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Hobbit, a care robot supporting independent living at home: First prototype and lessons learned

David Fischinger [a,*], Peter Einramhof [a], Konstantinos Papoutsakis [b], Walter Wohlkinger [a], Peter Mayer [c], Paul Panek [c], Stefan Hofmann [e], Tobias Koertner [d], Astrid Weiss [a], Antonis Argyros [b], Markus Vincze [a]

[a] Automation an Control Institute (ACIN), Vienna University of Technology, 1040 Vienna, Austria
[b] Institute of Computer Science, FORTH, Heraklion, Crete, Greece
[c] Fortec group, Vienna University of Technology, 1040 Vienna, Austria
[d] Academy for Aging Research, 1160 Vienna, Austria
[e] Hella Automation GmbH, 9913 Abfaltersback, Austria

HIGHLIGHTS

- We present a care robot for aging in place by means of fall prevention/detection.
- Detailed description of sensor set-up, hardware, and the multimodal user interface.
- Detailed description of major software components and implemented robot tasks.
- Proof-of-concept user study (49 user) on usability, acceptance, and affordability.

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ABSTRACT

One option to address the challenge of demographic transition is to build robots that enable aging in place. Falling has been identified as the most relevant factor to cause a move to a care facility. The Hobbit project combines research from robotics, gerontology, and human–robot interaction to develop a care robot which is capable of fall prevention and detection as well as emergency detection and handling. Moreover, to enable daily interaction with the robot, other functions are added, such as bringing objects, offering reminders, and entertainment. The interaction with the user is based on a multimodal user interface including automatic speech recognition, text-to-speech, gesture recognition, and a graphical touch-based user interface. We performed controlled laboratory user studies with a total of 49 participants (aged 70 plus) in three EU countries (Austria, Greece, and Sweden). The collected user responses on perceived usability, acceptance, and affordability of the robot demonstrate a positive reception of the robot from its target user group. This article describes the principles and system components for navigation and manipulation in domestic environments, the interaction paradigm and its implementation in a multimodal user interface, the core robot tasks, as well as the results from the user studies, which are also reflected in terms of lessons we learned and we believe are useful to fellow researchers.

1. Introduction

Because of the fact that older adults prefer to independently live on their own at home as long as possible [1], the necessity of developing assistive technology is increasing. However, older adults themselves experience challenges in maintaining their home [2] and the need of assistive technology can be perceived as stigmatization [3].

Care robots are considered as one option to support independent aging in place. In recent years the development of this type of robot assistance quickly increased. Several research projects were focusing on the development of care robots for older adults, which can reduce loneliness, support in household tasks, and

* Corresponding author. Tel.: +43 158801376622.
E-mail addresses: peter.einramhof@gmail.com (P. Einramhof), walter.wohlkinger@gmail.com (W. Wohlkinger), s.hofmann@inno-cube.at (S. Hofmann), Tobias.Koertner@altersforschung.ac.at (T. Koertner).

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Fig. 1. The "naked" Hobbit robot (left) and the Hobbit robot (prototype 1) used for the first round of user trials (right) in Austria, Greece, and Sweden.

connect users to the outside world (e.g. KSERA [4], DOMEO [5], Cogniron [6], Companionable [7], SRS [8], Care-O-Bot [9], Accompany [10], HERB [11]). A large number of studies on the impact of care robots on older adults (a thorough overview can be found in [12]) demonstrate their positive effects and it also seems that the elderly in the Western society are open for this kind of technology.

However, most of the developed robotic platforms are still research platforms, which did not enter private households as robotic products so far. Only pet-like social companion robots with limited (but essential) care functionality, such as the seal-like robot Paro [13], are available in the market for end users. To our conviction, one of the biggest challenges is still the development of a multifunctional care robot for independent living, which is affordable for end users.

