Zeitschrift für Gerontologie und Geriatrie

Robotereinsatz in der Langzeitpflege: Fallstudie zum Einsatz eines mobilen Roboters zur Unterstützung von Physiotherapie

--Manuscript Draft--

Manuscript Number:	
Full Title:	Robotereinsatz in der Langzeitpflege: Fallstudie zum Einsatz eines mobilen Roboters zur Unterstützung von Physiotherapie
Article Type:	Themenschwerpunkt
Keywords:	Older adults; ambient-assisted living; long-term care; care robots; human-robot interaction
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Funding Information:	EU ICT (Project 600623 'STRANDS') — Not applicable

Abstract: Background. Healthcare systems in industrialised countries are challenged to provide care for a growing number of older adults. Information technology holds the promise of facilitating this process by providing support for care staff, and improving wellbeing of older adults through a variety of support systems. Goal. Little is known about the challenges that arise from the deployment of technology in care settings; yet, the integration of technology into care is one of the core determinants of successful support. In this paper, we discuss challenges and opportunities associated with technology integration in care using the example of a mobile robot to support physical therapy among older adults with cognitive impairment in the European project STRANDS. Results and discussion. We report on technical challenges along with perspectives of physical therapists, and provide an overview of lessons learned which we hope will help inform the work of researchers and practitioners wishing to integrate robotic aids in the caregiving process.

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Robotereinsatz in der Langzeitpflege

Fallstudie zum Einsatz eines mobilen Roboters zur Unterstützung von Physiotherapie

Robot Deployment in Long-Term Care

A Case Study of a Mobile Robot in Physical Therapy

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Zusammenfassung

Hintergrund. Viele Gesundheitssysteme stehen vor der Herausforderung Pflegeleistungen für die steigende Zahl an alten Menschen zu gewährleisten. Informationstechnologien stellen eine vielversprechende Möglichkeit dar, diesen Anforderungen gerecht zu werden, in dem sie in verschiedenen Anwendungsformen zur Unterstützung von Pflegepersonal oder zur Steigerung des Wohlbefindens alter Menschen eingesetzt werden. *Ziel.* Bislang ist noch wenig über jene Herausforderungen bekannt, die sich im Zuge des von Technologien im Pflegebereich ergeben. Allerdings stellt aber gerade die Integration solcher Technologien im Pflegebereich eine der bestimmenden Faktoren hinsichtlich der künftigen Unterstützung des Pflegepersonals dar. In diesem Beitrag diskutieren wir daher Herausforderungen und Möglichkeiten welche mit der Integration von Technologien im Pflegekontext einhergehen, anhand eines Fallbeispiels, in dem ein mobiler Roboter im Rahmen des EU-Projektes STRANDS als Assistent im Bereich der Physiotherapie von alten Menschen mit fortgeschrittener Demenz eingesetzt wurde. *Resultate und Diskussion.* In diesem Paper wollen wir vor allem technischen Herausforderungen, die mit dem Einsatz eines Roboters im Pflegekontext einhergehen sowie Perspektiven der involvierten Physiotherapeuten fokussieren um einen Überblick über Erkenntnisse und Erfahrungen zu bieten. Damit hoffen wir Wissenschaftlern und Praktikern wertvolle Informationen zu bieten, die im Zuge der Integration von assistiven Robotern im Pflegebereich künftig nutzbar gemacht werden können.

Keywords: Senioren; Ambient-Assisted Living; Langzeitpflege; Robotereinsatz in der Pflege; Human-Robot Interaction

Abstract

Background. Healthcare systems in industrialised countries are challenged to provide care for a growing number of older adults. Information technology holds the promise of facilitating this process by providing support for care staff, and improving wellbeing of older adults through a variety of support systems. *Goal.* Little is known about the challenges that arise from the deployment of technology in care settings; yet, the integration of technology into care is one of the core determinants of successful support. In this paper, we discuss challenges and opportunities associated with technology integration in care using the example of a mobile robot to support physical therapy among older adults with cognitive impairment in the European project STRANDS. *Results and discussion.* We report on technical challenges along with perspectives of physical therapists, and provide an overview of lessons learned which we hope will help inform the work of researchers and practitioners wishing to integrate robotic aids in the caregiving process.

