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Robotic assistants in personal care: A scoping review

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ABSTRACT

The aim of this study is to present an overview of the technological advances in the field of robotics developed for assistance with activities of daily living (ADL), and to present areas where further research is required. Four databases were searched for articles presenting either a novel design of one of these personal care robotic system or trial results relating to these systems. Articles presenting nine different robotic personal care systems were examined, six of which had been developed after 2005. These six also all have publications relating to their trials. In the majority of trials, patient independence was improved with operation of the robotic device for a specific subset of ADL. A map of the current state of the field of personal care robotics is presented in this study. Areas requiring further research include improving feedback and awareness, as well as refining control methods and pre-programmed behaviors. Developing an affordable, easy to use system would help fill the current gap in the commercial market.

1. Introduction

The use of robotics for a variety of applications has become increasingly common in recent years, especially to replace repetitive or potentially dangerous tasks. However, while the field as a whole is rapidly expanding, the more specific area of domestic service robots remains relatively underdeveloped. These robots must interact very closely with humans during operation as opposed to their industrial counterpoints, so producing a commercially viable system poses a challenge. This article aims to present technological advances in the field of personal care robotics for the application of assistance with activities of daily living (ADL). For the purposes of this study, a personal care robot will be defined as a system containing a manipulator with at least 3 degrees of freedom that is able to perform everyday activities through interaction with a single user.

Many of these systems have been developed for individuals experiencing upper limb impairment (ULI). ULI refers to some deficit in upper extremity function, often related to an acquired or congenital medical condition. There are many possible causes, some of the most common being spinal cord injury (SCI), stroke, acquired brain injury (ABI), cerebral palsy (CP) or amyotrophic lateral sclerosis (ALS). Within this vast range of causes, there is also a wide range of disabilities and each individual will experience different combination of symptoms. Therefore, it is important to consider the huge amount of variation in potential users of such a system as it is being designed and tested.

Research and development in personal care robotics dates back to the 1980s [1]. However, due to rapid technological acceleration, the majority of advances have occurred in the last 12 years. All of the most recent technology, builds on the earlier attempts to design such systems, so all relevant developments in the field are accounted for within the past 12 years worth of literature. Therefore this study reports all of the robotic systems developed in this area, but only systems developed since 2005 are critically assessed.

Results of trials involving any of the systems presented since 2005 are also analyzed in this study. The devices have been reviewed primarily based on their ability to improve user independence by minimizing caregiver involvement. Secondarily, the tasks that each system helps the individual to perform are compared to present a picture of the current state of the field and where further research is required.

Within the reviewed studies, the tasks used to determine an individual's level of independence are often some subset of activities of daily living [2]. An ADL may consist of a number of fundamental activities including eating, mobility or hygiene-related tasks.

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Table 1
Previous personal care robots.

System name	Year	Purpose	DOF	Interfacing method(s)
Handy 1 robotic hygiene station [6]	1987	Commercial	5	Keyboard or joystick
Manus ARM (later became iARM) [7]	1990	Commercial	5	Keypad, single switch or joystick
Care-O-Bot [8]	1999	Commercial	7	Touch screen
MOVAID [9]	1999	Commercial	8	Keyboard, computer mouse, other MS3 input devices
MATS Home Care Arm [10] (later became ASIBOT)	2005	Research	5	Joystick or touch screen
JACO [11]	2011	Both	7	Joystick
ASIBOT [12]	2012	Research	5	Joystick, touch screen or voice recognition
Personal Mobility and Manipulation Appliance (PerMMA) [13]	2013	Research	6 (per arm)	Joysticks or touch screens
Hobbit Mutual Care Robot [14]	2015	Research	5	Speech control, gesture recognition or touch screen

Instrumental activities of daily living, or non-fundamental activities that still allow independence, have also been studied in the context of assistive robotics, and are reviewed in this paper. Often, they involve slightly more complex skills such as preparing a meal or using the telephone [2].

