Little Helper: A Multi-Robot System in Home Health Care Environments

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ABSTRACT

Being able to live independently and self-determined in one's own home is a crucial factor for social participation. For people with severe physical impairments, such as tetraplegia, who cannot use their hands to manipulate materials or operate devices, life in their own home is only possible with assistance from others. The inability to operate buttons and other interfaces results also in not being able to utilize most assistive technologies on their own. In this paper, we present an ethnographic field study with 15 people with motor disabilities to better understand their living environments and needs. Results show the potential for robotic solutions but emphasize the need to support activities of daily living (ADL), such as grabbing and manipulating objects or opening doors. Based on this,

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we propose Little Helper, a tele-operated pack of robot drones, collaborating in a divide and conquer paradigm to fulfill several tasks using a unique interaction method. The drones can be tele-operated by a user through gaze-based selection and head motions and gestures manipulating materials and applications.

KEYWORDS

multi-robot system; healthcare environment; ethnographic study; activities of daily living; people with disabilities

INTRODUCTION

Robotic solutions can make a significant contribution to improving care by relieving and supporting care assistants (e.g. nurses or relatives) and having the potential to improve the quality of life of those in need of care [2]. The use of robotic systems benefits in particular people with severe physical impairments, such as people with tetraplegia, who can not use their hands to interact with physical materials by proving alternative interaction mechanisms. Many people with severe physical impairments wish to be able to live independently and self-determined in their own home instead of being cared for in inpatient facilities. The wish for outpatient care is supported by Article 19 "Living independently and being included in the community" of the UN Convention on the rights for people with disability[1]. This is also reflected in national law, e.g. in the German law the social security statute book XII provides the principle "Outpatient care over inpatient care" §13 (1) SGBXII[2]. Physical impairments, which are associated with loss of function in the arms, hands and possibly the mobility of the upper body, limit the ability to live independently considerably. Activities of daily living (ADLs) like eating and drinking, moving around or to occupy oneself can only be achieved with assistance from others. For instance, the persons concerned are dependent on getting drinks and meals prepared, provided and presented. Outpatient care is needed many hours a day or 24/7. This group includes people with tetraplegia, multiple sclerosis, muscular dystrophy, and diseases with similar effects. There are currently several assistive technologies that are designed to enable independent eating and drinking - including eating utensils placed on a table (e.g., iEat, Obi) or robotic arms attached to an electric wheelchair (e.g., JACO, iArm). These products have in common that at least residual functions in either hands, arms and upper body are needed to operate the devices. Recent and ongoing research projects take up this problem and aim to develop robotic solutions for independent living for these usergroups. Examples are the Robots for Humanity Project (testing the PR2 Robot as an assistive mobile manipulator) of Chen et al. [5], AsRoBe Project (testing a mobile service robot with people with a physical disability in a real live environment) [6] and the research of Fattal et al. about SAM, an assistive robotic system to assist people with quadriplegia [7]. These projects have in common, that such a robotic device is designed to assist with several activities of daily living. The robotic device is usually very large,

[1] http://www.bmas.de/SharedDocs/Downloads/DE/PDF-Publikationen/a729-un-konvention.pdf?__blob=publicationFile

[2] https://dejure.org/gesetze/SGB_XII/13.html

consisting of a robotic arm on a mobile module. Theses robots require a barrier-free environment and rooms with sufficient space to fit in and to be able to move around safely. It can be expected that not all buildings will meet these requirements. On the other hand, smaller technological devices that may support certain activities of daily living, e.g. reading or eating, are bound to certain locations and positions and do not offer the same flexibility a human assistant can provide. However, people with these severe impairments are often reluctant to ask their human assistant continuously for small tasks.

In this contribution, we first present an ethnographic field study with 15 people with motor disabilities, aimed at understanding their living and support environment as well as their needs. Based on the results, we suggest Little Helper, a mobile multi-robot system which enables flexibility and enhances a human's opportunities regarding different tasks. In contrast to drones in the context of an unmanned aerial vehicle (UAV), Little Helper uses, for the most part, unmanned ground vehicles (UGV) to perform tasks on tables and floors. The interaction design is assignable between both kinds of drones.

RELATED WORK

In this abstract, we draw upon two strands of related work. First, we review approaches which deal with experiences with flying drones. Second, we present work that exploits the multi-agent system as a mechanism for allocation of duties.