Keywords: Older adults; ambient-assisted living; long-term care; care robots; human-robot interaction

Main text:

Introduction to the Topic

Assistive technology – including robots – has potential to support caregiving for older adults in various ways, for example, by supporting care staff, or providing mental and physical stimulation for residents of care facilities. However, it is important to consider the needs of care facilities, their residents, and the extent to which currently available technology is able to provide support to develop accessible and acceptable systems. To this end, it is important to consider challenges and opportunities that arise from the caregiving context, and that result from technical limitations.

1. Introduction

The growing number of older people in industrialised countries increases pressure on healthcare systems to provide care that is both affordable and meeting the emotional and physical needs of older persons. In this context, the integration of information technology holds promise of supporting caregiving processes: for example, assistive technology has been developed to provide reminders and empower individuals to live independently in their own homes [20], to encourage older adults to participate in preventative therapy [28], or software systems that can support staff in care facilities [29]. Findings from case studies (e.g., [6] and [29]) suggest that it is suited to support informal carers and professional care provides alike who are looking to offer quality care to ageing populations.

However, an important aspect that needs to be considered particularly when discussing the potential of information technology to support long-term care are challenges that arise from the practical deployment of new technologies in caregiving environments. While assistive technology for older adults has made big advancements in the last few years – for example, the development of companion robots [2], and more comprehensive, intelligent systems to support home care (e.g., ambient-assisted living systems utilizing voice interaction as proposed by Portet et al. [23] – there are a number of unique challenges that need to be considered when taking technology out of lab environments into the field.

To this end, our paper provides insights from a case study around robotic support for older adults in long-term care that investigated the potential of a mobile robot to support physical therapy in the large-scale European project STRANDS (see Appendix, section 1). Specifically, the case study explored whether older adults could be engaged in a Nordic walking group led by a robotic pacesetter who would guide them on indoors walks (see Appendix, section 2). In our paper, we aim to provide an overview of the practical and technical challenges on the basis of findings from the case study. We combine perspectives of care and technology experts to provide a comprehensive overview of relevant considerations, and to discuss lessons learned with a focus on technical limitations, opportunities, and practical challenges that need to be considered when integrating robots in long-term care. Thereby, we hope to provide valuable information that can be helpful for practitioners and researchers alike considering the benefits of technology integration in long-term care.

2. Background

This section summarises previous efforts in the development of technology to support well-being among older adults, and it discusses related work that has explored the deployment of technology in long-term care.

Designing Technology to Support Well-Being of Older Adults

Throughout the last decades, numerous attempts have been made to develop technology that contributes to the well-being of older adults, particularly focusing on supporting older persons while attending to individual personal needs, and assistive technology to support independent living. For example, the potential of entertainment software and social networking tools was explored to support engaging leisure activities and to connect older persons with peers (e.g., [1]). In this context, developers try to integrate aspects of entertainment and socializing with preventative applications; for example, work by Müller et al. [21] investigates the potential of social, game-based tools to promote balance training and falls prevention among older adults.

Additionally, numerous research projects have looked into the development of ambient-assisted living solutions and other tools that can help older adults maintain independence. Among others, Grönwall and Verdezoto [9] explored tools to enable older adults to monitor blood pressure in their own homes, and Lee and Dey [14] discuss systems designed to offer adults reminders to take medication. With respect to robotic deployment in the home, many studies focus on the requirements of older adults for robot deployment in domestic areas (e.g., [19]). The main findings indicate that older adults prefer robot assistance for instrumental tasks like housekeeping (garden work, cleaning), for manipulation of objects (picking up and moving heavy items, finding and fetching items) and reminder functions, but that older adults preferred human assistance in terms of cooking, personal care and leisure activities. In this context, Prakash et al. [24] explored the potential of robotic aids in the provision of medication; their findings suggest that older adults' acceptance of the approach largely depends on their attitudes towards robots, outlining the variety of factors that play into the successful integration of robotic assistance.

While many of these results are promising in terms of the benefits that technology could have for older adults, further considerations regarding the suitability of such technologies for older adults are necessary to address challenges that arise from the practical deployment of technology in the homes of older adults, and in residential care.

