in an elderly care facility. A first pilot phase will be carried out in the beginning of 2010. The scenarios will be examined and analyzed with usability tools especially developed for this area of application in order to continue further optimizing.

Results with regards to advantages of scenario-based processing can already be expressed. This does not only include the optimizing of the transfer of knowledge between developer and user, but also involves the exchange between developers of different development directions, like RA and AGV. Reasonable assumptions concerning anticipated acceptance (e.g. by the care facility management, nursing staff and seniors) can be distinguished on the foundation of request analysis, as well as on the iterative adjustments of the planned scenarios of the pilot phase.

Establishment of a "Knowledge-Transfer Loop"

The research that represents the groundwork of this paper is focused on the use of two autonomous mobile robots (see Figure 1 and Figure 2) which shall be enhanced to assist in care work activities. The research begins with an assessment of an elderly care facility, where the RA "Care-O-bot® 3" [http://www.care-o-bot.de] manufactured by the Fraunhofer Institute for Manufacturing Engineering and Automation IPA (Stuttgart, Germany) and the AGV "CASERO®" of the company MLR System GmbH (Ludwigsburg, Germany), will eventually be tested, and follows the

impact of this assessment on development and commercialization processes. The concerns of the research surpass the issue of usability to understand how knowledge is generated at the front-line of service work and transferred back to engineers and commercial firms designing and marketing robots for service functions (Frenkel et al. 1999).

Figure 1: Robot assistant Care-O-bot® 3

Figure 2: Automated guided vehicle CASERO®

The question if and how the quality of life of elderly persons in care facilities can be improved with the support of new technologies with the aim to enhance whose independence through the use of service technology, implies essentially the accomplishment of a requirement analysis (Rip et al. 1995). Within an intensive investigation of the requirements, specific aspects of the care-workers workday life as well as daily routines of the elderly inhabitants of the care facility anteceded. Suitable approaches for the field research are qualitative methods (Strauss/Corbin 1997). This data is very fruitful to be used in combination with the scenario-based design. The very detailed information about the field turned out to be indispensable to figure out convenient scenarios for the planned insertion of RA and AGV in this sector.

Assessing the support needs of care service providers at the care facility is just the first step to examine how technical innovations in the field of hospital care services

can be promoted. The scenario-based design is capable to convert this knowledge in plans for the specific further manufacturing of the artifacts. Transcribing the emerged needs of the requirement analysis in a narrative track of charts turned out to be a favorable procedure of optimizing knowledge transfer and communication between those who develop service robots, the service providers and the patients in such facilities. After adjusting the scenarios based on the estimation of the developers of the RA and AGV they should be presented again to the intended user (e.g. the care-workers and patients of the care facility) to figure out if the scenarios are still fitting their intentions and requirements. This process of adjusting the scenarios between developer and intended user has to be looped until every participating party is satisfied. Therefore the combination of an accurate requirement analysis with the scenario-based design turns out to be an iterative process of knowledge transfer; for which reason we would like to characterize it as a proceeding of 'knowledge-transfer loop'.

Based on the setup of several scenarios by adjusting the findings of the requirements with the technically feasible, the artifacts (RA and AGV) will be developed for an aligned operation in a care facility for seniors. In the following the scenario-based design as well as the results of the iterative process described above concerning the establishment of suitable application of RA and AGV in care facilities for seniors will be presented.

User-Centered Development

The scenario-based design is a user-centered design method. Scenarios are narrative stories consisting of at least one actor with a social, motivational and emotional background and personal goals along with objects and tools the actors deal with. The actor is usually called "persona" which is a description of a specific person who is a target user of a system being designed, providing demographic information, needs, preferences, biographical information, and a photo or illustration (Cooper 1999). Typically, multiple personas are developed in the early stages of Design that represent the spectrum of the target audience. The point of developing personas is to avoid the trap of designing for the "average" user that doesn't actually exist, and instead to make sure that the system will work for somebody specific rather than no one in particular (Usability First).

Personas are one piece of a scenario; the other piece is a description of how this person would typically interact with the system being designed. A scenario describes a sequence of actions and events which lead to a result. Thereby the level of detail in

the scenarios is adapted successive and iterative so that they become the basis of all phases in the user-centered design process - from analysis to implementation and evaluation.

