Co-Designed Technology for Elderly Care: Mobile Robots and Passive RFID for Nighttime Safety

Mirka Leino
Faculty of Technology
Satakunta University of Applied Sciences
Pori, Finland
mirka.leino@samk.fi

Sari Merilampi
Faculty of Technology
Satakunta University of Applied Sciences
Pori, Finland
sari.merilampi@samk.fi

Pauli Valo
Faculty of Technology
Satakunta University of Applied Sciences
Pori, Finland
pauli.valo@samk.fi

Zahangir Khan
Faculty of Medicine and Health Technology
Tampere University
Tampere, Finland
zahangir.khan@tuni.fi

Johanna Virkki
Faculty of Medicine and Health Technology
Tampere University
Tampere, Finland
johanna.virkki@tuni.fi

***Abstract*— Ageing of the world's population is one of the significant challenges of the modern era. As the care resources are limited, new tools are needed for supporting elderly to live high quality life. Technology is identified as one of the potential tools. In this article, a combination of mobile robotics and RFID technology is used to provide a new tool for care homes, especially targeted for helping in night shifts. By combining passive RFID and mobile robots in a unique way, we create a system that can take actions in preventing potential accidents by identifying, alerting and helping a care home client at risk. The design process followed a co-design approach, where the use scenario and technical setup were created in a multidisciplinary collaboration. This was followed by building a laboratory version of the system, in which a mobile robot identifies and greets a person wandering in the care environment at night, and gently guides the person back to the room for a safe night. Although there are multiple technical details, which need to be developed further, the laboratory test results were very encouraging.**

Keywords— co-design, elderly care, mobile robots, patient safety, passive RFID

I. INTRODUCTION

Autonomous mobile robots (AMR) can be utilized in a variety of beneficial routine tasks, but also in critical additional tasks in versatile healthcare environments. They free professionals from e.g., transport [1], disinfection [2] and patient data collection [3] tasks and allow people to focus on their core work [4][5]. Further, robots can take over nursing tasks [6], remote patient physical condition monitoring, and vital sign measuring [7].

Robotics may also provide solutions for a significant societal challenge the world's ageing population is causing. In January 2019, over one fifth of EU-27 population was aged 65+ years old, and forecasts indicate that the number of seniors in the EU will further increase and reach 149.2 million in 2050, which is 28.5 % of the EU population [8][9]. Thus, providing high quality care for elderly people has become one of the important issues in the society. One trend is to support elderly living at home as long as possible. Thus, care home residents are typically elderly with already severely declined functional capabilities. Dementia is one of the major causes of disability and dependency among older people worldwide. Therefore, it is especially important to develop solutions for care homes to provide high quality living for the memory impaired clients [10].

People with dementia have been shown to have disturbed sleep/wake rhythms [11]. This is challenging, as there are limited numbers of nurses in care home night shifts. Memory impaired persons may also be physically relatively fit. Night-time wandering may increase the risk of accidental fall. For example, fall occurrence is relatively high at night-time in hospital wards [12]. Additionally, night-time activity may also disturb other residents. However, it is unpleasant to lock the residents in their own rooms in order to avoid them accidentally escaping, falling, or waking up others by wandering around. In this paper we describe a friendly way of identifying and guiding a wandering person back to the person's own room. Our solution is based on a novel combination of passive RFID (radiofrequency identification) technology and robotics. The initial concept and the technical setup were created by following a co-designing method in a multidisciplinary workshop. Subsequently, an early prototype system was created.

II. MOBILE ROBOTS AND PASSIVE RFID

AMR can navigate independently on their maps, plan the fastest or the most practical routes between two points, and redesign the route if necessary. They can avoid and bypass collisions and contamination with humans and other moving, stationary, or contaminant objects, obey calls from different operators, give spoken instructions, and reorganize their actions according to the signals from the environment [13][14].