Technology Deployment in the Home and in Long-Term Care

A growing body of research addresses the development of technologies designed to be embedded in long-term care, and there are numerous examples of technology deployment in caregiving environments, each associated with unique challenges outlined below.

For example, Gerling et al. [7] studied the integration of console games as social activity in long-term care over the course of four months. Results of the project revealed that inviting residents to engage with technology in a social setting was problematic (e.g., participants felt self-conscious), suggesting that factors emerging from technology deployment in the environment of the specific care home and abilities of residents need to be considered in addition to general aspects relating to the accessibility of technology for older adults. Addressing the needs of staff rather than directly focusing on those of older adults, Webster and Hanson [29] investigated the benefits of a software support system for staff in long-term care, suggesting that it could be of substantial assistance when interacting with residents by providing individual background information and residents' needs for members of staff.

With respect to robotic deployment in long-term care, projects have previously explored the potential of robotic assistance, for example focusing on older adults living in retirement communities [22], or as a conversational aid in a care centre attended by older adults on some days of the week [26]. Focusing on ambient-assisted living solutions, Caine et al. [3] investigated how older adults responded to the presence of monitoring technology – including a mobile robot – and how it affected older adults' privacy enhancing behaviour. Findings demonstrate that older adults adapted their behaviour in the presence of such technologies in a way that allowed them to protect their privacy, suggesting that further research is necessary to facilitate seamless integration of technology in care, and improving the acceptability and understanding of technology to the point where older adults do not feel like they need to modify their own behaviour.

Finally, research has also begun to address needs of staff in long-term care facilities catering to older adults who experience substantial age-related changes and impairments. Work by Smarr et al. [27] presented a social assistive robot with entertainment and communication support functions to older adults and staff members. Results showed that staff perceived both tasks positively. In another study [17], older adults and care staff had to rate their preferences in a list of different predefined tasks. Findings show that care staff prioritized tasks like lifting heavy objects, monitoring the location of people, switching electrical applications or lights on or off, reminding of daily routines, escorting residents to meals or using the robot as a walking assistance for older adults.

However, little is known about the practical requirements that would arise throughout robotic deployment. This shows that despite big advances in the general development of technology to support wellbeing among older adults, researchers and practitioners still face substantial challenges when integrating technologies in long-term care. In the remainder of our paper, we will discuss an exemplary case study of robotic pacesetting for an indoors walking group. Thereby, we provide an overview of practical and technical challenges that need to be considered when integrating a robotic support system in a long-term care facility catering to older adults with cognitive impairment.

3. Challenges and Opportunities of Robot Deployment in Long Term Care: Insights into the STRANDS Project

Within the four year project STRANDS (see Appendix, section 1) an assistive robot was introduced to the long-term care hospital “Haus der Barmherzigkeit” in Vienna Austria. This institution primarily houses older adults with cognitive impairment and dementia (see Appendix, section 3). One aim of this project is to investigate methods of long-term adaptation and learning for mobile robots in the care context and other real world work environments and to study the social impact of the introduction of robot technologies to these areas of deployment. In this section, we provide an overview of challenges and opportunities that were identified in a collaborative process between researchers and staff from different professions throughout different deployment phases. In this context, we focus on results addressing caregiving-related aspects along with considerations that focus on limitations and the potential of robotic technology.

3.1 Background: Requirements Analysis and Walking Group Deployment – Robotic Pacesetting

If robotic aids should support the care sector in future, it is necessary that these aids are developed in such a way that end users accept and use them. Therefore, a user-centred design approach was conducted in the course of the STRANDS project to assess requirements of different stakeholders at the care site [10]. In this context, the project not only took into considerations the needs of older adults, but also worked with physical therapists to identify their needs with respect to robotic support in a caregiving environment. No specific tasks imposed from robot-developers or researchers were predefined. This should enhance creativity in the consideration of potential tasks to be identified by staff in different working areas of a care home.

