Eldercare Robots in the Age of AI: Are We Ready to Address the User Needs?

Piotr Skrzypczyński[1], Sławomir Tobis[2]

[1]Institute of Robotics and Machine Intelligence,
Poznań University of Technology, ul. Piotrowo 3A, 60-965, Poznań, Poland
[2]Department of Occupational Therapy, Poznan University of Medical Sciences,
ul. Święcickiego 6, 60-781, Poznań, Poland
piotr.skrzypczynski@put.poznan.pl; stobis@ump.edu.pl

Abstract. This position paper presents an attempt to analyse the requirements of older users they formulate with respect to healthcare assistive robots to be used at home. This study is based on matching the hands-on experience with the use of a mobile robot at patients' homes within the ENRICHME project to the briefly sketched state-of-the-art in AI-based robotics. We consider three aspects of the robotics and AI technologies that are particularly important to the autonomy, safety, and user acceptance of eldercare robots: human-aware navigation, recognition of the user's state and actions, and natural means of man-machine communication. The outcome of our study identifies the key AI solutions that need to be integrated in such a robot, and challenges that still need to be addressed by research. This brief paper can serve as a background for discussion on how to take user-specific requirements into account in research and implementation of eldercare robots.

Keywords: Healthcare robot · eldercare · artificial intelligence

1 Introduction

The ageing society in Poland and the increasing number of people with prolonged diseases and disabilities (also as a result of the SARS-CoV-2 pandemics) poses an increasing problem. As the shortage of medical and care workers becomes evident, we need to rely more on assistive technologies [16]. However, these technologies still cannot address specific needs of older people. Not only if the robot has to physically interact with objects, but also whenever a more proactive behavior or conversational engagement of the robot is expected, for example during a dialogue with an older person with memory problems [18]. We thus formulate the thesis that the limited acceptance of existing assistive robots for older people at home is largely due to the mismatch between the communication interface capabilities of the robot, the needs of older adults and the limited ability of the robot to recognise situations requiring its own actions.

While robots have been developed that work as domestic helpers addressing the medical, physical or cognitive issues [4, 14, 16], and are even commercially available, they are complicated and expensive. However, the last decade witnessed enormous progress in AI-based robotics that opened new possibilities, such as affordable 3-D sensing and powerful machine learning methods. Hence, in this short paper we provide a simple case study of the requirements by an average older person interested in having a robotic helper at home, and then we identify the AI and robotic technologies that are crucial to better acceptance of such a robot at home.

2 Do We Really Know the User Needs?

Important user experience concerning the use of an autonomous robot to support older people with mild cognitive impairment (MCI) was gathered in the ENRICHME project [13]. The project investigated user acceptance, attitude towards the robot, perception of the robot and the perceived levels of its naturalness, animacy and intelligence. Whereas the results showed high acceptance of the robot in the context of enjoyment and positive social influence, the perceived level of usefulness, and the social presence were scored somewhat lower, with the participants, who were more computer savvy being less afraid of using the robot.

In order to illustrate the exemplary needs of an older person, we present one case, already in the context of the new pandemic situation. Mrs. Zofia is 78 years old and lives alone in a large apartment block. Her children and grandchildren are in constant telephone contact with her. She has no friends in the area where she lives, so she has to cope with everything on her own. Before the pandemic she used to meet frequently with her friends, but now they only call each other for fear of COVID-19. Zofia does not use a computer. Although she has a modern smartphone, she does not know its functions. Zofia has suffered from hypertension, diabetes and hypothyroidism for many years. She takes a lot of medications, and sometimes forgets to take them at the right time, and then it happens that she takes the whole day's medication at once. She often looks for various items - such as her glasses or keys. Since the beginning of the pandemic she has felt lonely as she leaves the house less often. She is independent in her daily activities, she still does a little shopping herself and cooks for herself (however, not every day). Sometimes she forgets to eat the dinner she cooked the day before. She knows that if someone was with her, she would be more mobilised.

The user needs that are identified in this case study are as follows: (i) reminders about medication; (ii) reminders about food and drink; (iii) help with cooking – showing recipes and how to prepare them; (iv) physical exercise; (v) cognitive exercises; (vi) leisure activities, "to have someone over"; (vii) help with finding objects. One important observation is that these needs are mostly related to gathering and processing information, rather than physical help given by someone. Hence, they can be addressed by a robot that is mechanically simple (a manipulator arm is not needed), and therefore affordable. However, this robot must have advanced perceptual, cognitive and learning capabilities, in order to interact with the user and to recognise the semantics of the environment, as well as the meaning of the actions it needs to take.