Therefore our aim is to develop an affordable multifunctional care robot that sustainably enables independent aging in place. According to gerontological studies, falls are the leading cause of injuries among elders. EU-wide 30% of people over 65 and 50% of those over 80 years fall each year and falls are the main reason for moving to a care facility. Subsequently, our main goal is to develop a care robot which prevents falls by picking up objects from the floor, detecting falls by patrolling through the apartment, and handling emergencies by calling relatives or in last instance the ambulance.

Many questions about how a care robot can be developed that offers high usability and user acceptance, but is affordable for its intended target group are still unanswered. What is the right compromise between user expectations and system capabilities? How can existing hardware and software be used to develop a robotic product and not another research platform? Which interaction paradigms are really beneficial for older adults? To address these challenges, we designed and developed the Hobbit robot.

In this article we present results from the development of the first Hobbit robot prototype (subsequently called PT1, see Fig. 1) and the first set of user trials in a controlled laboratory setting in order to explore the reception of Hobbit from its target user group. Section 3 describes the overall system, including the mobile platform, the sensor system, the arm and gripper, and the multimodal user interface. The components are described in Section 4 expanding on navigation, human detection and tracking, gesture recognition, grasping, and object learning and recognition. Next, the robot tasks are presented in detail in Section 5 followed by a description of the user study and its results on perceived usability, acceptance, and affordability from the perspective of potential end users. Throughout the article lessons learned from the PT1 development are presented for all sub domains. Thereby we want to share our experiences with fellow researchers and make our knowledge available in the research community as a stepping stone towards affordable robotic products for private users.

2. Motivation and contribution

State-of-the-art robots which should increase the quality of life for older adults can be divided into three main categories: (1) social companion robots, (2) household service robots, and (3) telepresence systems. Social companion robots for elderly should decrease the feeling of loneliness and are often designed in a way to substitute real pets. The most prominent example is Paro. Paro [13] is a seal type mental commitment robot. It has been developed for those who cannot take care of real animals and those who live in places where pet-animals are forbidden. Paro is designed to provide three types of effects: psychological, such as relaxation and motivation, physiological, such as improvement in vital signs, and social effects such as instigating communication among inpatients and caregivers. Paro is affordable and publicly available, but obviously limited in support functionalities when it comes to household tasks.

Household service robots for older adults are those that take over household tasks in order to enable independent aging in place. One of the most popular examples is the *Care-O-Bot* research platform [14], developed at the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). Care-O-Bot is designed as general purpose robotic butler which can fetch and carry objects and also detect emergency situations (e.g. a fallen person) and contact help, however, it is an expensive research platform not intended for the end user market. Similarly, MobiNa, a small (vacuum-sized) robot was developed by Fraunhofer, specifically aiming at performing fallen person detection and video calls in emergency. Another prominent example is the robot Hector developed within the EU project CompanionAble [15]. Hector was designed as a robotic assistant for older adults integrated in a smart home environment and a remote control center to provide the most comprehensive and cost efficient support for older people living at home. However, also Hector is only available as research platform.

Telepresence systems for older adults or homebound people are intended to enable medical and social assistance for communication with parents, nurses, doctors, and patients, such as InTouch Health's RP-VITA remote presence robot, VGO Communications' post-op pediatric at-home robots, Double Robotics Double telepresence robot, and the Giraff telepresence robot. Most of these systems are affordable and are available also for the end consumer market, however, as social companions they only offer very limited support besides social connectedness.

The basic motivation for the development of Hobbit was to combine the three main aspects of the above-mentioned categories (decreasing loneliness, support in household tasks, medical and social assistance through remote communication) in one affordable robotic product (meaning around 15 000 Euro in costs for purchase) for aging in place. Thereby our main goal is that the robot provides older adults with a feeling of safety and being supported in everyday tasks. Consequently, the main functionalities the robot should provide are emergency detection (the robot should autonomously patrol through the apartment after three hours without any user activity and check if the user is ok), handling emergencies (automatically calling relatives or an ambulance and calming the user), as well as fall prevention measures (clearing the