The study resulted in a summary of possible tasks for a robot deployment in long-term care, including ideas such as the transportation of medical dispense material, guiding of care home visitors, or receptionist duties. As one of the more novel ideas, physical therapists suggested that the robot could accompany the “Nordic-walking” groups in physical therapy [11]. In these groups, physiotherapists walk indoors with older adults with severe dementia to enhance their mobility. This scenario was chosen for implementation as robotic pacesetting for a walking group offered the opportunity to connect the project directly with daily routines in the care of older adults, while also exploring some of the wider technical challenges associated with the STRANDS project.

After the implementation phase, the fully autonomous robot companion was tested in the course of the walking group sessions at the care hospital (see Appendix, section 3). For one month, the robot accompanied the walking groups twice a week. Participating therapists and members of our research team evaluated this test phase to gain an understanding of the prevailing challenges and opportunities of this specific robot task. Prior, during and after the robots test phase the therapists assessed their perception of the robot’s performance, looking at aspects such as group cohesion, the amount of communication between them and the participants, as well as the mood and motivational level of participants. After the conclusion of the deployment phase the therapists were asked about their subjective experience in group interviews.

3.2 Challenges and Opportunities – Therapists’ and Developers’ Views on Robotic Pacesetting

In this section, we discuss the most important issues that emerged from deployment with focus on perceptions of staff (for more details see [11]) along with technical challenges. We also comment on some observations regarding resident interaction with the robot and, further explore future technical requirements.

3.2.1 Therapists' Perspectives on Robotic Pacesetting

In general, therapists had a positive attitude towards the robot expressing curiosity and excitement about having the robot accompany their walking groups. They appreciated the entertainment function of the robot and fed back, that the robot had a positive influence on the participating older adults, animating them to sing or dance along, clapping their hands or whistle to the rhythms of the music. A restless older lady could use the robot as point of orientation and thus stay closer to the group. Another participant, who, in the course of dementia, lost the ability to speak, could connect more to the group activity due to the robots music offer. Ratings of the therapists also indicated that the robot positively influenced group coherence, motivation and the atmosphere of the group [11].

With regards to resident interaction with the robot, about six of ten participants tried to interact with the robot although therapists experienced that they needed guidance to use the touchscreen despite the menu being structured in a simple way. Older adults pressed randomly on the screen or pressed icons and did not let go again. Another observation was that participants forgot about their "plan of action" during navigation through the menu due to dementia and thus needed support by the therapists. Three participants were just looking at the robot and one older lady ignored the presence of it during the sessions.

Besides the evaluation of therapists' and residents' interactions with the robot, the deployment phase also revealed technical shortcomings. There were several instances in which technical problems impacted the therapists' perception of the robot. For instance, if the robot got stuck or showed other navigation related problems, it was experienced more of a burden than a helper.

3.2.2 Technical Challenges in Robotic Pacesetting

To further explore technical challenges associated with the task presented before, this section focuses on robotic navigation in the caregiving environment, and discusses perspectives around interaction design for long-term care settings.

Moving is hard… for a robot in a care setting

In fact, the robot's navigation ability was most frequently reported to be causing issues and as affecting the perceived usefulness of a robot in such a therapy session most negatively. From the analysis of qualitative reports obtained from therapists and augmented with information from other care staff, the following categorisation of observed issues has been established, and underlying problems for such reported issues have been identified from system logs:

1. *Situations where the robot stopped moving at all and also after significant waiting time (in the order of minutes) could not continue the tour:* These situations were rare during the 30 days deployment of the robot, and most of them need to be attributed to the immaturity of a research prototype robot employed in the study. For example, a reason for this failure was that the on-board PCs that had been added to increase computational power of the original design had a fatal power failure. Indeed, such failures have very little to do with the state of the art in research, but underpin the need for scrutiny and diligence in product development to maximize availability and robustness of robots in professional applications; a requirement that is addressed by many commercial robot developers making suitable products available today.

2. *Situations in which the robot appeared to be "stuck" but continues after a (sometimes long) time:* This technical shortcoming highlights a general challenge still evident in today's state of the art robots, whenever they enter a human-inhabited environment. The robot's navigation software is at its core composed of long-established and well-matured technology[1], so it did not fail in this case. But robot navigation systems have mostly been designed to enable it to quickly move from one place to another, avoiding obstacles on the way. However, most of these obstacles are considered static, which is an assumption that clearly does not hold in a busy environment such as a care home. This problem has been addressed in a number of works, which try to overcome this problem either by modelling the dynamic "flow" of crowds around a robot [25], or by explicitly taking time into account when planning a route for a robot [12], or even seeking the human's help [14] to unblock the robot. These advances that are all aimed at making robots' navigation more robust and increase the perceived safety of humans around them will eventually mature and be available off the shelf. The findings of our study only underpin the relevance of this direction of research.