Passive RFID (radiofrequency identification) technology provides automatic identification and tracking of products and items [15][16], but also people [17][18], achieved with energy source-free and wirelessly addressable electronic tags. As each tag has a unique identification number (ID), it is possible to identify tagged people from a distance with an RFID reader, which can be attached for example to a mobile robot. The use of UHF (ultra-high frequency) enables working distances of several meters.

By combining passive RFID and mobile robot's features, we can create a system that supports different healthcare environments during the daily routines. Mobile robots can take actions in preventing potential accidents, for example by identifying, alerting and helping a care home client at risk during the night, which will provide a new level of security for elderly care.

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III. SCENARIO DEVELOPMENT BY CO-DESIGN APPROACH

The design process in this study followed a co-design approach [19], which refers to the collective creativity of a multidisciplinary group of people. In co-design, the users are given the position of 'expert of his/her experience', and the play a large role in knowledge development, idea generation, and concept development. Usually, the process starts with a pre-design phase or so called fuzzy front-end of the design process, in which understanding of users and contexts of use is increased, and technological opportunities are explored. After this phase, the process follows the traditional design process, where the resulting ideas for product are developed first into concepts, and then into prototypes that are refined on the basis of the feedback of the future users. As the end users of the developed product are elderly with memory impairment, they were not involved in the development process in such an early phase. Instead, elderly care specialists were used as user proxies in the co-design process. Through user proxies, too early prototypes do not cause frustration in actual end-users, but the idea can be visualized, and the useful characteristics identified [20].

In this study, the co-design process started with a design workshop, in which 10 persons attended. The group included "elderly care specialists / end user proxies" (3), technology providers (3), service designers (2), mobile robot researcher (1) and RFID researcher (1). The workshop included presentations of the technology as well as dementia and elderly care. This was followed by identifying a design challenge for prototyping. The workshop continued by identifying key features of the systems, which technologywise are also possible to develop. The process followed by building a laboratory version of the system.

IV. PRACTICAL IMPLEMENTATION

In the technical setup (presented in Fig. 1), the RFID reader was CAEN RFID Proton R4320P, which was used with MtI Wireless Edge MT-242040/NLH/K and Times-7 Slimline A5020 antennas. The tags were basic commercial UHF RFID tags that were attached to the back and front of the test subject. The used mobile robot was Omron LD-90.

We use mobile robots and RFID technology to identify a person wandering in the care environment. The system can be used first to identify, if a memory impaired resident leaves the personal room at night. In this case, the robot can go to the person before the person is far from the room. After identifying the person near the robot, the robot kindly greets the person and reminds about the night-time (Fig. 1). Then the robot asks the person to follow the robot back to the own room, while the RFID reader constantly monitors whether the person is following the robot or not. After guiding the person back, the robot wishes good night and confirms the person's location to be at the personal room again (Fig. 2). In case the person does not follow the robot, it can first go a short way back, try to locate the person and ask the resident to follow the robot again. If the person does not follow even then, the system trickers the nurse call. The robot may also identify people in the care environment corridors without having a notice about person leaving their room. The system identifies if the person is a nurse or client. In case the person is identified as a client, the same procedure begins as in case the system has notified the robot about person leaving the room.

This scenario utilizes a data fusion of an autonomous mobile robot capable of self-navigation, an RFID reader system, and a versatile database. The first novelty value of the scenario comes from the integration of the RFID reader system into the mobile robot. Once the RFID reader is integrated into the mobile robot, the robot can carry the reader to different destinations as needed. The mobile robot has its own logistical tasks, which it performs in the order assigned to it. At the same time, the RFID reader can monitor the presence or absence of various tags on the routes of the mobile robot. The mobile robot constantly knows its location on the map, so it can control the RFID reader to use different location-specific reading modes. For example, near a front door, the mobile robot can direct the RFID reader to view the ID numbers of people passing through the door and check the system to see if they are allowed to go out, or by departmental doors to identify people to determine if they are allowed to pass from that department to another. In this scenario, the mobile robot must be able not only to navigate independently on its map but also to avoid moving and stationary obstacles. A mobile robot most commonly uses laser scanners and/or 3D camera to identify obstacles, but ultrasonic sensors, for example, can also be used as an additional aid.