Previous research in flying drones delivered a great amount of knowledge in human-drone interaction. Cauchard et al. found in their research, that the user should always have a feeling of naturalness, safety, and perceived control over the drone, also in autonomous performed tasks [3]. In addition, they observed "Interacting with a person" and "interacting with a pet" as the preferred high-level design metaphor. On the feedback side, Cauchard et al. found that human interpretations of drone behavior are often based on expectations formed by animal behavior [4]. Yeh et al. observed an increase of the mental stress of any human in the vicinity of the drone if it produces noise [13]. Moreover, they found that on average, the personal space of the drone and human was closer when compared with the personal space between human and human. Further, visual feedback, e.g. a lighting ring around a drone to communicate navigation parameters, can significantly improve the perception of the robot as a work partner [10]. To reduce privacy-related fears, Uchidiuno et al. did research in providing privacy-preserving technology, e.g. preventing the capture of data by blocking, obstructing, or re-orienting the drone [11]. Furthermore, head-mounted displays in an augmented reality context can significantly improve user understandings of robot intention and increase objective task efficiency [12].

To organize and coordinate such a group of mobile robots in a common space, multi-agent systems (MAS) are a good approach to reach this goal [8]. In a MAS, each subsystem has a specific goal and deals with that goal only. Once all the small tasks are accomplished the big task is accomplished, too.

However, the necessary organizational structure of MAS does not necessarily derive from explicit structuring, but can also be implicit in emergent behavior [9].

USER STUDY

In order to understand the living and care environments of the intended user group, we carried out an ethnographic analysis with 15 persons with tetraplegia, multiple sclerosis, Locked-In Syndrome, and similar diseases. All of them were living in their private homes supported by care assistants. The study focused on participatory observations of activities of daily living, such as eating and drinking, which were recorded with videos and photos, semi-standardized qualitative interviews took place. The chosen method allowed not only a comprehensive recording of the requirements regarding drinking and food intake but also gave a deeper insight into the life situation and further unmet needs. The 15 interviews have been analyzed qualitatively.

All participants emphasized the wish to live more independently, meaning to be able to be on their own for several hours without the need of a care assistant. All interviewed participants welcomed robotic solutions in order to gain increased autonomy, wishing that the robotic aid should assist with several activities of daily living. Furthermore, participants appreciate the possibility that a robotic aid relieves the care assistants, too. Another result of the analysis is, that although eating and drinking is an important subject, the participants mentioned a variety of other unmet needs. The most commonly mentioned wish was to be able to grab and manipulate objects, e.g. picking things up or open doors. This would also enable to fulfill tasks related to eating and drinking, like setting the table, meal preparations/cooking or to add some seasoning. Other expressed wishes related to leisure activities or basic care. Robotic aids for leisure activities are mainly wished for activities like reading (flip pages) or computer and video games (using a game console). Mentioned issues of basic care are to comb one‘s hair, to be able to scratch one's self (e.g. scratch the nose) or to clean one‘s tooth. Participants complained that it is more than annoying to ask for help for any task. This plays a crucial role with respect to drink sufficient amounts of liquids per day, where they preferred to rather gulp huge amounts instead of sips distributed over a longer time.

The ethnographic analysis showed, that not all homes have the sufficient space for large, mobile robotic devices like the ones mentioned above. Also, people with tetraplegia and similar diseases often have other huge devices such as lifting systems, additional wheelchairs or shower chairs which need sufficient storage spacer [1]. Participants emphasized that robotic aids should not be too big and require to much space. Also, some were concerned a robotic arm on a rather big platform might need a large charging station and have a high power consumption. Some would prefer a robotic arm attached on their wheelchair. This way they would have the robotic arm with them where ever they are. Others do not like to have to carry an aid (robotic or other) close to their body or attached to the wheelchair. This group also mentioned that they wanted a robotic aid that they can use while resting in their bed. Another concern towards using a robotic arm as drinking aid was, that it is stigmatizing if the arm is too big and/or the design to appalling or showy. Instead, the participants would prefer a robotic aid which is small and lean and designed like a “cool” lifestyle product (e.g. such as the Apple iPhone). Further concerns mentioned were safety and data protection as well as a complex and time-consuming usage of a robotic aid. Two participants asked if they would need technicians as assistants rather than care assistants in the future. All participants said, that they need robotic aids which are easy to use and do not need many instructions on how to use them (“plug and play”). It is important that not only the user but also the care assistants easily understand how the robotic aid works.

LITTLE HELPER

The results of the study suggest to concentrate on an approach focusing on simple robotic solutions for specific tasks instead of pursuing single, monolithic systems. We propose a distributed system of Little Helper which operates according to the principle of “divide and conquer”, in which tasks are processed jointly by different robotic solutions. In addition, robotic solutions no longer need to operate e.g. a light switch but can simply interact with smart-home devices over the network. The distributed system would also allow the integration of a wide range of sensor information from different individual bots in task planning and execution. For this purpose, easy-to-use control software is needed, which allows non-technicians to network the individual systems at the touch of a button. The individual bots in such a system would be much simpler in their complexity and thus cheaper to produce. Bots of different types could also have very different components and functionality. This allows small but specialized devices, focusing on different activities of daily living, as proposed by the participants of the user study, such as setting the table, meal preparations/cooking or to add some seasoning and comb one‘s hair, to be able to scratch one’s nose, or to clean one’s tooth. In turn, a gripping bot can be designed in different forms for specific gripping tasks, such as the provision of a beverage bottle or the opening of a can. The aim for these different bots is to act in concert, thereby being capable of performing much more complex tasks. For the user, however, the access has to remain simple and transparent, without the latter having to consider which bot they operate for which task.