3. *Robot perceived as a threat:* Very much relating to the previous point, the robot's navigation is considered generally safe. For a roboticist that means that the robot will not actively drive into a person, and usually researchers in robotics are very much satisfied by their robot efficiently navigating between places while not bumping into things and people. But, utilising such traditional state-of-the-art navigation approaches might well cause a robot to drive up very close to humans, or, plan paths that conflict with the human's intention to walk

[1] Most of the robot's software is build using ROS, the Robot Operating System, http://www.ros.org/, which also contains a navigation subsystem, which can be considered the most commonly used within the robotics research community.

along which are situations in which the robot could be perceived as threatening. Navigation in humans is determined by many factors, such as conventions (e.g. passing people on the right or left, depending on the cultural preference), establishing eye contact to convey intention, and even an assessment of the others' abilities. In a sense, humans are negotiating non-verbally when they manage space in the proximity to other people. Enabling a robot to master this challenge even closely to the way humans do it is still on-going research in the field of "human-aware navigation" with all its different facets [15]. Within the STRANDS project this challenge is also tackled, by enabling the robot to continuously adapt to the appropriate navigation methods [5] taking the past experience of encounters with humans into account. One key challenge for this is also perception, i.e. to be able to see and recognise people in the vicinity of the robot [4], which indeed becomes even trickier if people sit in wheelchairs or are of largely varying posture or body height, which also has to be taken into consideration. As general policy, robots are usually designed to be very obedient to humans and if in any doubt, to stop and let any humans pass first [17]. This, however, then often leads to situations identified earlier where the robot does not move for a while, as it is waiting for situations that are considered safe to move. Consequently, it might also expose a rather "stuttering" motion, while it continuously tries to find a safe and comfortable way to move among humans, while these, at the same time, move as well. In a way, what we observe in human-robot joint navigation is not at all different to a situation we all know when we humans do a little "dance" when we are trying to pass each other in a narrow door or corridor, while negotiating who passes on which side.

Addressing these challenges should be a key objective for coming research into human-aware navigation, bringing together different cues and signals that help intuitive, non-verbal negotiation of spatial movements between robots and humans.

Interaction design is challenging… when audiences have diverse needs

A second major challenge besides navigation raised by the therapists was the interaction with the system itself via touch screen and short jingles as an auditory feedback of state changes. In the deployed therapeutic pacesetter system, the interface was designed for two audiences in mind. First, for the therapist, with the aim to empower them to exercise full control over the robots functionalities and, second, for the participants of the therapy session, to more closely involve them. The robot switched between the two modes by recognising the orientation of the

marker shown left. Normally, therapists were carrying the marker upside down on a lanyard, but when they wanted to stop the robot and enter the full menu that enabled to exercise more fine-grained control, they could hold the marker upright to the robot to identify themselves and their intention. This simple and intuitive authentication step prevented participants to access all the robot’s features uncontrolled and unsupervised. For participants, even the simplest touch interface, just showing one button “Weiter” (German for “Continue”, meant to indicate the intention to continue the tour after the robot stopped to wait for the group to catch up, see left) turned out to be confusing as they often had no clear understanding of its semantics, or had forgotten about its meaning during interaction due to the dementia. These occurrences add to studies that already showed that interface design for people with dementia and older adults poses particular challenges. Based on research findings, guidelines have been developed to guide interface design for this specific user group, but observations during walking group sessions with older adults with severe dementia showed that even simple interface designs did not entirely mitigate those issues.

