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AAL Robotics: State of the Field and Challenges

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Abstract. The field of "AAL Robotics", combining AAL and robotics as disciplines, has not yet been precisely defined and does not present accepted structures and concepts that would allow to communicate unequivocally its methods, projects, and approaches. The paper presents a method of defining and categorizing AAL robots and presents the resulting classes of robots with regard to the activities they assist. The classification is useful in that it is able to cover the breadth of the field, but a more fine-grained description of functionalities will be needed in further research to establish the potential of robots to assist independent living of older adults.

Keywords. Robotics; Aged; Aged, 80 and over; Independent Living; Activities of Daily Living

1. Introduction

Ambient Assisted Living or Active Assisted Living, both abbreviated by AAL, have been introduced as names for a field of technology research and development with the general aim to facilitate and extend independent living (aging in place) of older adults. Both robotics and AAL are interdisciplinary areas of research with numerous interfaces to other branches of R & D. The last few years have witnessed an intensification of efforts in AAL Robotics within the AAL community but also in the HRI (Human-Robot-Interaction) and robotics research communities at large, as is illustrated by numerous projects and prototypes and the first arrivals of assistive robots on the market. Still, the field of "AAL Robotics", combining both disciplines, has not yet been precisely defined and does not present accepted structures and concepts that would allow to communicate unequivocally its methods, projects, and approaches.

This paper presents preliminary results of a study of the potential of AAL robotics both for the target population and the robotics industry. After laying out the methods of the survey, the paper presents the resulting definition of AAL robots and classifies a broad sample of robots, arriving at categories based on the activities they support.

2. Methods

To generate the results presented in this paper a secondary analysis of literature was undertaken and the results were validated by means of an expert discussion.

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The following questions drove the research:

- How can the interdisciplinary field of robots in AAL be defined in a way suitable to allow simple identification of AAL robots and to enhance communication between stakeholders?
- Which criteria can be used to structure existing and future robotic solutions and how can solutions be clustered into different categories?

Relevant primary and secondary literature was identified based on keywords according to the respective research question above. Literature was searched for in literature databases, Google scholar, by means of hand-searching of references, web-searches for "robot" and "robotics" in combination with keywords "service", "assistive", "healthcare", "care", "eldercare", "assisted living" and by contacting investigators – in particular researchers involved in projects that target assistive robotic solutions.

In a first step literature was searched for relevant definitions of the keywords "ambient assisted living" and "robots". Identified definitions were analysed for shared concepts, words and phrases. The most widely shared concepts defining "ambient assisted living" and "robot" were adopted and integrated into our definition of "AAL robots". This definition was presented to six experts from robotics and the field of ambient assisted living during an expert workshop where the most important characteristics for both definitions were discussed and slightly altered to the version presented in this paper.

By using the key aspects of our definitions we were able to identify robotic solutions that met the criteria of the new class of AAL robots. To get an overview of robotic solutions within this new class, a database of currently 45 robots was built including the following information for each robot: robot name, company or project developing the robot, country of origin, use cases the robot is intended to support, a general description, the year of construction of the robot, the estimated technology readiness level according to NASA's TRL score [1], the price (if available) and an image of the robot. The information from the database was analysed for thematic correlations in a process similar to thematic analysis [2] by two independent researchers. In the same expert workshop, participants were also asked to group and categorize examples of robots on the basis of the previously established definitions and criteria.

3. Results: Types of AAL Robots

3.1. Defining AAL Robots

Describing and categorizing robots that belong to the field of ambient assisted living (AAL) is a necessary task in order to provide an overview on the state of the art of this specific field and to improve communication about potential usage scenarios and future R & D. Although several researchers have already named groups of robotic solutions that assist people and hence at least partly represent the group of AAL robots, no commonly agreed definitions for either AAL robot or its individual terms "robot", "assistive technologies" and "ambient assisted living" could be found.

The main discrimination of AAL robotics from previous definitions such as "assistive robots" [3], "personal care robots" [4], "healthcare robots" [5] and "service robots" [6] is the specificity to the target group. For our research we defined an AAL robot as a robot that:

1. assists the target group of older users (and users with disabilities).
2. supports the target group during daily life or work.
3. improves or maintains the independence of the target group.

ad 1: the term "assists" was chosen in order to include also solutions that were not developed with the intention to serve the AAL target group. In addition, it expresses that the robotic solution also has to be applicable for the target group – potentially excluding solutions that were designed for the group but are not senior-friendly.

ad 2: the term "daily life or work" refers to the entirety of activities of daily living, defined as the activities needed to perform the tasks necessary for independent living, which are commonly described in three categories: [7]