3 Key AI and Robotics Technologies

Considering the presented case study, and the results of previous investigations concerning healthcare robots for the elderly in home environments [10, 14, 13], we select three areas of technological improvements that are crucial for addressing the needs of older users that have to live with autonomous robots as their companions and domestic helpers.

3.1 Human-aware Navigation in Home Environment.

A fundamental ability of an autonomous robotic companion is to navigate safely and accurately in home environment, which can be cluttered, semi-structured, and non-stationary. Accurate localisation that exploits laser, visual or RGB-D sensing is necessary to interact with objects at known locations. Recent algorithms combine learned object detection and/or semantic segmentation with Simultaneous Localization and Mapping (SLAM) techniques in order to provide high localisation accuracy in dynamic environments [9]. Global localisation [21] is necessary whenever the robot gets lost due to perception failures, occlusions, etc., or it starts operating in a new environment. A robot should plan its motion taking into account the information about the user activity to avoid collisions with humans. Also spaces, where activities are performed, and affordance spaces that denote potential activity spaces (e.g. an area next to a couch or chair) should be considered to determine what areas should not be traversed at the given moment [12]. The planning algorithms should also consider social conventions and the interpersonal zones that correspond to certain actions [18].

3.2 Recognition of the User's State and Actions.

A healthcare robot should observe the older user in order to respond quickly in case a dependent person goes through a distress situation. To implement this, the robot needs to identify humans, distinguish the user from others, and identify the pose of the person. Person detection is accomplished using 2-D laser, RGB-D, visual or thermal data, with best results provided by multi-sensor systems, e.g. the one used in ENRICHME [3] that combined laser, RGB-D and thermal perception. Recent person detection, pose estimation [19], and re-identification solutions are mostly based on deep neural networks [17] that outperform classic approaches by a large margin when implementing classification or semantic segmentation tasks [15]. One important issue for eldercare robots is fall detection, as for the older population, over one-third of falls lead to major injuries. While there are some fall detection techniques based on wearable sensors, vision-based methods are most appropriate for an autonomous robot [7]. These methods can recognise human pose, human movement or both, and detect a fall in case the established criteria are met. Convolutional or recurrent neural networks are used to detect falls, with the LSTMs being able to handle the dynamics in image sequences [7]. Detection and classification of potential obstacles can be also used to prevent falls by alerting the user before a dangerous situation occurs [6].

3.3 Information Processing for Efficient and Intuitive Communication.

The conversational abilities of a healthcare robot for older adults are central in the light of the identified user requirements. Conversation methods leverage Natural Language Processing (NLP) techniques [8], and a broad family of planning and reasoning algorithms [1]. Particularly relevant is the capability of producing contextualised interactions that may range from reminding healthy dietary suggestions [11], through helping to follow a rehabilitation programme at home, to supportive messages when it comes to react, for example, to an older person who is experiencing disorientation or memory problems [1]. The robot should respond actively to situations that were not pre-programmed by the developer; which is possible employing the Dual Process Theory [15], with an intuitive planning system that "thinks fast" whenever the response time is crucial and a deliberative component ("thinking slow") that optimises the plans. Machine learning should be leveraged to distill computation-intensive algorithms into learned policies to obtain a set of skill-specific experts that form the system of intuitive responses. It is important to engage the robot and user within a natural conversation with the content managed in real time [1]. Conversation based on speech seems to be a better way to attract the attention of an older user than employing an on-screen interface [18]. As the robot can gather user-specific data, including medical information and observational data, privacy and safety standards in processing of sensitive data must be carefully formulated and enforced [5].

Machine learning can also help in providing the older person with information and entertainment content gathered from the Internet, e.g. by implementing a customised recommendation mechanism and removal of fake news. The postulated ability to assist while preparing meals also can be implemented using machine learning techniques, as shown by the solution from [2], which suggests modifications to culinary recipes to address specific dietary requirements.

A much more challenging task is to find physical objects in the environment, to help users with memory or sight problems. This task was implemented in ENRICHME using RFID tagging [3], but can also be accomplished using visual sensing with learned object detectors and active perception [20].

4 Conclusion

This short position paper builds upon the previous research, mostly related to the ENRICHME project and published in the healthcare context, but confronts the identified requirements of older users with the recent AI and robotics developments, mostly based on the fast pace progress in machine learning. From this analysis we conclude that the key technologies in the areas of machine perception, state estimation (with respect to both the robot and the user) and planning are ready to be implemented in home healthcare robots. The remaining challenges concern mainly the more natural ways of communication based on speech processing and NLP, with the ability to learn the user's specific behavior and to use the information acquired from the external sources (e.g. the Internet) to help the user in everyday activities, encouraging and advising the older person more like human companions do.