It is a well-known problem that speech output raises expectations in persons that the robot will also understand natural, spontaneous speech. Hence, in this setting we had explicitly disabled the speech synthesis and replaced it with audible notification (such as a jingle when the robot started to move). Nonetheless, we found that many participants were anthropomorphising the robot in terms of its abilities to hold a conversation. While it is acknowledged that speech processing and understanding has made a lot of progress, the expectations raised by the somewhat anthropomorphic design (head including eyes, general statue) of the deployed robot will still go unmet with the robot’s abilities. This ties in with general design guidelines and considerations for robots in care outlined in **Error! Reference source not found.**, and indicates that a holistic approach to interaction design is required that takes into account appearance and familiar interaction patterns.

4. Lessons Learned

Building on the core issues discussed in the previous section – robotic navigation in care environment and its impact on perceived usefulness of robotic aids, and interaction design for diverse audiences in long-term care – this section outlines lessons learned with a focus on design, development and deployment opportunities for future projects.

1. Variation of abilities

   The care environment can be deemed as one of the hardest for interactive mobile robots, both from a navigational as well as from interaction point of view. A robot will encounter many people with a largely varying set of capabilities in terms of their own locomotion: People in wheelchairs cannot easily get out of the way of a robot. People using a walking aid are limited in their agility and ability to circumvent a robot. In general, as people grow older they often become more insecure about their own ability to move safely, leading to increased anxiety around a moving robot. These are challenges for robot navigation hardly explicitly researched today, and demanding much more attention of the robotics research community. The same variation of abilities is encountered when robots interact with people in a care setting. Possible interaction partners range from visitors, over staff, to residents, each with their own specific set of expectations, experience, and cognitive ability. The principle of designing "one fits all" solutions needs questioning, and appropriate answers tailored for the setting, particularly when working with individuals with a range of cognitive abilities [8].

2. Low level abilities and interfaces need to fit or destroy the perceived usefulness

From our studies we have identified that it is often the technology commonly considered rather low-level in terms of robotics that poses the biggest challenges. As discussed in this paper, robotic navigation and simple interaction via touch screen or speech output are mostly considered solved in the research field. However, the specifics and variability of the care environment demand for more flexible and adaptive solution.

3. Iterative design and participatory design is essential

The findings and considerations presented in this article stem from an in-depth analysis of data gathered in a 30 days deployment of a mobile robot platform in an actual care home. The analysis of such data is a highly cross-disciplinary endeavour, requiring input from staff, sociologists, and roboticists, leading to a systematic interaction analysis of exposed system behaviour and internal processing models [18]. In fact, given that experience from long-term deployment of autonomous, interactive robots in care is still scarce, the community still needs to gather a lot of experience and insights into the needs and requirements, demanding iterative, participatory approaches to design and implementation of such system. This calls for robotics researchers to learn more from and about needs of people being and working in care, as well as the openness and enthusiasm of care institutions to learn more about and to explore the robot technology in a most integrative and cross-disciplinary manner.

5. Conclusion

This paper illustrates some of the challenges associated with the deployment of mobile robots in long-term care. With respect to practical implications of our work, we believe that the following aspects need to be considered:

- Requirements analysis has to balance needs of the care environments, residents, but also consider system quality that can currently be delivered, and be ready to adapt solutions to run reliably,
- further efforts need to be made to explore the design of user interfaces that are suited for user groups with diverse cognitive abilities,
- and care professionals, long-term care facilities, and technology developers need collaborate on the design, development and integration of care robots can we provide solutions that truly suit residents' needs.

We hope that our paper contributes to the identification of current challenges, and will help researchers and practitioners address common issues associated with robotic deployment in long-term care in the future.

Appendix: Information Boxes

1) STRANDS

STRANDS (http:// strands-project.eu/) is a research project, funded by the European Commission’s 7th Framework Programme, involving six academic partners from all over Europe, and two industry partners. In its core, the project aims to develop intelligent mobile robots that are able to run for months in dynamic human environments. The challenges that are particularly looked at by the STRANDS project are to provide robots with continuous learning and adaptation, which means that these robots should automatically learn from their environment and the humans surrounding them continuously, and, over time, use the experience they gather to become better at the services they offer. Hence, one can say that the academic partners in STRANDS provide robots with the longevity and behavioural robustness necessary to make them truly useful assistants in a wide range of domains, with support in care of older adults being one of those.