As an example individual bot, we present SwipeBuddy (see Figure 1). SwipeBuddy is a physical robotic device that acts as a mobile ebook reader and photo browser and can be controlled by using head movements. Its main tasks are to a) hold a digital device (e.g. Amazon Kindle) b) provide an interaction mechanism with the device to swipe pages and c) flexibly move around so that it does not interfere with parallel activities (e.g. eating). The SwipeBuddy acts as an r-c mobile ebook-reader that can be positioned using head movements. The SwipeBuddy consists of two main parts. The mobile robotic device itself and the interaction interface. The prototype of SwipeBuddy was built with parts of the Makeblock kit.[3]. The interaction concept consists of a **M**agnetic-**A**ngular**R**ate-**G**ravity

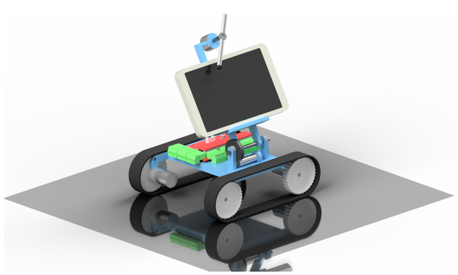

Figure 1: Draft concept of the SwipeBuddy. To increase mobility the robot is equipped with a continuous track vehicle propulsion. Furthermore, it features a tilting platform to change the tilt and therefore view-angle of the mobile device.

[3]Ultimate 2.0 — 10-in-1 robot kit (https://www.makeblock.com)

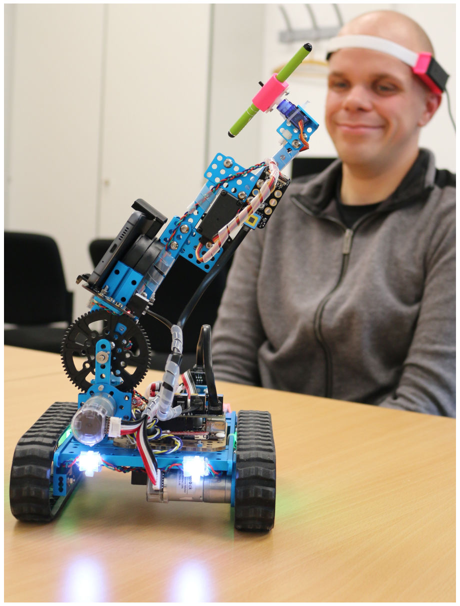

Figure 2: The user is steering SwipeBuddy by his head movements. The white headlamps are turned on.

(MARG) sensor that is mounted on a headband. We choose a continuous track vehicle propulsion (caterpillar track) for high maneuverability, i.e. turning around its own axis. The mobile device is placed on a tilting platform that allows the user to easily manipulate the view-angle of the device. The swiping mechanism consists of a tip of a stylus for capacitive touch displays and a motorized arm which provides contact pressure for swipe and scroll. In our interaction design, the user can switch between different modes to steer the robotic platform, change the tilt angle of the electronic device, and perform a forward or backward swipe action. Using a mechanical swipe mechanism enables a user to activate a swipe action with any application and with any device. A software controlled swipe would be device dependent and thus less flexible. Additionally, an idle mode is available to block all interactions to put the sensor headband on or off. In particular, the user is switching modes by performing a movement along the yaw-axis, while movements in roll and pitch axis are used in each mode differently, e.g. to tilt the device or swipe pages. To provide a visual feedback to the user about which mode is selected and to help to orient, 25 RGB LEDs are installed and used in a way that supports intuitive insight. Furthermore, all LEDs are mounted at special positions and on special parts of the robotic system where they could be recognized easily (see Figure 2).

CONCLUSION

With the Little Helper we presented a concept of a self-organizing and self-coordinating collection of assistance robots for people with severe physical impairments. It does not aim to replace care assistants but supports the user group for very specific tasks where users might not feel comfortable constantly asking for help. Thereby, it helps to empower people with such functional losses to increase the degree of an independent life. Our conceptional approach allows the integration of many activities of daily living, e.g. moving things, opening bottles, opening and closing doors. The interaction for users with tetraplegia will be based on hands-free input modalities, such as speech, gaze-based, or head-based interaction.

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