Scenario-based design has several advantages. First, it focuses on the user and his internal and external needs when handling the future product. Second, in most cases scenarios are established implicit, anyway. Therefore it is reasonable to make them explicit and write them down. Because of the vividness and tangibility of scenarios they enable rapid communication about the topic. They improve both communication between members of the project-team and communication between the project-team and clients or other stakeholders: Scenarios are a key communication tool for interdisciplinary design teams. The narrative style helps the various team members with their own mental models to identify with the situation and the users (represented by a persona). Scenarios built a common understanding of the problem space and help find a common language for the design process. Compared with use cases, scenarios are more flexible and for novices easier to understand. Furthermore scenarios are able to describe complex topics and they are verifiable by defining objectives, which can be tested later in the process. Another advantage of the scenario-based design is that it avoids problems which can appear in connection with the solution first approach. Although scenarios are concrete, they are incomplete and therefore more flexible. Hence a prematurely fixation on one, first solution will be avoided.

In the course of an ongoing project (WiMi-Care) we followed suit the scenario based design approach as mentioned above: Extending over several days, different researchers were engaged in the requirement analysis of a care facility for seniors. Different methods were employed, e.g. focus groups, context interviews, questionnaires, user observations (for every shift), review of manuals, handbooks, specifications and documented best practice examples.

This way we could acquire enough data about the involved persons, their daily tasks and the tools and objects they use for handling the tasks as well as their work environment and all technical constrains. The results of this analysis were summarized in terms of three personas and four problem scenarios which illustrate the actual state. During this phase the design of the personas and scenarios was refined by several iterations. The personas cover two inhabitants and one care provider who are described by means of their age, their ethnic background, their life situation, their environment, their behaviors & habits and their motivation & problems while doing their tasks.

In the focus of the upcoming scenarios are - figured as a persona - the nurses of the care facility. We typified the findings of the nurses as a 43 years old staff nurse who has been working in an elderly care facility for 12 years. In stressful times, she has to perform several tasks in parallel. Additionally, she sometimes has to interrupt and reschedule because of high priority tasks. She would like to spend more time with the inhabitants, but time-consuming routine tasks concerning logistics and administration keep her away.

We could address four main scenarios, which cover the majority of the daily tasks in the elderly care facility. All four scenarios have been refined according to the scenario-based design process. The first two scenarios are meant for the *automated guided vehicle system* CASERO®, while the two others are designed for the *mobile robot assistant* Care-O-bot® 3 (see Figure 1 and Figure 2).

Transport-scenario

The transport scenario deals with typical logistical routine task which occur in care facilities like the transport of food trays, medication, laundry, waste and mail.

Figure 3: Sketches of the Transport-Scenario with the AGV CASERO®

The autonomous transport of this stuff will disburden the staff from time consuming and cumbersome work which is not – and should not – be the primary focus of health care staff.

Night-Duty-Emergency-Scenario

The night shift scenario aims at the assistance of the care worker as she is responsible for two floors all by herself.
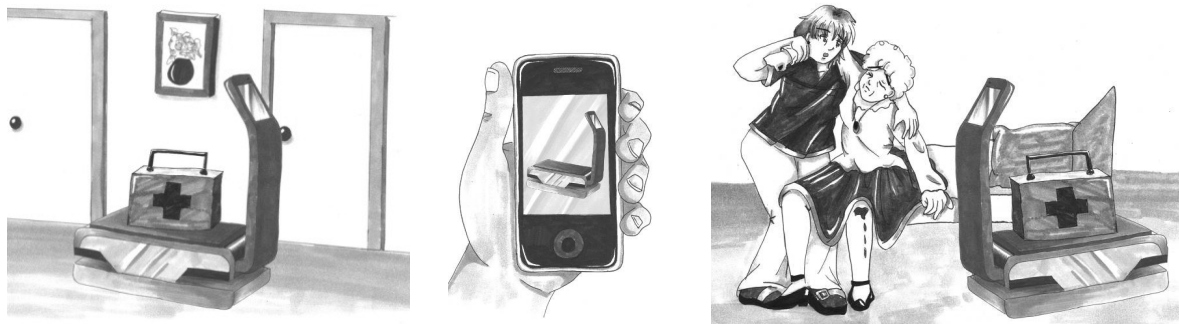

Figure 4: Sketches of the Night-Duty-Emergency-Scenario with the AGV CASERO®

Goals of this scenario are the increase of the patrol-coverage, the decrease of reaction times in case of an emergency, to provide context-aware information in case of an emergency, to serve as a first-aid station and finally to serve as a two-way communication station.