- ADL: activities of daily living in the narrowest sense are physical tasks related mainly to basic bodily function and maintenance, such as eating, toileting, dressing, grooming, and washing/bathing, as well as ambulation.
- IADL, instrumental activities of daily living, are cognitively and, in part, physically more demanding, and include the ability to shop, prepare food, do the housekeeping and laundry, to manage medication, administration and finances, and to use the telephone and outdoors transportation.
- EADL, extended activities of daily living, refer to the ability to participate in social and enriching activities, and to engage in hobbies or in (paid or volunteer) work.

ad 3: although this criterion may seem redundant with regard to 2., it is necessary to distinguish robots that can be operated independently by the older adult from those that need abilities (such as bending, lifting, good eyesight …) for daily operation which cannot be commonly expected from older adults who need robot assistance.

Similar to the variety of terms used for robots with assistive goals, the term "robot" itself has various definitions (see e.g. [8]). For our goals of structuring the field of assistive living robots we defined the term robot as follows:

A robot is a mechanism that has sensors and actuators, makes sensor-based decisions and is capable of visible motion.

This definition of robots is closely in line with existing definitions that mostly also include the capability of (semi-)autonomous acting (sensor-based decisions) [8] and the ability to move or actuate [6]. The term "visible motion" was chosen since studies suggest that visual motion has relevance for the perceived social presence of robots and it represents a typical characteristic that people use to differentiate between robots and machines [9] [10].

3.2. Types of AAL Robots

Table 1 summarizes the currently described and categorized types of AAL robots together with the activities that they (are intended to) support. Descriptions of and an example for each class of robots are given below the table.

It has to be noted that not all example robots described in what follows have been designed explicitly as AAL robots in our sense. Likewise, they vary in their degree of "robot-ness", e.g. with regard to autonomous decision-making): although included in our broad definition, these examples are, on one or more dimensions less typical AAL robots than others. The class of AAL robots is therefore best conceptualized as a radial category [22].

Table 1. Types of AAL robots by application field and assisted activites

Robot classes	ADL supported	IADL supported	EADL supported	other needs supported
primary mobility aids (wheelchairs, lower limb exoskeletons, scooter robots, robotic walking aid)	all	cooking shopping cleaning	all (through mobility)	stability (by some)
secondary mobility aids (fetch&carry robots, robot trolleys)	----	carrying shopping	----	---
manipulation aids (robot arms, upper limb exoskeletons)	all	all	hobbies work	---
personal care robots (mostly specialised robots)	eating, drinking bathing toileting	----	----	---
household robots (specialised cleaning, cooking etc. robots)	----	cleaning cooking	----	---
companion robots (including telepresence robots)	---	management (health, administration) use of services use of transportation (tele)shopping	learning, cognitive training reading writing participation, social activities entertainment	safety physical training company
emotional robots	---	---	entertainment cognitive training	company

3.3. Primary mobility aids

This class of robots shares the ability to directly support the mobility of the target group by supporting their movements or navigation between locations. In this way the class augments the mobility of the users. Typical subclasses of this class include: robotic wheelchairs, lower limb exoskeletons, "scooter robots" and robotic walking frames.

One example is the assistive robot “Friend II - functional robot arm with user-friendly interface” [11] (see Figure 1) which was developed to assist older users and users with disabilities to navigate, move and support activities of daily living such as cooking and serving meals.

3.4. Secondary mobility aids

This class of robots supports the users by alleviating their need for mobility; in this way supplementing the lacking mobility or strength of users. Typical subclasses of this group include robots fulfilling fetch&carry tasks and robotic trolleys. Our example “Botlr” (Figure 1) is a system designed to deliver goods to users inside a hotel or care residence. The system uses a wheeled base and a tray for goods to autonomously deliver objects to the entrance of users’ premises [12].

Figure 1. Examples of robots for each robot type (from left to right): upper row - primary mobility aids, secondary mobility aids, manipulation aids; lower row - personal care robots, household robots, companion robots, emotional robots

3.5. Manipulation aids

This class includes robot arms and exoskeletons or “wearable robots” [23] for upper limbs. In the ideal case, they assist the user with all activities that require dexterity and/or strength of a hand or an arm and so are of more general use than those personal care robots that are or contain a robot arm with a pre-defined activity (see 3.2.4). “Asibot” [13] is a manipulator robot with 1.3 m of reach and 2 kg of payload. The applications are oriented mainly to domestic assistive tasks for elderly and handicapped people. The robot has a gripper to manipulate different objects or tools. The applications that have been tested in real environments are: eating, drinking, shaving, make up, tooth cleaning, etc.