References

1. De Benedictis, R., Umbrico, A., Fracasso, F., et al A Two-Layered Approach to Adaptive Dialogues for Robotic Assistance. IEEE Int. Conf. on Robot and Human Interactive Communication (RO-MAN), (2020), 82–89.
2. Bień, M., Gilski, M., Maciejewska, M., et al.: RecipeNLG: A Cooking Recipes Dataset for Semi-Structured Text Generation. Int. Conf. on Natural Language Generation, (2020), 22–28
3. Coşar, S., Fernandez-Carmona, M., Agrigoroaie, R. ENRICHME: Perception and Interaction of an Assistive Robot for the Elderly at Home. International Journal of Social Robotics, 12, (2020), 779-–805.
4. E. J. G. van der Drift, E. J. G., Beun, R., Looije, R., Blanson Henkemans, O. A., Neerincx, M. A.: A Remote Social Robot to Motivate and Support Diabetic Children in Keeping a Diary, ACM/IEEE Int. Conf. on Human-Robot Interaction (HRI), (2014), 463–470.
5. Fosch Villaronga, E., Felzmann, H., Pierce, R., *et al.*: Nothing Comes between My Robot and Me: Privacy and Human-Robot Interaction in Robotised Healthcare. Data Protection and Privacy: The Internet of Bodies, Hart Pub. (2018).
6. Gruszczyński, D., Stefańczyk, M.: Active fall prevention: robotic vision in AAL. arXiv:2103.09298v2, (2021).
7. Gutiérrez, J.; Rodríguez, V.; Martin, S.: Comprehensive Review of Vision-Based Fall Detection Systems. Sensors, 21, 947, (2021).
8. Jay, C., Hareem, S., Katelyn, B., *et al.*: Case Report: Utilizing AI and NLP to Assist with Healthcare and Rehabilitation During the COVID-19 Pandemic. Frontiers in Artificial Intelligence, 4, (2021).
9. Ji, T., Wang, C., Xie, L.: Towards Real-time Semantic RGB-D SLAM in Dynamic Environments. IEEE Int. Conf. on Robotics and Automation (ICRA), (2021), 11175–11181.
10. Łukasik, S., Tobis, S., Kropinska, S., Suwalska, A.: Role of Assistive Robots in the Care of Older People: Survey Study Among Medical and Nursing Students. Journal of Medical Internet Research, 22, (2020).
11. Łukasik, S., Tobis, S., Wieczorowska-Tobis, K., Suwalska, A.: Could Robots Help Older People with Age-Related Nutritional Problems? Opinions of Potential Users. International Journal of Environmental Research and Public Health, 15, (2018).
12. Möller, R., Furnari, A., Battiato, B., Härmä, A., Farinella, G.: A survey on human-aware robot navigation. Robotics and Autonomous Systems, 145, 103837, (2021).
13. Piasek, J., Wieczorowska-Tobis, K.: Acceptance and Long-Term Use of a Social Robot by Elderly Users in a Domestic Environment. Int. Conf. on Human System Interaction (HSI), (2018), 478–482.
14. Robinson, H., MacDonald, B. Broadbent, E.: The Role of Healthcare Robots for Older People at Home: A Review. Int. J. of Social Robotics, 6, (2014), 575—591.
15. Roy, N., Posner, I. Barfoot, T, *et al.*: From Machine Learning to Robotics: Challenges and Opportunities for Embodied Intelligence. arXiv, 2110.15245, (2021).
16. Sapci, A. H., Sapci, H. A.: Innovative Assisted Living Tools, Remote Monitoring Technologies, Artificial Intelligence-Driven Solutions, and Robotic Systems for Aging Societies: Systematic Review. JMIR Aging, 2(2), (2019).
17. Tian, Z., Chen, S., Wang, D., Lu, J.: A Survey of Person Re-identification Based on Deep Learning. Int. Conf. on Computing and Pattern Recognition, (2021), 36—42.

18. Tanioka T, Yokotani T, Tanioka R, *et al.*: Development Issues of Healthcare Robots: Compassionate Communication for Older Adults with Dementia. International Journal of Environmental Research and Public Health, 18(9), 4538, (2021).
19. Wang, J., Sun, K., Cheng, T. *et al.*: Deep High-Resolution Representation Learning for Visual Recognition. IEEE Trans. Pattern Analysis and Machine Intelligence, 43(10), (2021), 3349–3364.
20. Wang, Q., Fan, Z., Sheng, Wh. et al.: Finding misplaced items using a mobile robot in a smart home environment. Frontiers Inf Technol Electronic Eng., 20, (2019), 1036—1048.
21. Wietrzykowski, J., Skrzypczyński, P.: PlaneLoc: Probabilistic global localization in 3-D using local planar features. Robotics and Autonomous Systems, 113, (2019), 160—173.