Activity-scenario

In addition to regular care tasks there is only little time left for entertaining activities with the elderly people or even to motivate them to interact with other inhabitants.

Figure 5: Sketches of the Activity-Scenario with the RA Care-O-bot® 3

The goals of this scenario consist in the support during occupational therapy and to provide a rich database of songs, poems etc.

Drink-Catering-Scenario

Another central problem is the adequate supply of the inhabitants with water. As an exemplification this scenario will be explained bit more detailed. Elderly people tend to drink not enough. This may have various causes like: forgetfulness or avoidance concerning incontinence problems or a reduced thirst feeling. One of the care workers' most important jobs is to offer drinks to the patients. The amount of water has to be documented during the day in order to induce adequate measures in case an inhabitant has not drunk enough and thus ensure his or her well being. Currently the protocol consists of a paper based list were the staff writes the fluid intake from memory. At the shift's end the entries are summed up. This process is not very reliable considering their stressful job.

Some ideas were generated how the Service Robot Care-O-bot® 3 may support this task; e.g. by the preparation of cans and mugs, the autonomous distribution of drinks, journalizing the fluid intake for every person (date, time, amount, person), providing an intuitive interface to manually add / edit / delete entries and by providing an alarm management for persons at risk (consume projection).

**Figure 6: Sketches of the Drink-Catering-Scenario with the RA
Care-O-bot® 3**

Other ideas were rejected because of their technical infeasibility or because the staff refused them, e.g. with regard to violation of privacy if the robot would enter the inhabitants' room. The scenario was visualized using a story board (see Figure 6). A smorgasbord of requirements was derived for the robot and its interface: Distinct identification of persons and a sufficient space between robot and inhabitant in order to comfort the person as well as the autonomous journaling, protocol presentation and calculation plus visualization of the estimated intake; finally the movement over non planar surfaces and recognition of the fill quantity of a mug or can.

The main tasks and processes for this scenario are: The nurse orders the robot to prepare various cans, mugs, etc. Thereupon the nurse orders the robot to distribute the drinks, which should be able to independently journaling the distributed drinks and get an overview of the manually journaling of served drinks by the nurse. Finally provide an overview of the served drinks for all inhabitants. The necessary information objects which are needed during these steps are documented in an information scenario along with a navigation concept for the whole user interface.

Impact of User-Orientation upon the Technology Development

As the service robot industry is a relatively young branch and the technological progress is very fast, product development is often based on the actual state of technology of the enterprise or research institute. Especially in research institutes, products tend to be developed as demonstrators in order to show the current competences of the institute and the improvement of technology in comparison with

former developments. This kind of product development may lead to systems that are not satisfactorily adapted to the needs of customers and users.

As stated above, the "scenario-based design" approach allows a user oriented technology development. The scenarios are directly derived from the requirement analysis, thus ensuring that the product development performed by the RA or AGV leads to appropriate, functional products. A great advantage is the fact that technical details are left out or fade to the background during the scenario development. This enables people without a technical background to actively take part in the development process. The vivid presentation of the scenario helps to focus on the identified requirements and the way users, represented by the created personas, may work with the product and profit from it.

Paying less attention to technological questions and focusing mainly on the scenario entails the danger that the developed technological task cannot be accomplished with state-of-the-art technology. In robot applications typically the level of cognition and artificial intelligence needed to successfully perform a complex task might turn out to be insufficient. This problem is amplified by the fact that people without a background in robotics often tend to underestimate the complexity of routine tasks that humans perform without effort.

The conclusion reached in the ongoing project (WiMi-Care) is, that the user oriented scenario design and the technology development done by RAs and AGVs has to be an integrated process. In several iteration steps, the developed scenario has to be checked for technological feasibility. In case the developed tasks are too complex to be carried out by a service robot, the scenario has to be adjusted. In the following, the way of scenario development is shown by means of the potation supply scenario.

The potation supply scenario will be carried out by Care-O-bot® 3, a domestic service robot developed by Fraunhofer IPA (Graf et al. 2009). Care-O-bot® 3 was completed in 2008 and is characterized by a product like system design and for the first time provides the potential to apply manipulating mobile service robots in everyday environments. The robot is equipped with the latest state-of-the-art industrial components including omni directional drives, a 7 DOF redundant manipulator, a three finger gripper and a flexible interaction tray that can be used to safely pass objects between the human and the robot. In order to serve drinks to elderly people, Care-O-bot® 3 already possesses several abilities.