Prior to the current study, a 2013 review of desktop-mounted and wheelchair-mounted robotic arms for assistance with ADL was conducted [3]. There were 20 relevant studies identified, that were separated into two categories: user task preference and user-interface performance measurements of commercialized and developing assistive robotic manipulators [3]. Only studies conducted with clinical trials using ADL tasks to evaluate performance and categorized using the International Classification of Functioning, Disability and Health frameworks were considered [3]. While this previous study had similar inclusion criteria to the current study regarding the robotic systems, it focused on the method of efficacy assessment. This article will report on the systems themselves to create a map of the current state of research within the field. Furthermore, this study will also include autonomous robotic systems for ADL assistance that therefore have navigation and drive capabilities, as opposed to systems that must have a mounted base.

2. Literature search methodology

Publications regarding robotic systems for personal care were searched for on four databases: Elsevier Science Direct, IEEE Xplore, Google Scholar, and PubMed Central Canada. Searches were performed for articles including “activities of daily living”, or “personal care”, and a word including the root word “robot” and including “assistive technology”. As previously mentioned, only systems presented in the past 12 years have been examined in further detail.

There was a total of 3475 articles returned from these searches. The initial articles were collected in a common database and duplicates were eliminated. Inclusion criteria were then applied to narrow down the number of articles as follows. The article must present a robotic system being designed by its original research team to help the user perform everyday tasks. It must have the capability of being controlled entirely by the trial participant or individual user, and must implement safety features including speed control and emergency stops. Furthermore, articles that presented studies evaluating the design and performance of these manipulators were also included.

A set of exclusion criteria were also laid out to help refine the articles included in the review. Articles were not included if they presented a system with functions that fall outside of the scope of providing assistance with ADL. For example, robots that are merely for entertainment or social purposes, or those that have other purposes within the medical field. Studies were also excluded if they did not present completed designs or trials of their respective systems. Therefore only designs that were ready to enter clinical trials or had already completed clinical trials were included.

Also outside the scope of this article, but significant to the field is the Robots for Humanity Project [4–6]. This project presented case studies where a general purpose robot (PR2 from Willow Garage) was adapted for a quadriplegic individual to perform activities such as scratching an itch and shaving independently. While it provides valuable proof of concept, this and other articles presenting general purpose robots modified for assistance with ADL were excluded from critical assessment. The process and number of articles eliminated at each step of the literature review and selection process can be seen in Fig. 1.

After applying inclusion criteria, eliminating duplicates and performing a references search for other relevant articles, 15 articles were deemed acceptable to include in this study. These articles presented 9 novel robotic systems, 6 of which had been developed since 2005 and had studies that presented trials on their efficacy.

3. Review

3.1. Robotic personal care systems

There are a variety of personal care robots that have been presented in scientific literature for the purpose of helping individuals perform activities of daily living. There are also a few of these systems that have become commercially available. Table 1 contains the names of these systems, the year in which they were initially presented in literature, and whether they are for research or commercial purposes. It also shows the degrees of freedom (DOF) and method(s) of controlling each of the manipulators.

The robotic systems prior to 2005 represent the first reported developments in this field and helped to set the stage for further technological progressions [7–10]. Many of the systems evaluated in this study build on the technology presented in these early devices. The following presents a summary of the unique aspects of each system developed since 2005.

The third iteration of the Care-O-Bot system became available in 2009 [9]. The purpose of this system was to assist in tasks such as object fetching and manipulation and has navigation, object learning and object detection capabilities [9]. The robot has omnidirectional drive, a sensor array for navigation and interfacing, and the robotic arm is equipped with a three finger gripper containing tactile sensors [9].

A more recent iteration of the Care-O-Bot was presented in 2015, as the Care-O-Bot 4. This system is marketed as a general purpose robotic butler, primarily for fetching and manipulating various everyday household objects. As it is a more general purpose service device, as opposed to specifically aiming to help with ADL performance, no trials on this iteration have been presented in literature.

In 2011, a robot called JACO became available in both commercial and research versions through a company called Kinova [12]. This manipulator is designed specifically to help individuals with physical disabilities perform ADL. One unique aspect of this system is that its joystick may be mounted by the user’s feet if movement

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