The vision of the project is that such long-lived robots (robots will be running on their own up to 120 days) will be able to learn from a wider range of experiences than has previously been possible, creating a whole new generation of autonomous systems able to extract and exploit the structure in their worlds. In the care setting, this approach is expected to more easily integrate the robot into the overall workflow, adapt to users’ needs and to robustly cope with somewhat unexpected situations.

The robot that STRANDS develops software for is a mobile platform approximately the same size as an average human. The robot is based on a SCITOS G5 mobile robot platform, that is equipped with various specialised sensors, enabling the robot to see and detect humans, to avoid obstacles in its way, and to map out its surrounding. The robot is based on a SCITOS G5 mobile robot platform. It is equipped with a SICK s300 laser range finder for navigation, a Kinect-like sensor mounted on a pan-tilt unit for people perception, a touch screen on its back and an actuated pair of eyes as a focal point for human interaction. Via speech output and a touch screen software developed within STRANDS, the robot can interact with people around it, offering information services, guidance, or specialised services developed in collaboration with therapists and professionals at the care site. The software developed by the STRANDS consortium is freely available to other researchers and interested parties, helping them to develop next-generation, adaptive robots that can robustly operate for extended periods of time on their own and learn from their experience.

2) Robot as Pacesetter

As part of the presence of the STRANDS robot at the care site, the robot acted as a pacesetter in physical therapy, namely the “walking group”. Residents with progressed dementia receive different therapeutic interventions at the care site. One intervention is the “walking group” in physical therapy with the goal to maintain the mobility of the residents, to provide them with diversion in their daily routines and to engage them in an activity with other residents. During the walking group, as well as in all other tasks it engaged in, the robot was navigating autonomously using a navigation framework implemented by the STRANDS consortium, featuring reactive obstacle avoidance based on the sensor input, and continuous path planning to move along the institution using a so-called topological map. This map re-defined the coarse route for the robot and also resting areas and other actions executed during the walking group at waypoints (such as playing tunes in certain parts of the environment). The robot’s maximum speed during deployment was 0.55m/s, adjusted to the speed of the quick walkers. To prevent the robot going too far ahead of the slow walking group, certain waypoints were installed where the robot waited for the group to catch up. A specific marker detection system [13] was employed to reliably identify the therapists and allowing them to take on the role of an “administrator”, e.g., enabling certain control functions (such as aborting the tour, re-routing, continuation, etc.) only to them. The robot autonomously identified the therapists and reacted to them accordingly. Details regarding the design and implementation can be found in [11], but it should be noted that the system also encouraged interaction with the participants of the therapeutic session itself, by allowing them to choose music to be played during the tour or to trigger the robot to move to the next position in the tour via simple interactions on the touch screen. Allowing the participants to engage with the robot themselves was indeed one of the explicitly desired and also regularly used features.

2) **Deployment Site**

In the course of the 4-year project STRANDS the robot platform is deployed every year at the care hospital “Haus der Barmherzigkeit” in Vienna, Austria. Founded in 1875, this care hospital specializes in the long-term care of older adults with cognitive decline, dementia as well as multimorbidity and patients with vigil coma or severe multiples sclerosis. A total of 465 employees manage and provide the long-term housing and nursing for 350 residents. Additionally, medical ambulances and departments for occupational and physical therapy are integrated into the care hospital. The robot is deployed on the ground floor of the site including the lobby, ambulance, and therapy sections as well as the administrative wing. In this environment the robot encounters several site specific challenges: within the spacious deployment area much activity takes place e.g. the transportation of residents either by foot, in wheelchairs, or beds from units to the ambulances or therapy areas and the coming and going of employees and visitors. This constitutes a very busy environment the robot has to navigate through. Furthermore the robots tasks have to meet interests and abilities of various groups of potential users like doctors, therapists, care staff, visitors, or residents with dementia. Thus, interesting contents or tasks have to be integrated in easy structured menus or routines.

Funding

The work was partially funded by the EU ICT project 600623 ‘STRANDS’

Acknowledgements

We would like to thank all participants who contributed to our case study.

Compliance with ethical guidelines

Conflict of interst. There is no conflict of interest.

The study was approved by the University of Lincoln College of Science Ethics Board, and was also reviewed by Haus der Barmherzigkeit.

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