The navigation system allows the robot to find its way to the water dispenser and to specific locations in the care facility such as recreation rooms and the inhabitants' bedrooms. It also allows the robot to move on corridors avoiding collisions with humans or other obstacles (Graf 2005). The state of the robot's manipulation planning and manipulation control is advanced enough to operate the water dispenser

and to handle cups filled with water. The robot is also able to open doors (Reiser et al. 2008). Image processing abilities allow the robot to recognize cups, door handles and other objects that are necessary to fulfill the potation supply task (Kubacki/Baum 2006). The computer architecture including wireless communication is able to record the robot's work and the amounts of potation consumed by the care facilities' inhabitants.

During the requirement analysis, the already existing abilities of Care-O-bot® 3 led to the idea of serving beverages to elderly people and the development of the potation serving scenario. Nevertheless during the development process some other technological needs evolved. Most of them were considered to be realizable leading to technology development in several areas, for example: Face recognition technology will be implemented and improved in order to identify inhabitants and staff members. A sophisticated graphical user interface is developed, taking into account the special needs of elderly people and people having no experience with robots.

On the other hand, some technological difficulties were identified which were considered to be unsolvable with respect to the projects resources. One of these difficulties is the task to enter inhabitants' bedrooms and to insist on the elderly person taking a cup of water. While this behavior is considered normal for human staff members, a robot is likely to convey the feeling of intruding into the human's privacy and might even frighten the elderly people. In fact, the task to persuade a human without annoying him requires complex cognition skills. After identifying these problems the original scenario was changed in a way that Care-O-bot® 3 focuses on delivering beverages in public areas such as living areas.

Efficiency of "Boundary Objects" in the "Knowledge-Transfer Loop"

As a relevant result for a user-centered development of innovative technology we would like to emphasize the advantage of the scenario-based design within a detailed requirement analysis which constitutes the basis of the scenarios (EU 2009). We would furthermore like to stress that this proceeding could be highly recommended for the aim of a participative development of technological innovations (Joly/Assouline 2001; Joss/Bellucci 2002).

The scenario-based design allows the processing of relevant knowledge about various target groups, in which an effective and functional exchange is possible: The scenarios are illustratively converted into sketches and display a narrative image of the service. Hereby weak points and difficulties of operational sequences and their technical translation are identified in early stages, even before the actual technical

realization is initiated. Simultaneously, questions of occupational safety as well as legal aspects can be considered. A high acceptance can be achieved by clarifying criteria by the descriptiveness of the scenarios. Therefore such processing also enables a cost effective development of innovative technologies in general. It is especially suitable for strongly interactive micro system technology, e.g. the application of autonomous mobile systems in complex social systems.

The scenarios within an iterative process between relevant target groups are continuously adjusted until all involved parties consider the scenarios as being socially desirable and technically possible. The scenarios can be considered as a "boundary object" in which technical and societal innovation is efficient and coordination is possible by mediating the societal and technical factors through every party. This way, they provide themselves as a medium of an ideal participative technical development. The description of boundary objects as a first approximation by Star/Griesemer appears phenomenological as the result of a work in progress cooperation between heterogeneous parties: "The different commitments of the participants from different social worlds reflects a fascinating phenomenon - the functioning of mixed economies of information with different values and only partially overlapping coin. […] Rather, boundary objects act as anchors or bridges, however temporary." (Star/Griesemer 1989: 413f) The above described iterative process turns out to be a systematically compounded link between such heterogeneous groups as care workers, elderly persons and developers of autonomous mobile robot assistants. It allows realizing a well-balanced reconcilement of interests either of the technically possible as well as the socially desirable.

Conclusion

The focus of this paper lies in the presentation of a methodological approach for guiding an innovation process that considers the inter-relations of technical and societal issues by merging them into one knowledge-transfer loop through the combination of an intensive requirement analysis and the scenario-based design. We would like to stress that such a methodological path of a user-centered technological development could especially promote innovations related to upcoming needs of the demographic shift, e.g. solving problems associated with ageing societies.

The research findings will contribute to the further development of service robots. In the near future robots could help to reduce the stress and burden of care work by taking on time-consuming, yet routine tasks, and freeing up health care workers to focus on higher-skilled aspects of care provision. For the patients with acute care needs, robots may lessen their dependence on care workers and contribute to their ability to lead more independent daily lives.

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