Fig. 1. A mobile robot with an integrated RFID system detects a person in the hallway and identifies her.

Fig. 2. The mobile robot has safely guided the person back to her room.

When an RFID reader integrated in a mobile robot detects a lost or otherwise at the wrong time moving person on the robot's normal route, the robot can speak to contact and ask the person to follow the robot back to their room. The mobile robot's laser scanners ensure that the robot does not collide

with anyone, but to uniquely identify individuals, the robot needs an RFID reader and unique tags on the target persons. The RFID reader and mobile robot identify the people with RFID tags around them based on the database. This is a data processing issue, but also a security issue. Indeed, a database or several location-specific databases are at the heart of the whole scenario. Data fusion, which combines location information generated by a mobile robot, tag ID information read by an RFID reader, and database with information needed for the target and situation, enables person identification, return route planning back to the person's room, use of personal calming phrases in robot-person communication, and nurse calls automatically.

The prototype development required expertise in the integration of RFID system into the mobile robot but also in data fusion programming. The basic principle of the data fusion system is that first the system asks the mobile robot for the location of the robot. Second, the system asks the RFID reader what tags the reader detects, the signal strength and the direction of the tag based on which antenna detects it. Third, the data fusion system communicates with the database in order to figure out how all this information will affect to the actions in this particular case. An RFID reader on a moving mobile robot also posed challenges because the location determination of moving tags with a moving reader is not as straight forward as with a stationary reader. The different power requirements of all the devices needed special attention, as all of them are powered by the internal battery of the mobile robot.

V. CONCLUSIONS

This article presented a mobile robot and RFID technology combining prototype for elderly care. The prototype was developed by a co-design process, in which the user needs were identified, as well as the potential solution designed and developed by a multidisciplinary team. An important part of the process was to learn about the user needs, as well as about the technologies' possibilities. The process started by identifying a design challenge, which was to create a solution for identifying and guiding elderly care night-time wanderer back to the person's room. A laboratory version of the prototype was developed by using Omron LD-90 mobile robot and basic commercial RFID reader with appropriate antennas and passive UHF tags. The prototype development required expertise in data fusion to integrate the RFID, mobile robot and data base systems. A significant challenge has been met to get more accurate location of the tags that RFID systems normally provide. Special attention is also needed to power all the devices with different power requirements from the mobile robot's internal battery. However, the preliminary results from the laboratory tests are encouraging. Our future work includes to further test the prototype in a laboratory with a larger group of elderly care professionals, and iteratively develop the concept towards a system, which can be tested in the real use environment.

The co-design approach proved to be an effective way to include various stakeholders in the development process, which may improve the match between the real user need and the provided solution, as suggested in other articles [21][22]. The process evoked ideas which may not have been identified without multidisciplinary discussion and ideation. Through the process, the professionals who took part in the designing learned from each other, which also provided multiple other ideas for further development.

REFERENCES

[1] S. Jeon and J. Lee, "Vehicle routing problem with pickup and delivery of multiple robots for hospital logistics," in Int. Conf. on Control, Automat. and Syst., Gyeongju, Korea, Oct. 2016.

[2] C. R. Kovach, Y. Taneli, T. Neiman, E. M. Dyer, A. J. A. Arzaga and S. T. Kelber, "Evaluation of an ultraviolet room disinfection protocol to decrease nursing home microbial burden, infection and hospitalization rates," BMC Infect. Dis., vol 17, no. 1. Mar. 2017. doi: 10.1186/s12879-017-2275-2. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5335784/pdf/12879_2017_Article_2275.pdf

[3] D. Van der Putte, R. Boumans, M. Neerincx, M.O. Rikkert, M. de Mul M, "A social robot for autonomous health data acquisition among hospitalized patients: an exploratory field study," in ACM/IEEE Int. Conf. on Human–Robot Interaction, Daegu, Korea, Mar. 2019, pp. 658–659.