3.6. Personal care

This class of robots comprises systems that support personal care tasks such as bathing, toileting, brushing teeth, showering, eating and drinking. Typical subclasses are robotic toilets, robotic baths and robotic feeding support aids. The example shown in figure 1 is the feeding support aid “Bestic” [14]. Bestic can be best described as a small, robotic arm with a spoon. By choosing a suitable control device, the user can independently control the movement of the spoon on the plate and choose what and when to eat. The system autonomously performs various movements to support food intake, which qualifies it as a robot.

3.7. Household robots

This class of robots is distinguished by its support for housekeeping tasks such as cleaning and cooking. Typical subclasses include the various forms of commercial specialized cleaning robots such as robotic vacuum, window, and floor cleaners, such as the "Scooba" by iRobot [15], which is depicted in Figure 1. This robot is capable of autonomously swiping the floors of users homes by driving in a random pattern across the floors until it needs a recharge. Obstacles such as doorsills or furniture can either be navigated around or the user is asked to help. The current class of commercial household robots has, however, not been designed specifically for older adults, given that their operation may involve bending and lifting tasks.

3.8. Companion Robots

The class of companion robots typically facilitates communication with the user and integration into a smart environment to accomplish a wide range of tasks to support the target group including but not limited to monitoring of health, security or safety, cognitive support or communication and social support such as provided by tele-presence systems. Note that they are often combined with a) manipulation (robot arm) or b) passive mobility (fetch&carry) capacities; but some, especially the non-mobile ones, only rely on their communication with the user to give reminders or warnings.

A representative example of this group is the robot "Hector" [16] (see Figure 1) which was used within the Companionable[1] project (EU-FP7). The platform is targeted for use at homes of older users with mild dementia where it can navigate autonomously on wheels and provide motivating suggestions, an agenda to structure the day, medicine reminders, video conferencing, memory training and entertainment. The system uses voice and a touchscreen for communication and is able to recharge itself.

3.9. Emotional Robots

Emotional robots are used either in care institutions or in home care settings and typically represent either pets (mostly cats and dogs) or caricatures. Their benefits are derived from pet therapy and result from a set of psychological impacts of animals and animalistic robots on human. Certain benefits such as opening up in social communication could be shown in studies such as those of Wada and Shibata [18] [19]. Although they are often referred to as prominent examples of robots for older adults, they are only marginally AAL robots according to our criteria. The probably best-known example is the robot seal "Paro" [17] (Figure 1). The robot is mainly used in care institutions and supports primarily the caregivers in their social work with the elderly people. The robot represents a baby seal and is capable of reacting to pet strokes with movements of flippers and head as well as acoustic signals.

4. Discussion

The wide range of application areas of AAL robots shows that the typical AAL robot does not exist. Even inside most classes it is difficult to name a representative example because there exists a broad variety of ways in which activities of daily living can be supported. There are, as yet, not enough different types of robots at a technology readiness level (TRL, [1]) that would allow for long-term real life testing and evaluation, which will be essential to assess their practical contribution to independent living of older

[1] http://www.companionable.net

adults and to define and distinguish more precisely the respective application scenarios and user needs addressed by each robotic solution.

In part, the deficits of the current classification are due to the coarse granularity of the ADL as they are usually described and hence the definition of the specific activities for which older adults may need assistance. For example: ambulation means that a person can move, by his/her own means, from one place to another. In everyday life, however, it implies such activities as standing up from a lying or sitting position as well as moving on uneven terrain and managing barriers, steps or stairs. What is more, people usually move for a purpose which often involves lifting and carrying objects from one place to another. Difficulties with climbing stairs and lifting/carrying of heavy bags, and therefore need of assistance, are widespread in the population over 75, especially in women [20]. The classification of AAL robots as presented above, however, cannot answer the question which assistive robots address this need.

In order to improve granularity, the ongoing study will therefore detail the classification on the basis of the much more fine-grained ICF [21]. The combination of the resulting finer categories with the prevalence of specific needs for assistance in the target population will contribute to a more realistic assessment of the potential of AAL robotics.

5. Further Research

Any definition and classification effort is no more than a means to an end. The work presented here is no exception in that the definition and categorization of AAL robots constitute the basis for a study with the goal of assessing the potential of robotics in active assisted living. This assessment takes into consideration three pillars of AAL robotics:

- Technology: currrent foci of R & D and technology readiness level of robotic solutions in the different categories
- Users: demographic baseline data, economic, housing and family situation of older adults, health situation and needs for assistance, acceptance aspects
- Market: models of procurement and distribution, business models for the robotics industry, and not least ethical and legal frameworks necessary for the deployment of AAL robots.

The results of this assessment will be different depending on the type of assistance and technical solution. The present classification is expected to provide a conceptual framework for the formulation of such specific scenarios for each type of AAL robot.

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