[4] B. Kumar, L. Sharma, and S. Wu, "Job allocation schemes for mobile service robots in hospitals," in IEEE International Conference on Bioinformatics and Biomedicine, Madrid, Spain, Dec, 2018, pp. 1323-1326.

[5] S. Jeon and J. Lee, "Multi-robot multi-task allocation for hospital logistics," in 18th International Conference on Advanced Communication Technology, PyeongChang, Korea, pp. 339-341, Jan.-Feb. 2016.

[6] R.C. Locsin and H. Ito, "Can humanoid nurse robots replace human nurses?," J. Nurs., vol 5, no.1, Jan. 2018.

[7] K. A. Mamun, A. Sharma, A.S.M. Hoque, and T. Szecsi, "Remote patient physical condition monitoring service module for iWARD hospital robots," in Asia-Pacific World Congress on Computer Science and Engineering, 2014

[8] Ageing Europe ,2019 edition. Luxembourg: Publications Office of the European Union. Available: 10.2785/811048 [Accessed May 5, 2021].

[9] Eurostat regional yearbook, 2020 edition. Luxembourg: Publications Office of the European Union. Available: 10.2785/98733 [Accessed May 5, 2021].

[10] WHO, Available: https://www.who.int/news-room/fact-sheets/detail/dementia [Accessed May 5, 2021].

[11] P. Gehrman et al., "The relationship between dementia severity and rest/activity circadian rhythms," Neuropsychiatr. Dis. Treat., vol 1, no. 2, pp. 155–163, Jun. 2005.

[12] P.J. López-Soto et al., "Temporal Patterns of In-Hospital Falls of Elderly Patients," Nurs Res., vol 65, no. 6, pp. 435-445, Nov/Dec. 2016.

[13] V. Villani, F. Pini, F. Leali, and C. Secchi, "Survey on human–robot collaboration in industrial settings: Safety, intuitive interfaces and applications," Mechatronics, vol. 55, pp. 248-266, Nov. 2018.

[14] I. Nielsen, Q.V. Dang, G., Bocewicz, Z. Banaszak, "A methodology for implementation of mobile robot in adaptive manufacturing environments." J. Intell. Manuf., vol. 28, pp. 1171-1188, Apr. 2017.

[15] J. Virtanen, J. Virkki, L. Sydänheimo, M. Tentzeris, and L. Ukkonen, "Automated identification of plywood using embedded inkjet-printed passive UHF RFID tags," IEEE Trans. Autom. Sci. Eng., vol 10, no 3, pp. 796-806, Apr. 2013.

[16] K. Kordelin, J. Kordelin, M. Johansson, J. Virkki, L. Ukkonen, and L. Sydänheimo, "Development and implementation of an RFID-based tunnel access monitoring system, Science and Technology of Nuclear Installations, vol 2016, doi: 10.1155/2016/9897675

[17] Z. Khan et al., "Glove-integrated passive UHF RFID tags—Fabrication, testing and applications," IEEE J. Radio Freq. Identif., vol. 3, no. 3, pp. 127-132, Jun. 2019.

[18] X. Chen, H. He, L. Ukkonen, and J. Virkki, "The effects of added clothing layers on the performance of wearable electro-textile UHF RFID tags," in URSI Atlantic Radio Science conference, Cran Canaria, Spain, May-Jun. 2018.

[19] E. Sanders & P. Stappers, Co-creation and the new landscapes of design, CoDesign, vol. 4, no. 1, pp. 5-18, Sep. 2008.

[20] S. Merilampi, A. Koivisto, and A. Sirkka, "Designing serious games for special user groups—design for somebody approach. Br. J. Educ. Technol.," vol. 49, pp. 646-658, May 2018.

[21] Z. Piligrimienė, A. Dovalienė, and R. Virvilaitė, "Consumer engagement in value Co-Creation: what kind of value it creates for company?," Engineering Economics, vol. 26, no. 4, pp. 452-460, Oct. 2015.

[22] M. Steen, M. Manschot, and N. De Koning, "Benefits of co-design in service design projects," Int. J. of Design, vol. 5, no. 2, pp. 53-60, Aug. 2011.